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Adaptation and Mitigation Strategies for Climate Change

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Preface

Humanity is not isolated from the environment. We exist in the stream of life, from the past to the future. Mankind was born and evolved as part of the history of the Earth, which in turn forms part of the history of the Universe. Therefore, we have to regard ourselves in historical terms and not forget our responsibility to the future. In other words, humanity has appeared and evolved during the Earth's history and owes a responsibility to the future. The old Chinese proverb that we study the past in order to learn new things should be recalled.

When we look back at the history of mankind, we realize that we have suffered from many different issues and calamities throughout our entire existence. In other words, there has been no easy time for us, and we have been fighting for our survival by overcoming those challenges. As part of the struggle, we have accumulated and clarified our knowledge. Science and technology are examples of this collected knowledge. Using results provided by science and applying technology, we have overcome many difficulties. However, it should be remembered that issues continue to evolve along with the development of our society. Our situation at the present time is not the same as in the past. Although a new technology resolves an existing issue, it may also create a new one. For example, the mobile phone has changed our lifestyle, and we can enjoy the advantages it provides. On the other hand, mobile phones facilitate certain new types of crime; hence, we are always confronted with new problems.

Since the Industrial Revolution, mankind has sought wealth and prosperity by making maximum use of energy and natural resources. Nature has been considered to have an infinite potential to process waste energy and resources. We have not recognized that disposal of waste material is necessary. In other words, it has been believed that however many burdens we place on Nature, she can clean up and repair what we have done. This was true when people's domain of activity was small. However, as that domain has expanded, the limits of Nature and the limits of growth have become all too evident.

When we look around us, it seems we face a multitude of concerns with few answers to them. Confronted by a difficult situation, we often tend to become caught up in a trap of pessimism. The pessimism itself is not entirely bad: when we think the future is not very easy, we tend to pay attention to future risks. It can be harmful, however, when a pessimistic view of the future causes us to lose the motivation necessary for overcoming the pressing issues.

To confront problems, we need collaboration between different disciplines, because twenty-first-century issues cannot be handled by a single discipline. As knowledge specific to a discipline expands, we need a group of specialists. In order to come together, individuals have to understand and acknowledge one another, which can be made possible through dialogue.

This book is a summary of two international conferences held in Honolulu, Hawaii, in 2007 and 2008, which were organized by TIGS (Transdisciplinary Initiative for Global Sustainability)/ Integrated Research System for Sustainability Science (IR3S), the University of Tokyo. TIGS was established at the University of Tokyo in 2005 to promote interdisciplinary research toward sustainability science. The first symposium was titled "Dialogue Between Social and Natural Sciences" and the second was "Adaptation Strategies for Climate Change." In the first symposium, a dialogue between different disciplines, in particular, social science and natural science, was conducted, while in the second symposium a dialogue between science, technology, economics, and policy was conducted in the field of adaptation for climate change.

Many stimulating papers are included in this book. Although their views might not appear to be as well coordinated as they could have been, the diversity seen here is very important for creating a new pathway to the future sustainable society. It is our hope that this book will give rise to new fields of research such as sustainability science.

July 28, 2009

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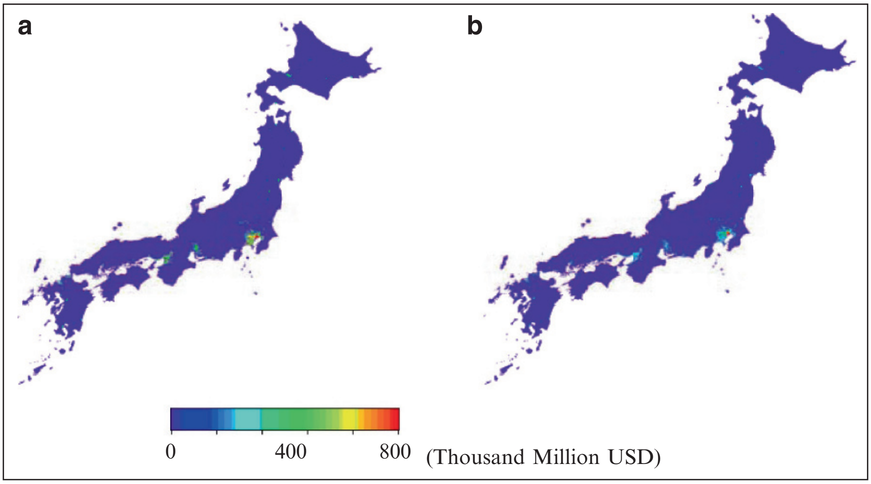

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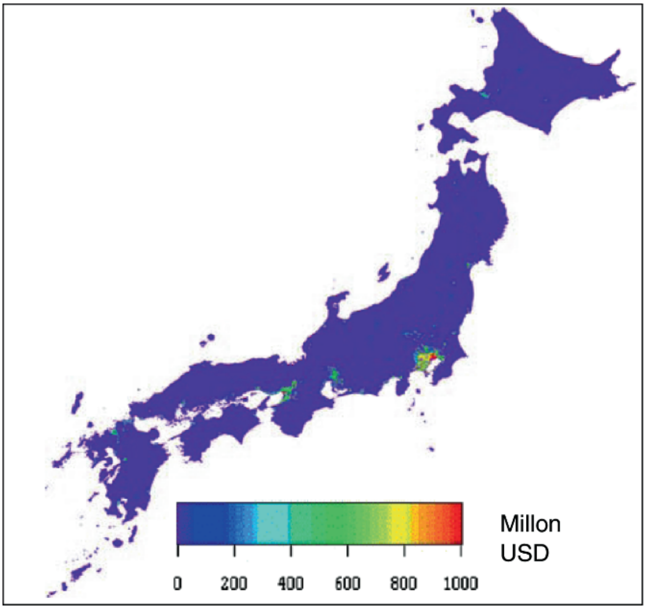

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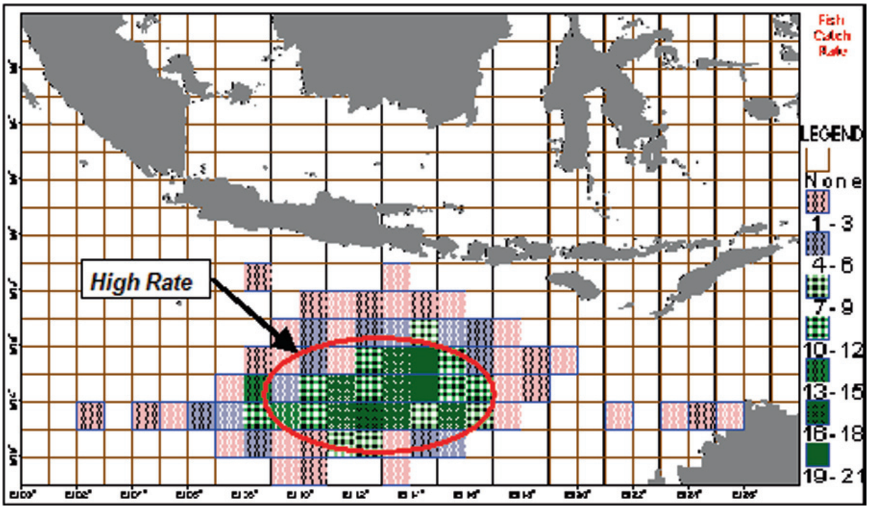

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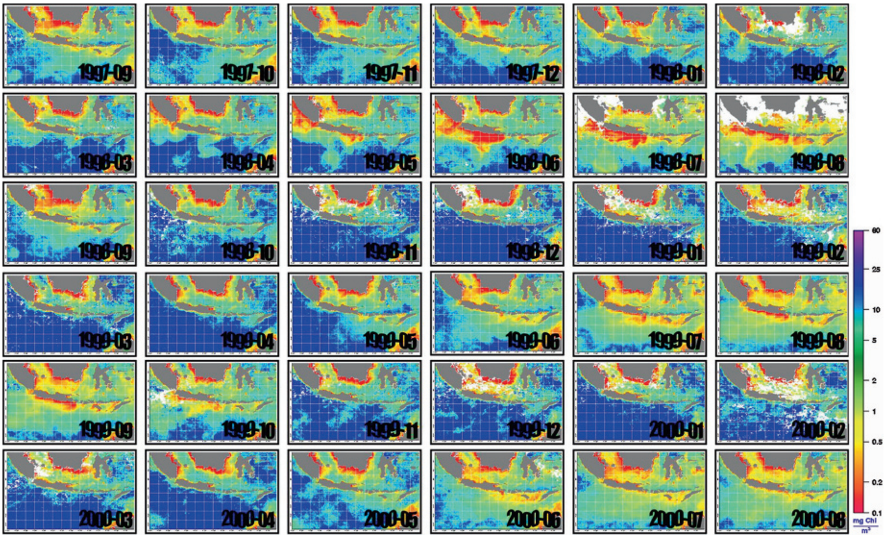

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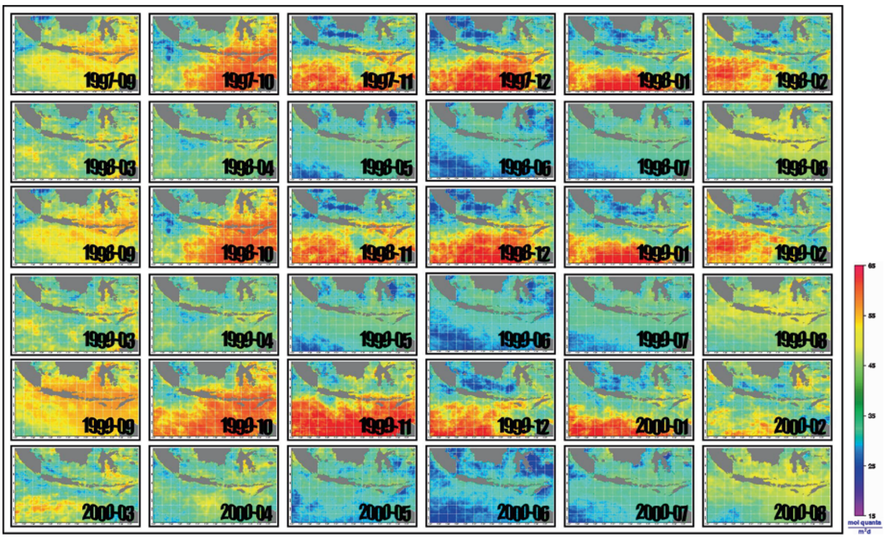

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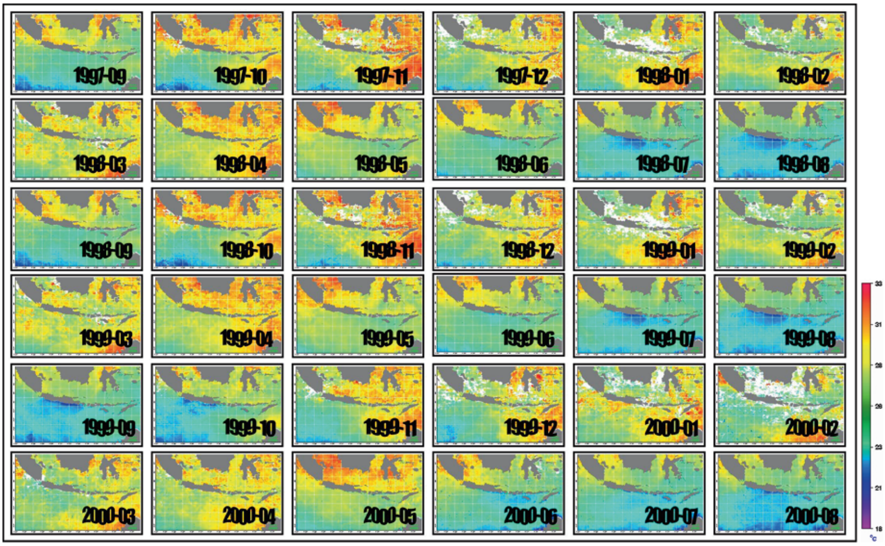

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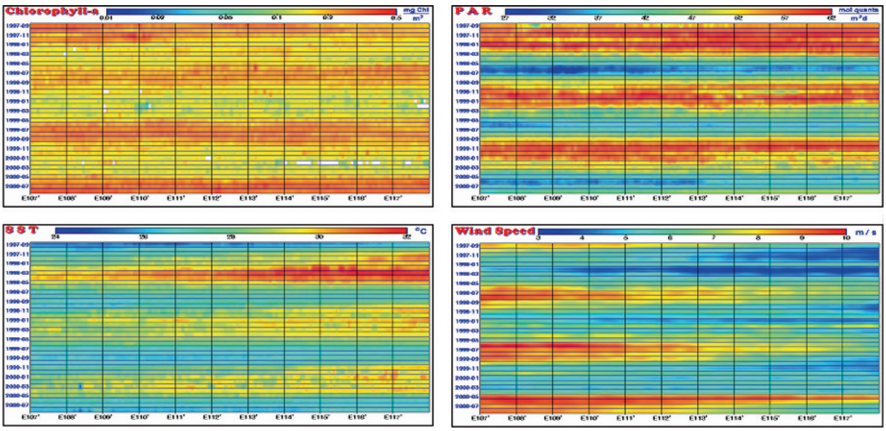

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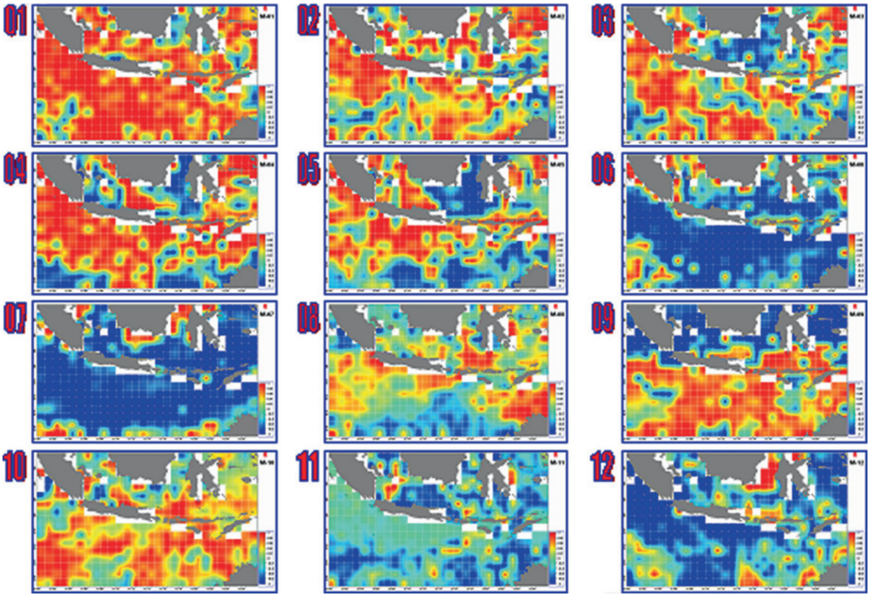

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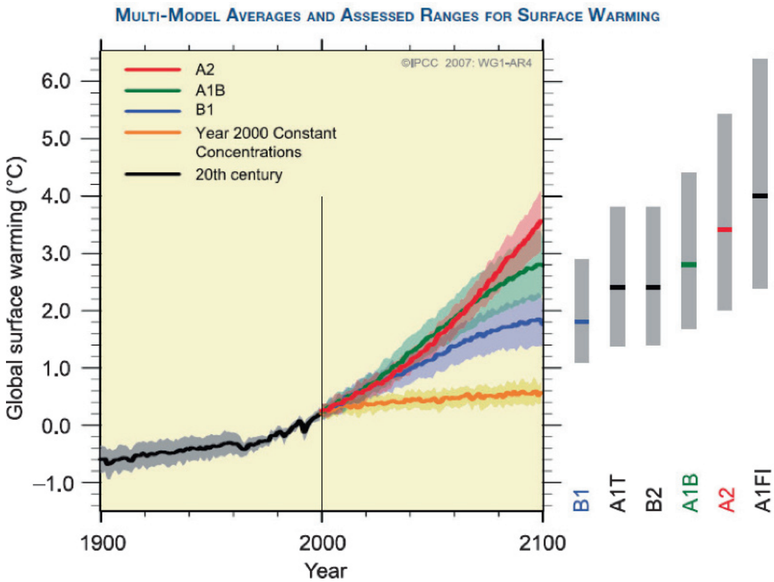

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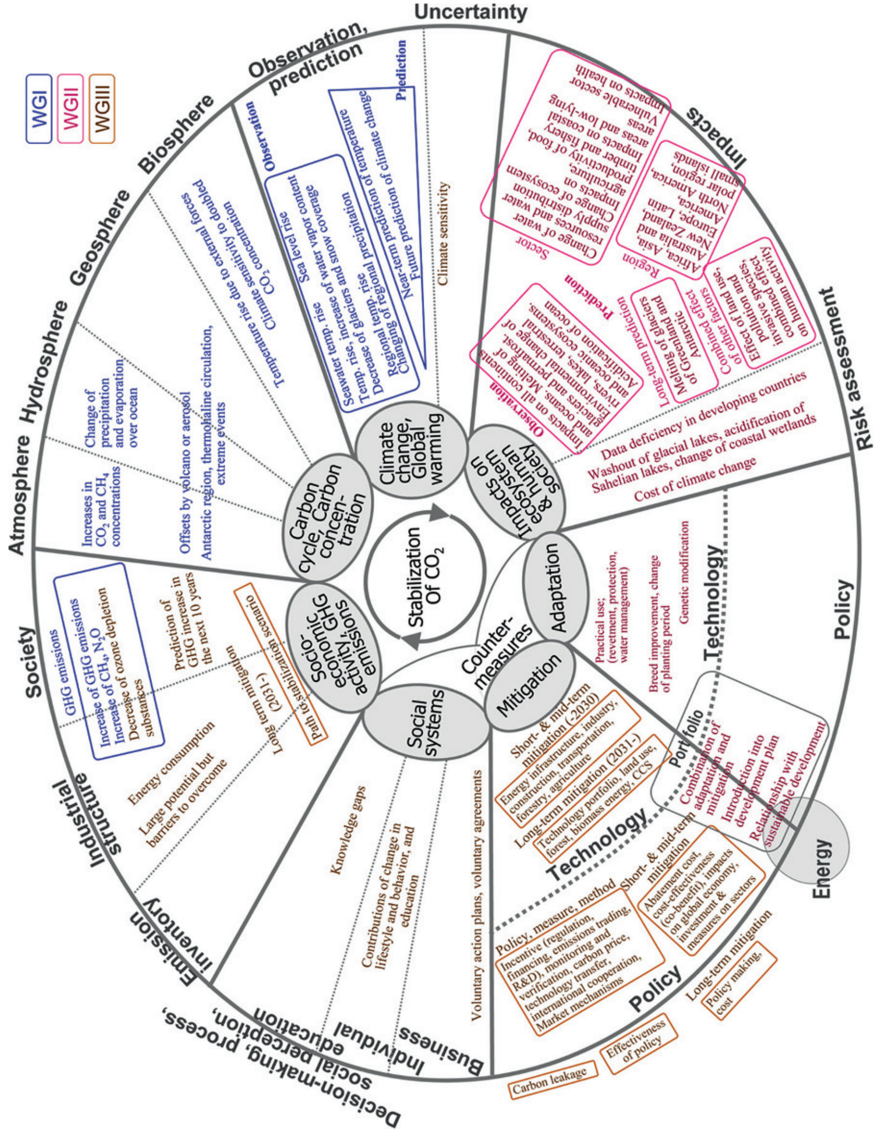

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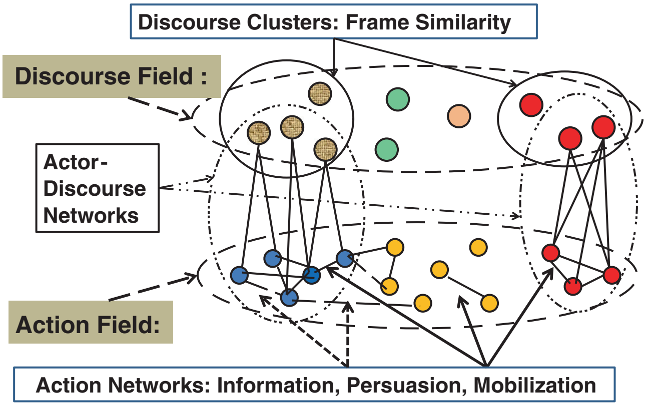

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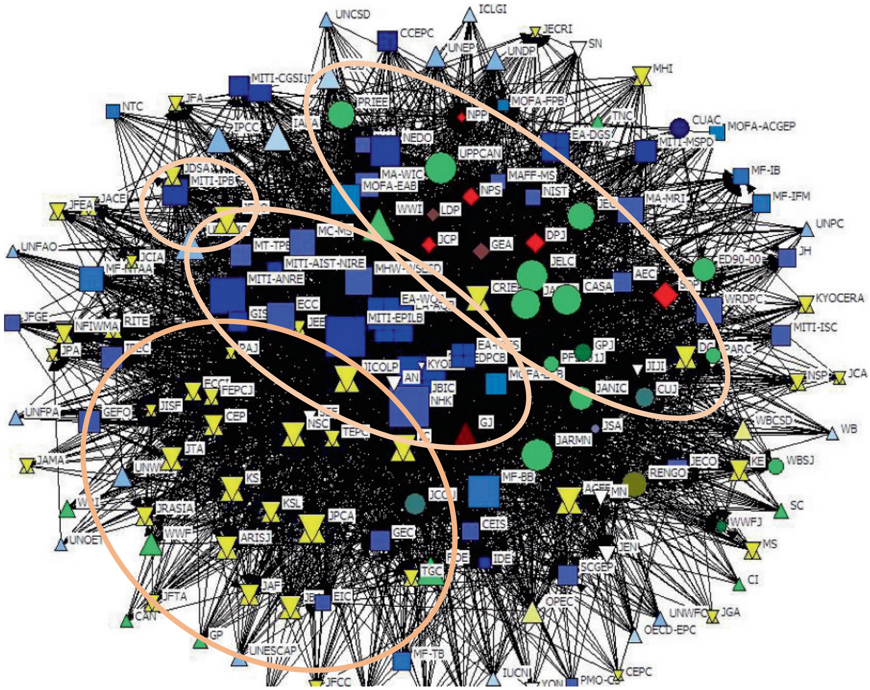

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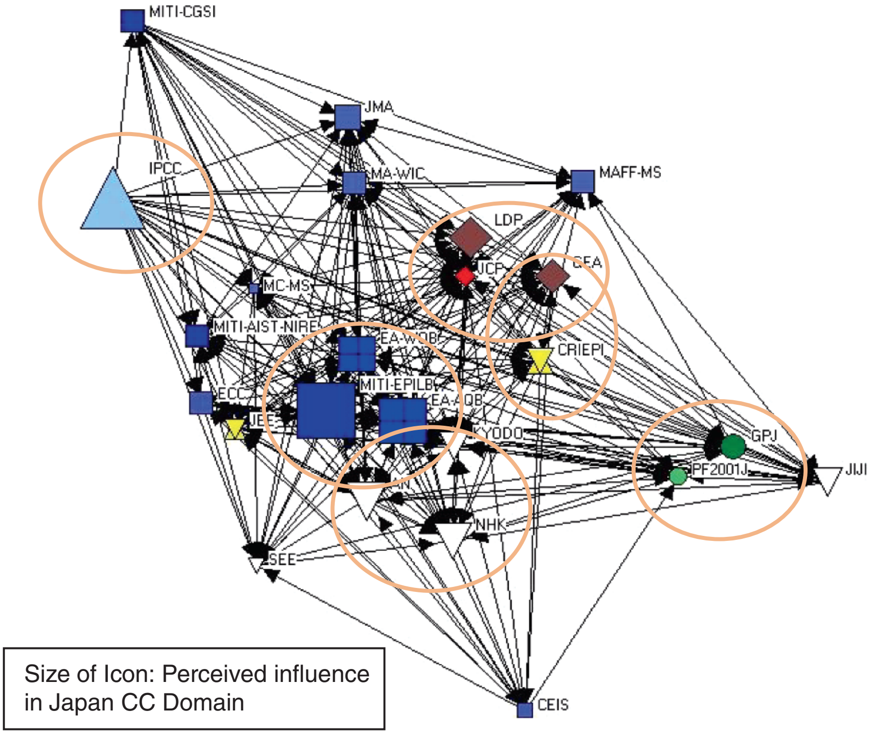

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Part I
Impacts of Climate Change

Chapter 1
Evaluating the Cost of Flood Damage Based on Changes in Extreme Rainfall in Japan

So Kazama, Ayumu Sato, and Seiki Kawagoe

1.1 Introduction

The fourth report of the Intergovernmental Panel on Climate Change (IPCC) provoked a significant amount of controversy, as experts have sought to apply it to climate change in Japan. In particular, the Ministry of Land, Infrastructure, Transportation, and Tourism (MLIT) organized a committee of experts responsible for implementing flood control policies (MLIT 2008). Japan is particularly vulnerable to flooding because of its steep geography and humid climate characterized by typhoons. Consequently, Japan has been coping with the problem of flood control for a long time (Takahasi and Uitto 2004). The number of floods, and, hence, the damage due to flooding, has increased since 2004. Even though these flood events may not be caused directly by climate change, many researchers are interested in the various problems of climate change and its broader implications for economic development.

General circulation models (GCMs) developed by a number of organizations have recently brought to light studies on the frequency of flooding and related projections. Kay et al. (2006a, b) used the regional climate model (RCM) based on HadRM3H and applied it to a simple hydrological model in 15 catchments of the UK smaller than 500 km^2. They then estimated changes in flood characteristics in each basin using a return period calculation. Here, the return period of extreme rainfall is the expected value of the recurrent interval deriving from frequency analysis. Cameron (2006) also derived a relationship between the return period and flood discharge by applying the RCM and hydrological model called TOPMODEL to a smaller dataset based on the UKCIP02 climate change scenarios. Combining GCMs and hydrological models can provide information not only on the impact of

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climate change but also on the influence of hydrological processes on change-of-surface conditions (Loukas et al. 2002) and the uncertainty of statistical evaluations on the flood regime (Prudhomme et al. 2003). These results require discussion on change of not only climate condition but also land use and social conditions.

In order to discuss different strategies and prioritize different options for implementing regional countermeasures against flooding associated with climate change, it is helpful to understand the costs of flood damage. There already exists an established literature estimating the costs of flooding due to climate change (e.g., Cline 1992). The IPCC (2007) reported estimates on economic damage caused by climate change, while the Stern report (2006) collected a variety of data and potential economic risks for each region in more detail. Over the period 2000–2100, Wada et al. (2005) predicted that the probability of daily maximum precipitation levels would increase by 20% throughout Japan and by approximately 40% for eastern Japan. For other examples, in an applied evaluation of the cost of adaptation to climate change, Gleick and Maurer (1990) assessed various options for adapting to flooding with return periods in the Bay area of California. In addition, Haddad and Merritt (2001) used hydrological data to evaluate water storage capacity and its costs for the regional scale management of water resources. The results of these researches can contribute to estimating the economic damage due to flooding and are helpful in planning and designing flood prevention methods.

Adapting to flooding caused by climate change is a matter of national policy. For example, Mirza (2002) discussed the implications of flooding in Bangladesh based on hydrological and damage data. Although flood prevention is a policy concern at the national level, we must consider the needs of each region and how these differences may influence the program design. For instance, Naess et al. (2005) mentioned different policy implications at the national and municipal levels in Norway. In contrast, Kitajima et al. (1993) estimated the cost of measures to counteract the rise in sea level in Japan by accounting for the total cost of all shorelines in Japan, but there is no discussion regarding which region should select countermeasures. The government should decide which adaptation methods would be the most appropriate for each region. Regardless of whether flooding countermeasures are considered in the context of climate change or more as a question of crisis management, it is important to develop these measures by taking into account regional variations in geology, population, and culture.

This kind of research has shown that a distributed hydraulic model can provide more detailed information on flood risks and flood prevention on a regional scale. For example, Dutta et al. (2006) assessed flooding countermeasures and their cost using distributed hydrological and hydraulic models on a small scale. Ichikawa et al. (2007) performed a cost–benefit analysis of land-use regulations using a hydraulic model with numerical map data. These studies have provided detailed understanding of the spatial distribution of flood protection effects in such small basins. However, no studies have yet attempted to show the costs of flood damage throughout an entire nation in order to compare the costs of regional countermeasures. Therefore, in the present study, we developed a method for estimating the costs of flood damage across Japan. This method relies on a hydraulic model based on extreme rainfall data as an input. The extreme rainfall intensity is calculated for every return period using past rainfall data and is used for discussion on flood damage by climate change shifting the return period in the future.

1.2 Methodology

1.2.1 Rainfall Data and Inundation Model

The distribution of extreme 24-h rainfall was obtained using the Auto Meteorological Data Acquisition System (AMeDAS) data from 1980 to 2000, as described by Ushiyama and Takara (2003). Here, it is noted that extreme and maximum rainfalls have different definitions (Chow et al. 1988). Past data decides the maximum rainfall and static statistics analysis provides extreme rainfall using past data in simple description. First, we carried out a frequency analysis on annual maximum 24-h rainfall data at every AMeDAS gauge station to calculate the return period for extreme rainfall. We used the generalized extreme value (GEV) probability distribution function with the probability weight moment (PWM) method in order to evaluate the GEV function parameters. The distribution function can estimate the return period of extreme rainfall (Chow et al. 1988). There are 1,024 AMeDAS stations throughout Japan. In addition, the Japan Meteorology Agency (JMA) provides a numerical map of average 24-h rainfall data every month; this map is generated from factor analysis and shows the spatial distribution of rainfall (JMA 1988). Second, we used regression to estimate the linear relationship between the average 24-h rainfall and maximum 24-h rainfall for each return period. Some data were not included either because they were unavailable or they were unreliable. The relationship was calculated for each different season, as shown in Fig. 1.1 Extreme rainfall data were estimated from the AMeDAS records, and maximum precipitation was defined to be the maximum value for the monthly average 24-h rainfall data during each season. Third, we inferred the distribution of extreme rainfall from the numerical map of average 24-h rainfall using the regression analysis expressed in Fig. 1.1 It is important to note that the estimation of extreme rainfall from this linear relationship (Fig. 1.1) does not have a small scatter, and we observed heavy rainfall patterns, such as typhoons or baiu rainfall, during some seasons. In order to consider the effects of climate change, we must pay attention to changes in the shape of the distribution function, which depend on the rainfall pattern. This means that changes in the rainfall pattern alter the distribution of extreme rainfall. Therefore, this study could detect extreme rainfall change based on current climate conditions, but not climate change.

The inundation model is a two-dimensional non-uniform flow model that uses a Manning roughness coefficient to take into account land use. The roughness values were estimated by calibration with respect to many Japanese basins. The land use data were obtained from the Geographical Survey Institute (GSI) of Japan. Extreme rainfall data from continuous periods of 24 h were applied spatially to the inundation

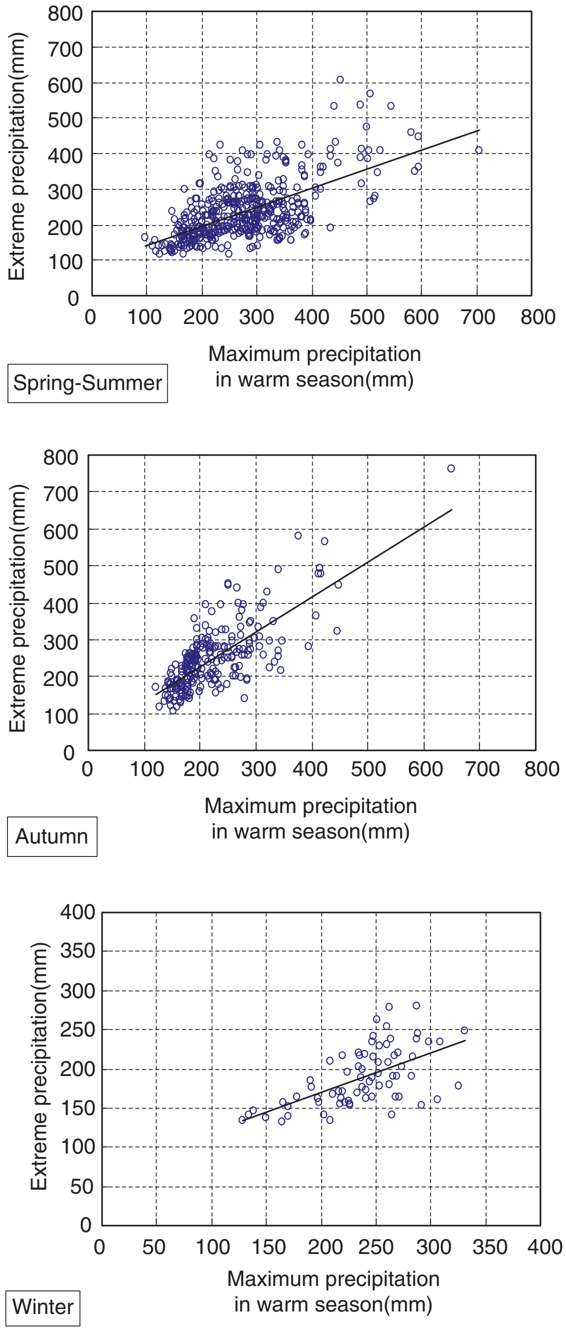

Fig. 1.1 Relationship between extreme rainfall and maximum precipitation in different seasons (maximum precipitation is selected as the maximum value in the dataset of monthly average 24-h rainfall during each season)

model as the input data. Given the topography of Japan, a flood wave caused by extreme rainfall in most rivers can reach the river mouth within 24 h, except in a few cases. Following data input, the inundation simulation was carried out for 1 week to determine the maximum water depth and inundation period, which were needed to calculate damage costs.

Inundation models in large areas usually apply hydrological functions, but we ignored these processes because, in the case of extreme rainfall, the soil is saturated, causing less infiltration; full water depth on leaves involves no interception with vegetation; and the saturation of the ambient air leads to less evapotranspiration. The 2D non-uniform flow models are shown in the following equations (Chow et al. 1988; Kazama et al. 2007). This model consists of a continuity equation and a momentum equation in two directions, which are applied to all regions:

$$\gamma\frac{\partial D}{\partial t}+\frac{\partial\ M}{\partial x}+\frac{\partial\ N}{\partial y}=0 \tag{1.1}$$

$$\lambda\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}\left(\frac{M^2}{D}\right)+\frac{\partial}{\partial y}\left(\frac{MN}{D}\right)+\gamma gD\frac{\partial(D+h)}{\partial x}$$
$$+\frac{\gamma gn^2M\sqrt{M^2+N^2}}{D^{7/8}}+\frac{1}{2}\frac{(1-\gamma)}{B}C_{\mathrm{D}}\frac{M\sqrt{M^2+N^2}}{D}=0 \tag{1.2}$$

$$\lambda\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}\left(\lambda\frac{MN}{D}\right)+\frac{\partial}{\partial y}\left(\gamma\frac{N^2}{D}\right)+\gamma gD\frac{\partial(D+h)}{\partial y}$$
$$+\frac{\gamma gn^2N\sqrt{M^2+N^2}}{D^{7/8}}+\frac{1}{2}\frac{(1-\gamma)}{B}C_{\mathrm{D}}\frac{N\sqrt{M^2+N^2}}{D}=0 \tag{1.3}$$

$$\lambda=\gamma+(1-\gamma)C_{\mathrm{M}} \tag{1.4}$$

where $M = uD$ represents the discharge flux in the x-direction, while $N = vD$ represents the discharge flux in the y-direction (m^2/s), g is gravitational acceleration (m/s^2), v and u represent the velocity (m/s) in the x- and y-directions, respectively, h represents elevation (m), n is the Manning coefficient ($s/m^{1/3}$) and D is the water depth (m), $1 - \gamma$ is the house occupancy ratio, B the house size (m), C_{M} the additive mass coefficient (=0.2), and C_{D} is the house drag coefficient (=1.0). It was supposed that B and γ are, respectively, given as constants of 14.941 and 0.411 in a residential area of land use data referring to the flood control economy investigation manual (MLIT 2005). Although original equations include non-linear terms, we have ignored them so as to avoid complex calculations and to consider the average amount within the dxdy area. Also in this model, the time interval and ground resolution have been selected as 1 s and 1 km, respectively. The Manning coefficient of the inundation flow has been referred in hydraulics formulas [Japan Society of Civil Engineers (JSCE) 1999] depending on land use. The equations have been solved using a finite difference technique expressing a forward difference scheme in time and a central difference scheme in space. This 2D, non-uniform flow model was tested in the eastern part of Sendai City in Japan, and was found to work well (Kazama et al. 2002). In addition, some inundation models involving finer spatial datasets can calculate accurate velocities that influence house destruction. The model proposed here does not require such a level of detail because it was carried out at the national level, and the manual for damage cost estimation does not include physical damage caused by hydraulic momentum.

1.2.2 Calculating the Costs of Flood Damage

The procedures for calculating the damage cost for each type of land use were determined based on the flood control economy investigation manual published by the MLIT (2005) and land-use grid data (KS-META-L03-09 M) (National Land Information Office, MLIT 2007). The following types of land use were included in the analysis: (1) paddy fields, (2) other agricultural lands, (3) residential areas, (4) golf courses, (5) traffic zones, (6) forests, (7) barren lands, (8) other land, (9) rivers and lakes, (10) beaches, and (11) coastal zones. The calculation method used for each type of land use type is described below.

Agricultural damage in paddy fields and other agricultural lands was calculated by multiplying agricultural assets by the damage rate corresponding to the inundation depth and inundation period. The agricultural assets were calculated by multiplying the paddy field surface area and other agricultural land areas by the price of agricultural production per unit area.

Paddy field damage was calculated using the following formula:

$$\begin{aligned}\text{damage (USD)} = {} & 489\ (\text{t/Km}^2) \times 2{,}480\ (\text{USD/t}) \\ & \times \text{inundation area (Km}^2) \\ & \times \text{damage rate by inundation depth}\end{aligned} \tag{1.5}$$

where 489 t/km^2 is the national median of the average harvest volume per unit area of paddy field in Japan and 2,480 USD/t is the unit price of rice in Japan in 1999. The damage rate is obtained from an empirical function, which will be explained later.

Damage to other agricultural lands was determined using the following formula:

$$\begin{aligned}\text{damage (USD)} = {} & 489\ (\text{t/Km}^2) \times 2{,}300\ (\text{USD/t}) \\ & \times \text{inundation area (Km}^2) \\ & \times \text{damage rate by inundation depth}\end{aligned} \tag{1.6}$$

where 5,770 t/km^2 is the national median of the average volume of tomatoes harvested per unit of land area in Japan and 2,300 USD/t is the unit price of tomatoes in Japan in 1998.

Since the goal of this study was to determine the distribution of flood damage throughout Japan, the production of various agricultural crops other than paddy rice was considered. Nevertheless, assessing the damage to all types of agricultural production proved to be difficult in this study. As a result, tomatoes were chosen to represent Japanese agricultural production, since they are widely grown throughout the country. In fact, average agricultural production is around 2,360 USD/t (Ministry of Agriculture, Forestry and Fisheries [MAFF] 2002). Tomato production, with a yield of 2,300 USD/t, approximates this value most closely.

In addition to crop type, the cost of agricultural damage depends on the stage of crop growth when flooding happens. For example, flooding in the winter causes almost no damage. However, the modeling in this study did not take into account the timing of flooding, and it assumed the worst case of damage occurring at the height of the growing season.

The types of land use suffering the most damage in flooding models are in areas of strong economic activity, i.e., residential and office areas with large assets and production. This type of land use can be divided into two subcategories (residential buildings and office buildings) based on national data on land use, reutilization changes, and economic and policy changes (site mesh KS-META-A02-60 M) (National Land Information Office, MLIT 2007):

$$\text{residential building damage} = \text{house damage} + \text{household furniture damage} \quad (1.7)$$

$$\text{office building damage} = \text{office building damage} + \text{redemption and inventory assets} \quad (1.8)$$

Damage to houses was calculated by multiplying house assets in each prefecture by the damage rate as a function of the water depth estimated by the inundation model. House assets were taken from data on prices per unit area summarized by the MLIT (2005), and the damage rate was obtained directly from the empirical data by the MLIT:

$$\text{house damage (USD)} = \text{house assets (USD/m}^2) \times \text{inundation area (m}^2) \times \text{damage rate by inundation depth} \quad (1.9)$$

Household furniture damage was calculated by multiplying household furniture assets by the damage rate to the flood depth. Household furniture assets were calculated by multiplying the number of households by the unit price per household:

$$\text{house furniture damage (USD)} = 129,720 \text{ (USD/household)} \times \text{inundation household (household)} \times \text{damage rate by inundation depth} \quad (1.10)$$

where 129,720 USD/m^2 is the national median of the valuation per household in Japan in 2004.

Office building damage was calculated in the same manner as house damage. Office depreciable assets and inventory asset damage was calculated by multiplying office depreciable assets and inventory assets by the damage rate as the flood depth evaluated by the inundation model. Office depreciable assets and inventory assets were calculated by multiplying the number of employees by the unit price per employee:

$$\begin{aligned}\text{depreciable asset damage (USD)} = &\ 56{,}210\ \text{(USD/employee)}\\ &\times \text{inundation influence working force (employee)}\\ &\times \text{damage rate by inundation depth}\end{aligned} \tag{1.11}$$

$$\begin{aligned}\text{inventory asset damage (USD)} = &\ 49{,}150\ \text{(USD/employee)}\\ &\times \text{inundation influence working force (employee)}\\ &\times \text{damage rate by inundation depth}\end{aligned} \tag{1.12}$$

where 56,210 USD/employee is the average amount of depreciable assets per employee in Japan (except in agriculture, forestry, and fisheries), and 49,150 USD/employee is the average amount of inventory assets per employee in Japan (except in agriculture, forestry, and fisheries).

Golf course damage was calculated as service sector damages. In this case, depreciable assets and inventory assets were used to estimate golf course damage:

$$\begin{aligned}\text{golf course damage} = &\ \text{depreciable assets + inventory assets}\\ &\ \text{(service industry)}\end{aligned} \tag{1.13}$$

$$\begin{aligned}&\text{depreciable asset damage (USD)}\\ &\quad = 42{,}360\ \text{(USD/employee)}\\ &\quad \times \text{inundation influence working force (employee)}\\ &\quad \times \text{damage rate by inundation depth}\end{aligned} \tag{1.14}$$

$$\begin{aligned}&\text{depreciable asset damage (USD)}\\ &\quad = 3{,}200\ \text{(USD/employee)}\\ &\quad \times \text{inundation influence working force (employee)}\\ &\quad \times \text{damage rate by inundation depth}\end{aligned} \tag{1.15}$$

where 42,360 USD/employee is the average amount of depreciable assets per employee in the service sector in Japan in 2005 (MLIT 2005) and 3,200 USD/employee is the average amount of inventory assets per employee in the service sector in 2005 (MLIT 2005).

Traffic zone damage was calculated from the relationship to general asset damage because it is too difficult to estimate traffic damage directly from traffic assets:

$$\text{traffic zone damage} = \text{general asset damage} \times 1.694 \tag{1.16}$$

where "general asset damage = house damage + furniture damage + office depreciable assets and inventory asset damage," and 1.694 is the ratio of the cost of damage to public facilities to the cost of damage to general assets (MLIT 2005).

Flood damage to the following land types was taken to be zero: forests, barren land, other land, rivers and lakes, beaches, and coastal zones. Moreover, the recovery cost for damages was also not considered for all land uses. Damage should actually be weighted based on local estate values and the type of industry, but we

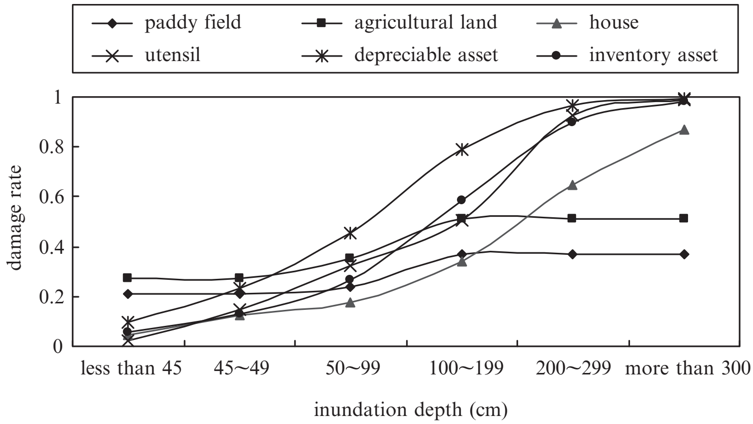

Fig. 1.2 Relationship between damage rate and inundation depth

assumed uniform conditions throughout Japan based on the manual, which does not take into account frequent price changes.

The damage rate depends on two parameters: floodwater depth and inundation period. The rate was obtained by the MLIT (2005) from empirical analysis using past data and was shown as discrete data used to prepare a continuous formula using a high-dimensional function for inundation analysis. Figure 1.2 shows the continuous relationship between the damage rate and inundation depth in the case of 1–2 days of inundation. Inundation depth and period are the maximum water depth and duration of water existence, respectively, with 7 days defined as the maximum inundation period in the simulation. Figure 1.2 shows that paddy fields and other agriculture lands undergo a gradual change in the damage rate compared to the other items. On the other hand, the damage rates of housing and assets show significant increases with increasing inundation depth. When the inundation depth exceeds 200 cm, the damage rate reaches nearly 100%. The relationship between the damage rate and inundation period is shown in Fig. 1.3. The damage rate of agricultural production rises depending on the flood period. For example, the damage rate increases by 30–40% for a 7-day inundation period. When the inundation depth in paddy fields exceeds 1 m with an inundation period of 7 days, the damage rate is 70%, while in other agricultural lands under the same conditions, the damage rate reaches nearly 100%. The overall effect of the inundation period shows that the damage rate increases with inundation period.

1.3 Results

We applied the inundation simulation to a scenario in which Japan implements no flood control measures and is subjected to extreme rainfall. We selected 5, 10, 30, 50, and 100 years as the return periods and estimated potential damage costs for the

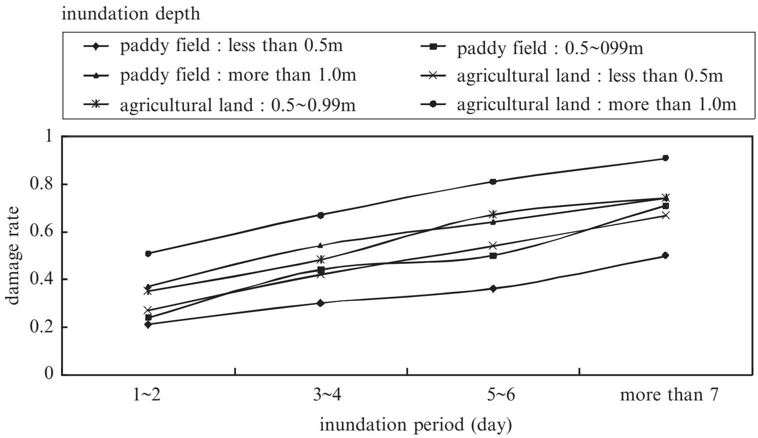

Fig. 1.3 Relationship between damage rate and inundation period

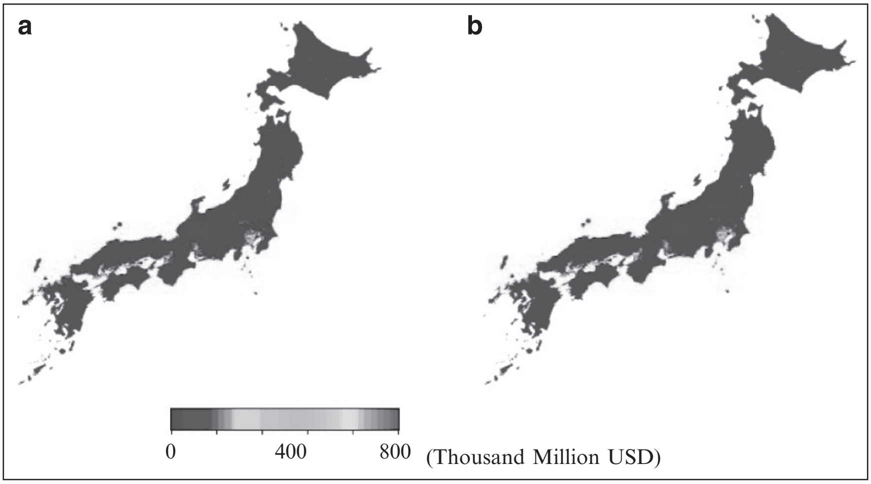

Fig. 1.4 Potential damage costs of flooding in Japan (thousand million USD). **a** Damage costs for 100-year extreme rainfall. **b** Damage costs for 50-year extreme rainfall (see Color Plates, Fig. 1.4)

flooding. Figure 1.4 shows the distribution of damage costs in Japan for extreme rainfall with 50- and 100-year return periods. The cost of damage in the different areas is very similar because Japan is primarily mountainous and only has small plain areas. Therefore, inundation areas do not expand to wider regions, even though the floodwater depth increases. This means that damage costs in the same areas increase as rainfall intensity increases. Large and highly populated cities have large damage costs due to the concentration of assets. These cities include Tokyo, Nagoya, and Osaka, which are located in lowlands.

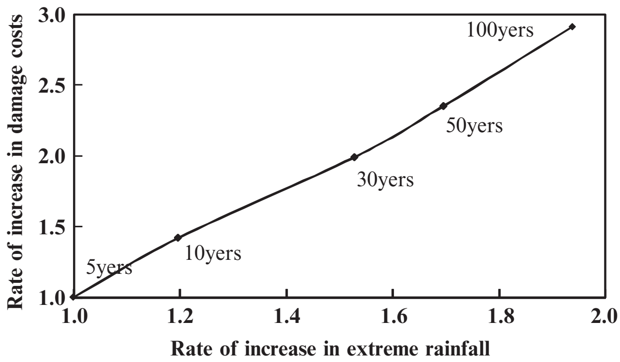

Fig. 1.5 Relationship between the rates of increase in extreme rainfall and flood damage costs from a 5-year return period of extreme rainfall

Figure 1.5 shows the almost linear relationship between the rate of increase in extreme rainfall and the rate of increase in flood damage costs from a 5-year return period. This relationship is due to the steep Japanese topography that concentrates flooding in limited plain areas surrounding steep mountains and does not allow it to expand widely, in contrast to the increase in water depth. The results of this simulation accurately characterize the damage from typical Japanese flooding events. Shifting from a 5- to 100-year return period doubles the extreme rainfall intensity and triples damage costs. The ratio of the rate of increase in damage to the rate of increase in extreme rainfall is 1.5.

1.4 Discussion

In our evaluation of the potential flood damage for no flood countermeasures, we assumed that, by developing its infrastructure, Japan can minimize flood damage in the case of extreme rainfall within a 50-year return period. The return period of 50 years is determined as the average of urban and rural areas that actually have infrastructures with almost 70- and 30-year return periods in Japan, respectively, although the infrastructure development should be different in each region. According to the assumption that Japan completed flood infrastructure for the 50-year return period extreme rainfall, the benefit of protective measures against flooding potentially caused by climate change can be estimated from the difference in damage costs between current and future situations. The MLIT uses this method to calculate the benefit of infrastructure renovation for flood control based on the flood control economy investigation manual (2005). The manual does not take into account the possibility that extreme rainfall will be affected by climate change: the return period shift caused by climate change is not taken into account, and changes in rainfall intensity are considered by only using a return period estimated from current statistical calculations. The benefit of these measures for flood protection with return periods of 50–100 years nearly equals the different potential damage costs.

Our simulation method was verified by estimating downpour damages in the Hokuriku district of Japan in 2004. The 2004 flooding occurred in a wide area and involved a variety of inundation cases in various regions in the Niigata prefecture. This disaster was determined to have a mean return period of 113 years and to cause 2 billion USD of damage in the Niigata prefecture alone (MLIT 2004). Similar to these numbers, our simulation calculates a return period of 100 years in the Niigata prefecture and a cost of approximately 1.7 billion USD, assuming a flood defense completion for 50 years of extreme rainfall.

To estimate investment costs for infrastructure construction, it is necessary to discuss cost–benefit ratios. To prepare for cost–benefit analysis in the future, we evaluate the benefit of flood protection. Table 1.1 shows the damage cost for each return period. In the same approximation of flood defense completion for 50-year flooding, the benefit to protect from 100-year flooding is the difference in damage costs between a return period of 50 years and of 100 years, which equals about 210 billion USD. Furthermore, the numerical simulation can show the distribution of the increase of potential damage cost from extreme rainfall with 50- to 100-year return periods (Fig. 1.6). The increase of the potential damage cost is the same as

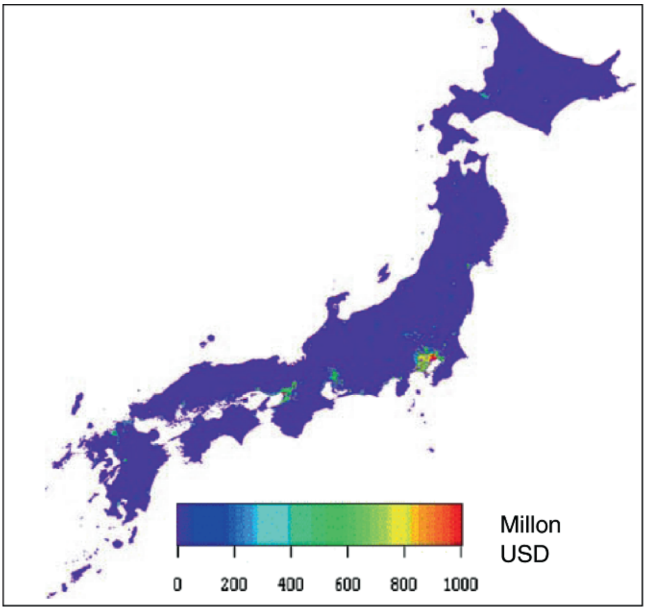

Fig. 1.6 Distribution of the increase of potential damage costs from rainfall with 50- to 100-year return periods (million USD) (see Color Plates, Fig. 1.6)

Table 1.1 Annual expected damage cost and return periods

Return period	Annual extreme probability	Damage cost	Interval av. damage	Interval probability	Av. annual expected damage cost
5	0.200	380			
10	0.100	550	470	0.1	47
30	0.033	770	660	0.067	44
50	0.020	910	840	0.013	11
100	0.010	1,120	1,020	0.010	10
150	0.007	1,130	1,130	0.003	3

Interval average damage is estimated from damage costs associated to two return periods. For example, the interval average damage, interval probability, and average annual expected damage cost of the 30-year return period are, respectively (770 + 550)/2.0, 0.100–0.033, and 660 × 0.067 (unit: billion USD)

the benefit to protect from 100-year flooding. The high-benefit areas are located in urban areas due to the high costs of flood damage in these areas.

Table 1.1 shows the relationship between the average annual expected damage costs and return periods. In this calculation, the interval average damage is the average value of damage costs in both return periods, the interval probability is the difference between both annual average extreme probabilities, and the product of these values is the average annual expected damage cost. The extreme rainfall shifting from 50- to 100-year return periods results in damages of approximately 10 billion USD damage per year, which is equal to the benefit of implementing infrastructure construction for flood protection. The annual expenditure for flood control in the MLIT regular budget is nearly 10 billion USD, which is similar to the expected damage costs. An analysis of cost–benefit ratios is necessary in order to estimate construction costs, which will make up a lower percentage of the MLIT budget.

There are a wide variety of options with different costs for flood countermeasures. Countermeasures should be evaluated according to regional differences, social structure, and culture. Although the absolute cost of damage or infrastructure investment estimated in our simulation is insufficient for decision-making, our modeling does indicate the relative distribution of damage costs, which is helpful for discussing countermeasures for protection from floods caused by climate change. The areas susceptible to large flood damage require complete flood defenses, such as super dikes or underground channels, because of the economic implications of flooding. On the other hand, areas vulnerable only to small flood damage require mitigation measures, warning systems, or evacuation plans. Recently, the MLIT has begun to discuss measures to protect against flooding caused by climate change, and the agency has presented many options for countermeasures (MLIT 2008). However, no discussions have dealt with measures tailored to specific regions of the country. Distribution maps of damage, such as that shown in Fig. 1.6, should prove to be helpful for developing such regional countermeasures to protect against flooding due to climate change.

1.5 Conclusions

This present study developed a method for estimating the costs of flood damage cost across Japan, which relies on a hydraulic model based on extreme rainfall data as an input. The extreme rainfall intensity is calculated for every return period using past rainfall data and is used for discussion on flood damage by climate change shifting the return period in the future.

Based on the above findings, we draw the following conclusions:

1. The rate of increase in extreme rainfall varies linearly with the rate of increase in damage costs.
2. Assuming that flood protection is completed for a 50-year return period of extreme rainfall, the benefit of flood protection for a 100-year return period of rainfall is estimated to be 210 billion USD.
3. The average annual expected damage cost for flooding is predicted to be approximately 10 billion USD per year, based on the probability of precipitation for a return period of 100 years and assuming that flood control infrastructures will be completed within the 50-year return period and will be able to protect from flooding with a 50-year return period.
4. Urban and rural areas are predicted to suffer high and low costs of damage, respectively.

Using numerical flood simulations with digital elevation data, we can obtain a map of damage costs across Japan, and this map can also be taken to approximate the investment needed for flood defenses. This map makes it easy to understand which areas are the most vulnerable to flooding in Japan. In this way, the present study will help in the development of flood prevention and protection options that take into account regional variations.

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Chapter 2
Impact of Global Warming on Agricultural Product Markets: Stochastic World Food Model Analysis

Jun Furuya and Shintaro Kobayashi

2.1 Introduction

Working Group I (WGI) of the Intergovernmental Panel on Climate Change (IPCC) reports that the average air temperature at the end of the 21st century will rise by 4.0°C from current levels, according to the fossil energy intensive scenario. Agricultural production will be affected by global warming through changes in yields and market prices. The dominant factor in rising temperature is the increasing concentration of carbon dioxide (CO_2), which represents the greatest exhaust quantity among the greenhouse gases (GHG) and has increased in volume from 280 ppm in the pre-industrial period to 379 ppm in 2005.

Increasing the concentration of CO_2 activates plant photosynthesis. Hasegawa et al. (2005) conducted field experiments in free-air CO_2 enrichment (FACE) and reported that, if CO_2 concentration increases an additional 200 ppm over the current level, the yield of rice will increase by about 15%. Yields of other crops such as wheat and soybeans will increase at the same rate; these yield increases at a higher CO_2 concentration are known as the fertilizer effect. Furthermore, water requirements will decrease because stomas shut a little under these conditions (Yoshimoto et al. 2005).

Increasing the concentration of CO_2 leads to positive impacts on crop growth; at the same time, however, the higher temperatures of global warming can obstruct crop growth. The rise in temperature shortens the growth period due to early flowering and fruit-bearing, and decreases the nourishment sent to the seed due to increased respiration; hence, seeds may not fully develop. Furthermore, high temperatures during the flowering period cause spikelet sterility. In the case of Japanese rice, it becomes difficult for the anther to tear when the air temperature is over 34°C, preventing pollination.

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In addition to the effects on plant physiological functions, increases in damage from diseases and harmful insects are anticipated. It has been suggested that an expansion of soybean cyst nematode and gray leaf blight in maize is probably caused by global warming (Rosenzweig et al. 2000).

Given these various effects, will producers and consumers of farm products be negatively impacted by global warming, or not? In an analysis by Jones and Thornton (2003), yield changes due to global warming are calculated using a crop model which estimates dry matter production. While this type of analysis is suitable for estimating regional impacts on crop production, it focuses only on dry matter production and does not reflect farmers' economic behavior. If farmers anticipate that the farm price of a crop will rise in the next year, they will increase the planted area of that crop.

When the impact of global warming on agricultural markets is analyzed, it is necessary to consider the farmers' supply response. Parry et al. (1999) analyzed the impact of global warming on world food security using a supply and demand model including both supply response models and crop models. The analysis is quite logical, but the structure is complicated and the parameters of the crop model are undisclosed.

In addition to the issue of rising temperature, fluctuations in agricultural production due to global warming should be considered when evaluating food security. Recently, the frequent occurrence of extreme weather events, such as droughts and floods, has threatened farmers' income. Global warming probably influences the circulation of the ocean and the atmosphere, and may lead to extreme weather events of this sort (IPCC 2007).

Considering such variations in production, a stochastic model approach is useful for realistic analysis. Tyers and Anderson (1992) extended their agricultural trade model to a stochastic model by including supply functions with error terms, and 200 sets of normally distributed random numbers were added to the error term. Their work demonstrated the policy implication that trade reduces commodity price fluctuations. Furthermore, some stochastic analyses using supply and demand models of agricultural products have been developed by the Food and Agricultural Policy Research Institute (FAPRI) for evaluating schemes to stabilize farm income. Along the same lines, Furuya and Meyer (2008) applied a multivariate stochastic model for evaluating the impact of water supply changes on the rice market in Cambodia.

Based on such research, this paper examines the possible effects of climatic change, focusing on global warming and its impact on world agricultural product markets, by using a stochastic version of the world food model developed by the Japan International Research Center for Agricultural Sciences (JIRCAS). The basic world food model was developed by Oga and Yanagishima (1996) and is extended to a stochastic model considering correlations among countries' temperatures and rainfall. The term of the outlook is 25 years, which is considered to be a mid-term projection. This stochastic analysis is different from analyses of uncertainty based on differences in climate models, such as the multi-model ensemble analysis by Neelin et al. (2006). Our stochastic model focuses only on fluctuations in temperature and rainfall for forecasting results from a global circulation model (GCM) at the Hadley Centre (HadCM3) for a socio-economic scenario.

2.2 Model

2.2.1 World Food Model

The JIRCAS world food model, known as the International Food and Agricultural Policy Simulation Model (IFPSIM), consists of yield, area, demand, export, import, stock, and price linkage functions for 14 commodities and 32 countries or regions. Among the commodities, wheat, maize, other coarse grains (which include barley, rye, oats, millet, and sorghum), rice, and soybeans are the crops covered. Equilibrium prices are obtained from the nested loop, i.e., domestic and international market clearance conditions. Furuya and Koyama (2005) estimated yield functions of crops including temperature and rainfall as variables, and replaced the original functions with the newly estimated functions in the IFPSIM. The estimated yield function is as follows:

$$\ln YH_t = a + b_1 T + b_2 \ln TMP_t + b_3 \ln PRC_t \tag{2.1}$$

where *YH* is the yield, *T* is the time trend, and *TMP* and *PRC* are temperature and rainfall, respectively, in the flowering or silking season. If the climate data is non-stationary, the following difference function is estimated:

$$d \ln YH_t = a + b_2\, d \ln TMP_t + b_3 d \ln PRC_t \tag{2.2}$$

where $d \ln YH_t = \ln YH_t - \ln YH_{t-1}$, $d \ln TMP_t = \ln TMP_t - \ln TMP_{t-1}$, and $d \ln PRC_t = \ln PRC_t - \ln PRC_{t-1}$. In this case, parameter *a* in function 2 is equivalent to parameter b_1 in function 1.

Figure 2.1 shows the flowchart of a leader country in the crop sector of the world food model. The leader country is selected from the large exporters; for example,

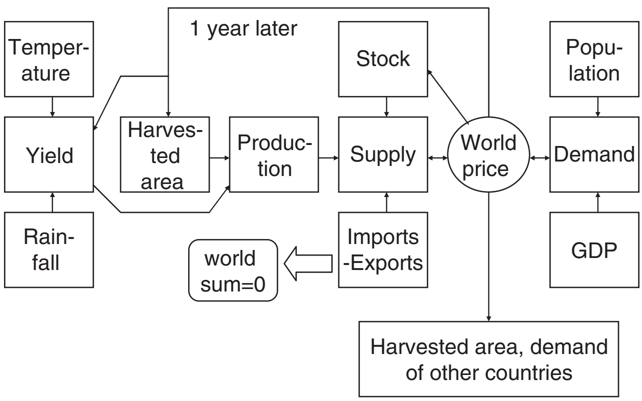

Fig. 2.1 Flowchart of a leader country in the crop sector of the world food model

the United States is the leader country in wheat, maize, other coarse grains, and soybeans, and Thailand is the leader country in rice. In this model, yield, area, production, imports, exports, stock, and demand are endogenous variables. Population, gross domestic product (GDP), temperature, and rainfall are exogenous variables. Temperature and rainfall data are generated for stochastic analysis.

2.2.2 Partial Stochastic Model

The temperature and rainfall variables entered into the yield functions are exogenous to the supply and demand model. To evaluate the effect of changes in temperature and rainfall during flowering or silking seasons on the world food market, these climate variables must be endogenized in a model, which will then recursively feed the supply and demand model. The following simple linear temperature and rainfall models are estimated:

$$TMP_{ijt} = a^T + b^T T \tag{2.3}$$

$$PRC_{ijt} = a^P + b^P T \tag{2.4}$$

where i is the identification number of the country and j is the identification number of the crop.

Equation errors are retained when comparing the estimates to the actual data. The errors' empirical distributions and correlations among countries, and two climate variables of the resulting errors, are maintained and employed to construct a set of random temperature and rainfall variables consistent with history. With the use of the historical error correlation matrix for countries and random draws on a normal distribution, correlated uniform deviates for each country are created through the standard normal cumulative distribution. These random numbers are transformed into draws on the empirical error distributions, which maintain their historical correlated relationship and distributions. This process creates 150 sets of error draws, which are then inserted into the temperature and rainfall forecasting model with the same functional forms as functions 3 and 4. However, data sets are forecasted based on the A2 scenario and are used to create 150 simulated future temperature and rainfall paths. The procedure for creating correlated random climate variables is based on the program of Richardson et al. (2000). This system is shown in Fig. 2.2.

2.3 Data

The temperature and rainfall data used for estimating functions 1 and 2 are average numbers reported by the Global Historical Climatology Network (GHCN). The climatic variables selected are monthly data for the flowering or silking season of

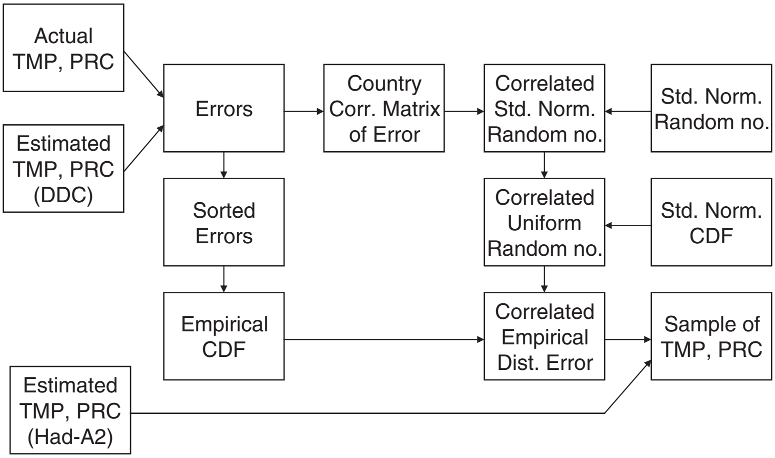

Fig. 2.2 Flowchart of random climatic data creation

each crop, as indicated in the cropping calendar of the United States Department of Agriculture (USDA) (1994). Temperature and rainfall in large countries, such as the US, vary greatly across regions; large countries are divided into regions based on the cropping map of the USDA (1994). The yield function for 'other Africa' is not estimated due to insufficient climate data. The basic estimation period is from 1961 to 2000.

The temperature and rainfall data used for estimating functions 3 and 4 are the average numbers reported by the Data Distribution Centre (DDC) of the IPCC. The data is based on that of the GHCN and modified to 0.5° grid data. The results of simulations by the Hadley Centre are reported as grid data; the DDC data is then used for estimating these functions. Table 2.1 shows the results of a correlation matrix of percentage errors for major wheat-producing countries. The Cholesky decompositions of these matrices are used for creating correlated standard normal random numbers.

The Hadley Centre provides grid data on the A2 scenario from the IPCC (HadCM3-A2). The A2 scenario assumes that each country maintains its own distinct culture and that trade, labor mobility, and technological transfer are restricted. Therefore, per capita GDP grows slowly and the annual average per capita income in 2050 is $7,200, while the world population reaches 11 billion. One of the simulation results is used for estimating the baseline of temperature and rainfall from 2001 to 2050 using functions 3 and 4. The correlated random errors are added to the baseline and 150 sets of climate data following the A2 scenario are obtained. Figure 2.3 shows the temperature of the flowering or silking season in the US based on actual data from the DDC for the period 1961 to 2000 and forecasting data from HadCM3-A2 for the period 2001 to 2050.

Table 2.1 Correlation matrix of % errors for major wheat-producing countries

	Temperature				Rainfall				
Country/region	EU	Ex-USSR	India	China	USA	EU	Ex-USSR	India	China
Temperature									
USA	–0.257	0.228	0.268	–0.031	–0.460	0.022	0.187	–0.063	0.110
EU		0.014	0.216	0.286	–0.045	–0.412	–0.447	0.216	0.166
Ex-USSR			0.058	–0.122	0.152	0.009	–0.522	0.100	0.169
India				–0.035	–0.246	0.125	0.021	–0.115	0.052
China					–0.150	0.148	–0.053	–0.134	0.101
Rainfall									
USA						–0.017	–0.138	0.020	–0.138
EU							0.212	–0.394	–0.047
Ex-USSR								–0.362	–0.092
India									–0.050

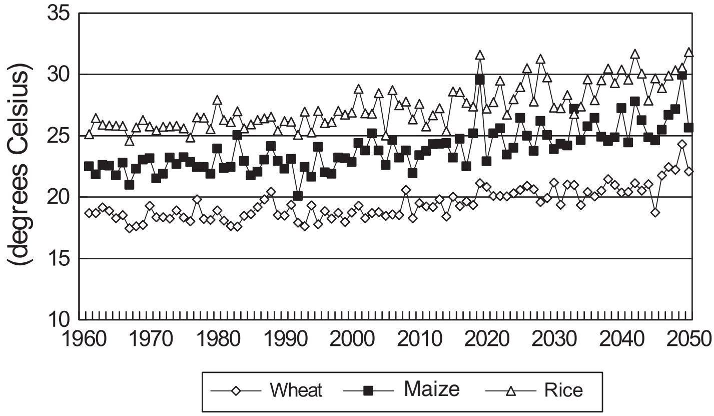

Fig. 2.3 Temperature of flowering or silking season in the US

2.4 Simulation of the World Food Model

The estimated parameters of rainfall and temperature by Furuya and Koyama (2005) are used in the stochastic version of the IFPSIM. The model is written in the FORTRAN 90 programming language; functions are included in the program for ease of development, whereas these functions are separate files in the original model. Parameters and data for rainfall and temperature are added to the database of the model and yield functions are changed as described earlier. If the estimated parameters are not significant at the 10% level, these parameters are set equal to zero, as shown in Tables 2.2–2.6. The model covers 14 commodities, including livestock products. The base year of the simulation is 1998 and the projection period is from the base year to 2030; thus, the intercepts of functions are not calibrated to the latest data.

The assumptions for the simulation are as follows: (1) the cropping calendar is fixed, (2) the cropping region is fixed, (3) the climatic variables directly affect yields, (4) the temperature and rainfall for all countries and regions follow the data of HadCM3-A2, (5) all parameters are fixed, and (6) trade policy is not changed, i.e., tariff rates in the base year are continued in subsequent years.

The yield functions of the simulation model of the US and the European Union for all crops, and those of all countries for soybeans, are specified as follows:

$$\ln YH_t = a + 0.1 \ln (PI_{t-1}/PI_{t-2}) + b_1 T + b_2 \ln TMP + b_3 \ln PRC \qquad (2.5)$$

where a is the calibrated intercept of these functions, PI is the subsidized producer price, b_1 is the parameter of the time trend (i.e., the annual increase in yield), b_2 is the parameter of temperature, and b_3 is the parameter of rainfall. The yield function of the simulation model for other countries for these crops is specified as function 1.

Table 2.2 Selected parameters for yield functions of wheat

Country/region	Temperature	Rainfall
USA	0.000	0.000
EU	−1.076	−0.117
Japan	0.000	0.000
Canada	0.000	0.344
Australia	0.000	0.443
New Zealand	−0.600	−0.214
East Europe	−0.660	0.000
Former USSR	−0.940	0.000
Mexico	0.000	0.000
Brazil	0.000	−0.199
Argentina	0.000	0.000
Other Latin America	−0.842	0.000
Nigeria	0.000	0.000
Egypt	−0.348	−0.021
India	−0.333	0.050
Pakistan	−0.482	−0.041
Bangladesh	−1.663	0.000
Republic of Korea	0.000	0.000
China	−0.530	0.000

Table 2.3 Selected parameters for yield functions of maize

Country/region	Temperature	Rainfall
USA	−1.226	0.186
EU	0.000	0.138
Japan	0.000	0.000
Canada	0.000	0.092
East Europe	0.000	0.476
Former USSR	−0.764	0.000
Mexico	0.000	0.000
Brazil	0.000	0.000
Argentina	−1.191	0.252
Other Latin America	0.000	0.000
Nigeria	0.000	0.000
India	0.000	0.000
Pakistan	0.000	0.000
Bangladesh	0.000	0.000
Indonesia	0.000	0.000
Thailand	−2.440	0.000
Malaysia	0.000	0.000
Philippines	0.000	0.000
Republic of Korea	0.000	0.000
China	−0.913	0.168

Table 2.4 Selected parameters for yield functions of other coarse grains

Country/regio	Temperature	Rainfall
USA	−1.525	0.000
EU	−0.772	0.000
Japan	−0.349	0.000
Canada	−0.489	0.189
Australia	0.000	0.423
New Zealand	0.000	0.000
East Europe	−0.492	0.000
Former USSR	−1.589	0.506
Mexico	0.000	0.000
Argentina	−1.439	0.144
Other Latin America	0.000	0.221
Nigeria	0.000	0.728
Egypt	0.000	0.000
India	−3.395	0.000
Pakistan	−0.292	0.000
Bangladesh	−2.800	−0.072
Republic of Korea	0.000	0.000

Table 2.5 Selected parameters for yield functions of rice

Country/region	Temperature	Rainfall
USA	−1.223	0.000
EU	1.282	0.000
Japan	1.043	−0.230
East Europe	0.790	0.000
Former USSR	0.000	0.000
Brazil	0.000	0.135
Other Latin America	0.000	0.000
Nigeria	0.000	0.000
Egypt	0.000	0.000
India	−1.994	0.000
Pakistan	0.000	0.000
Bangladesh	0.000	0.000
Indonesia	0.000	0.000
Thailand	0.000	0.000
Malaysia	0.000	0.000
Philippines	0.000	0.000
Republic of Korea	1.302	0.000
China	0.000	0.000

2.5 Results

Figures 2.4–2.13 show production from major producing countries and the world total for each crop. Averages, 90th and 10th percentiles, and randomly selected simulation results are shown in these figures. Figure 2.4 shows that the average

Table 2.6 Selected parameters for yield functions of soybeans

Country/region	Temperature	Rainfall
USA	–0.791	0.220
EU	0.000	0.000
Japan	0.000	–0.335
Canada	0.000	0.000
East Europe	–0.850	0.000
Former USSR	0.000	0.000
Brazil	0.000	0.000
Argentina	0.000	0.000
Other Latin America	–0.949	0.000
Nigeria	0.000	0.000
India	0.000	0.000
Pakistan	0.000	0.000
Republic of Korea	0.000	0.000
China	0.000	0.137

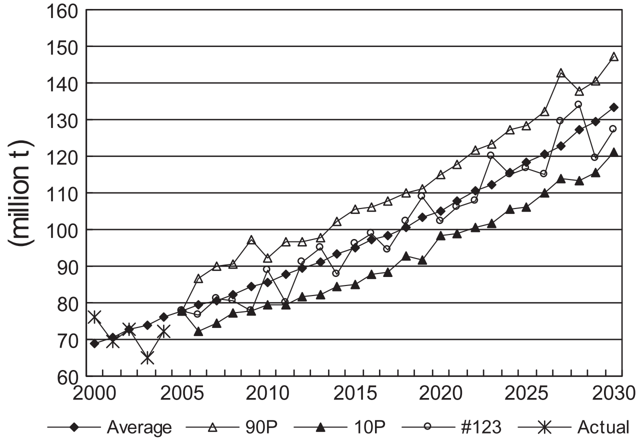

Fig. 2.4 Production of wheat in India. *90P* 90th percentile, *10P* 10th percentile, *#123* results of the 123rd simulation

production of wheat in India will increase by about 54 million metric tons (t) between 2006 and 2030 due to rising yields and an increase in planted area. The coefficient of variation (CV) of production is 4.57% during the period (the average CV from 2006 to 2030 for 150 results) and is higher than that of the world (1.65%), the fluctuation of which is shown in Fig. 2.5.

Figure 2.6 shows that the production of maize in the US will increase by 70 million t over the next 25 years. However, the variation is very high, with a CV of 8.12%, due to the relatively large negative parameter of temperature in the yield function. The variation in the production of maize in the world is also

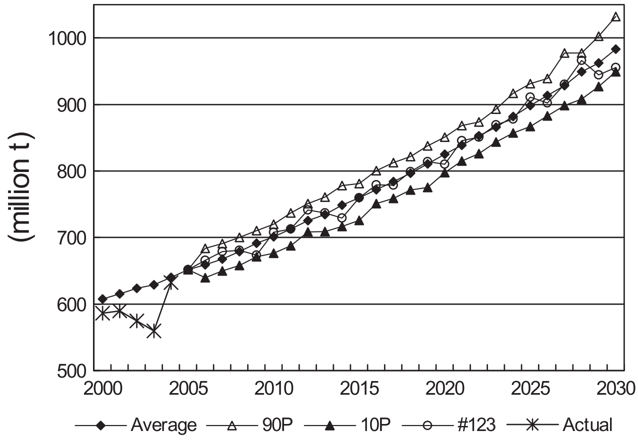

Fig. 2.5 Production of wheat in the world

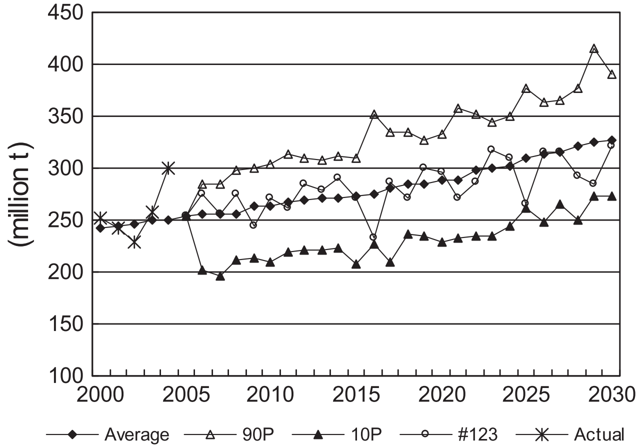

Fig. 2.6 Production of maize in the US

higher than for wheat, other coarse grains, or rice, as shown in Fig. 2.7. This is because the parameter of temperature in the US is large and its impact spreads to other countries because the US is the price leader in maize. Figure 2.8 shows the mean value and the variation in the production of other coarse grains in the former USSR. The share of production by the Russian Federation is around 60% in this area. The share of barley among the other coarse grains is around 50%. The parameter of temperature in the yield function is −1.59, showing that barley is vulnerable to higher temperatures. The CV in the former USSR will increase from 8.31% in 2006 to 9.42% in 2030. The total production in the world will increase by about 200 million t and the CV of production is 2.63% during this period, as shown in Fig. 2.9.

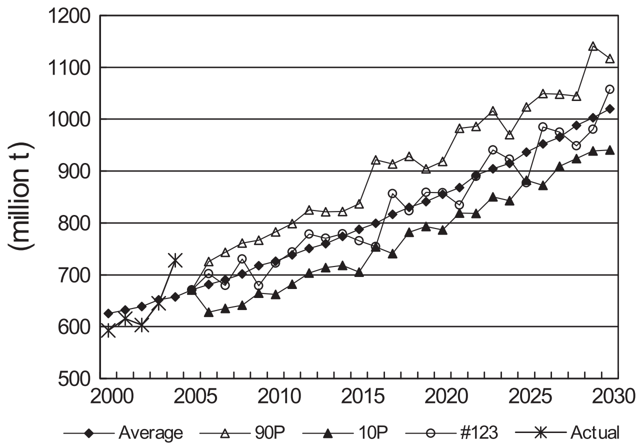

Fig. 2.7 Production of maize in the world

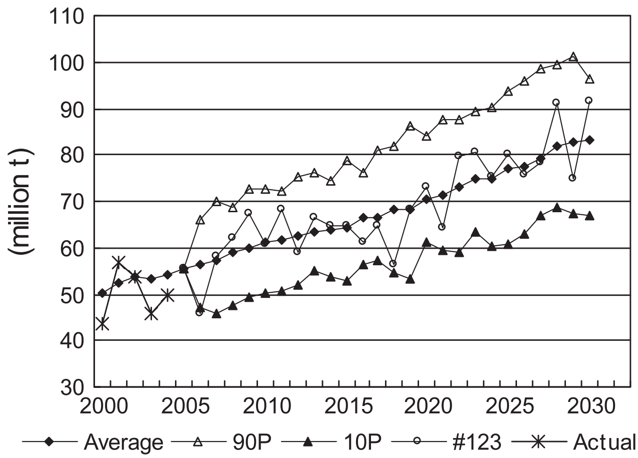

Fig. 2.8 Production of other coarse grains in the former USSR

Figure 2.10 shows the production of rice in India. The variation is higher than for other rice-producing countries. Parameters of temperature in the yield function for Korea, Japan, and European countries are positive numbers; however, those for the US and India are negative numbers. Ultimately, the variation of production in the world is smaller for rice than for other crops, as shown in Fig. 2.11. Figures 2.12 and 2.13 show the production of soybeans in the US and the world. The world trend follows that of the US due to the latter's large production share. The variation in soybean production is the highest of all crops and the CV increases from 6.50% in 2006 to 13.47% in 2030 in the world. The parameter of temperature in the yield function is a negative number in the US, which affects the world market, and these

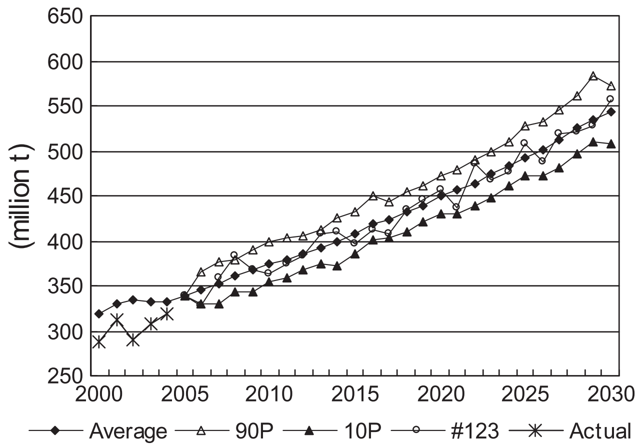

Fig. 2.9 Production of other coarse grains in the world

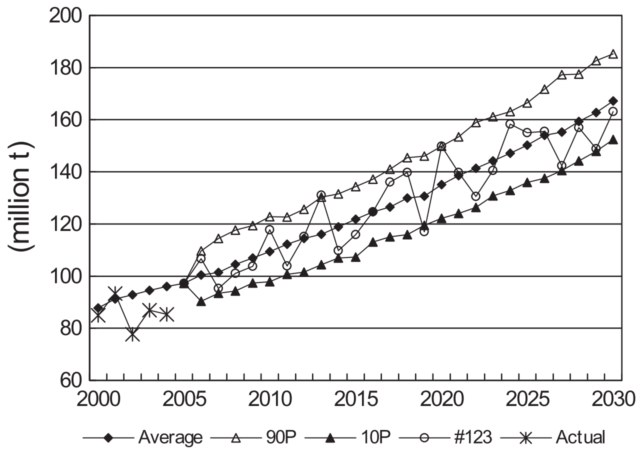

Fig. 2.10 Production of rice in India

yield functions respond to price in the model. Furthermore, supplies of soybeans are linked with oil and oil meal production. The own-price elasticity of feed demand is very high and a production shock in soybeans, such as a drought in a major producing country, will lead to an expansion of the variance in prices.

Finally, variations in the producer prices of five crops are investigated. Table 2.7 shows the average CV of producer prices in major producing countries between 2006 and 2010 and again between 2026 and 2030. Variations in producer prices will increase for all countries for all crops. Soybean prices in particular will increase by 20–25% in major producing countries, while the prices of other crops will increase by 1–2%.

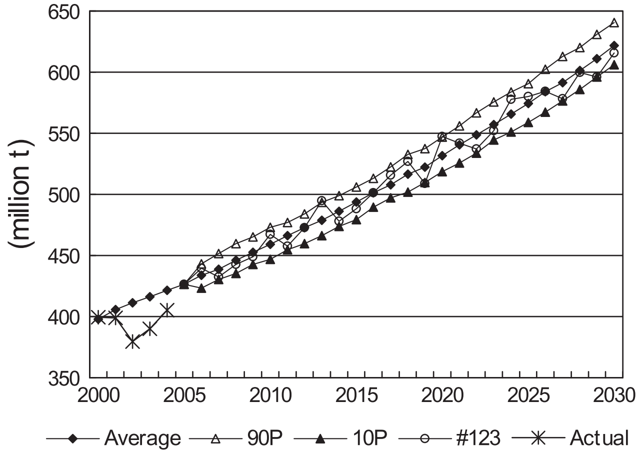

Fig. 2.11 Production of rice in the world

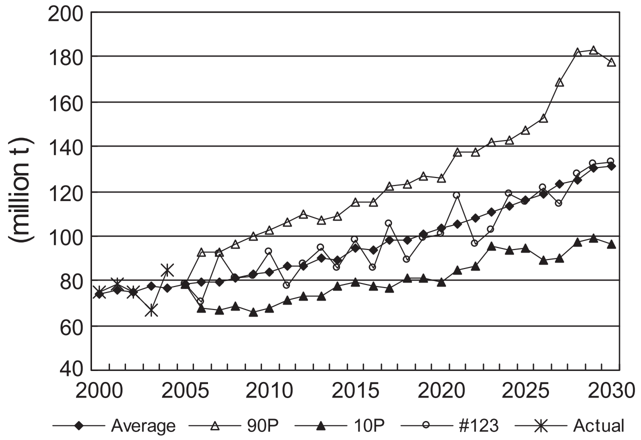

Fig. 2.12 Production of soybeans in the US

Soybeans are used not only as food, but also for feed and for producing oil. Thus, soybeans have two types of demand: food demand and input demand for livestock and oil production. These input demands are highly responsive to price changes. Furthermore, production is concentrated in a few countries, i.e., the US, Brazil, Argentina, and China. The evolutionary plant breeding of soybeans in the last two decades may lead to a higher production response to price changes in the simulation. The development of drought-tolerant varieties and the expansion of regions of production are necessary to ensure stable soybean supplies.

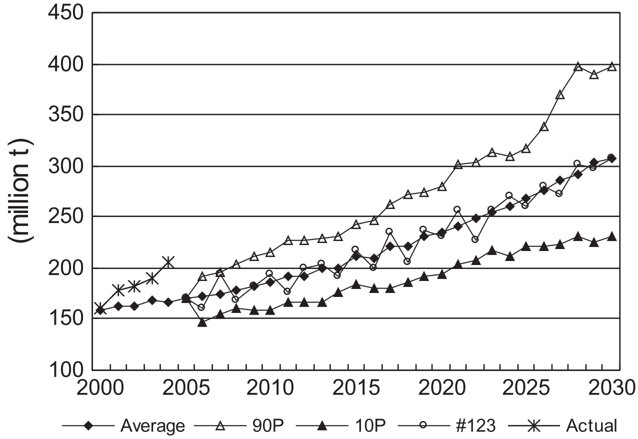

Fig. 2.13 Production of soybeans in the world

Table 2.7 Coefficient of variation (CV) of domestic prices

Country/region	Coefficient of variation (%) 2006–2010	2026–2030
Wheat		
USA	3.4	4.5
EU15	2.6	3.6
Ex-USSR	3.4	4.5
India	3.2	4.3
China	2.8	3.8
Maize		
USA	8.6	10.4
EU15	4.7	6.0
East Europe	9.4	11.3
Brazil	11.8	13.7
China	6.4	8.0
Other coarse grains		
USA	2.8	4.0
EU15	1.5	2.3
Australia	1.8	2.7
East Europe	4.0	5.4
Ex-USSR	4.0	5.4
Rice		
USA	1.3	1.9
India	9.7	10.2
Indonesia	0.4	0.4
China	0.0	0.0
Other Far East	1.5	2.1
Soybeans		
USA	15.0	35.6
Brazil	20.1	45.1
Argentina	18.5	42.2
India	11.5	28.4
China	8.7	22.0

2.6 Conclusions

Simulation results show that crop production in some countries or regions will be significantly affected by rising temperatures, with increased fluctuation. Crop production by the US, the European Union, and South Asian countries could suffer severe damage from global warming. The results of simulation using a world food model show that the changes in production resulting from variations of temperature are quite different for each crop in each country or region. However, the world total production for most crops other than soybeans is not severely affected.

These results are based on a mid-term simulation where available cropping regions, and the parameters of the supply and demand model, are fixed. To obtain more accurate simulation results, it is very likely that a long-term supply and demand model considering changes in income elasticities and shifts of cultivation zones is required. Based on forecasting climate data from the A2 scenario by the Hadley Centre, the drastic variation in crop production for some countries is remarkable. Countries that suffer higher price risk due to temperature variations may need to consider changes in cropping patterns and policies in order to encourage additional stock holding.

Acknowledgments We would like to thank Dr. M. Nishimori of the National Institute for Agro-Environmental Sciences for providing climate forecasting data for the A2 scenario from HadCM3 and actual data from the DDC. He calculated the average of these climate variables in each country and regions for flowering or silking seasons based on the cropping map of the US Department of Agriculture (USDA) (1994). We also thank Dr. S. D. Meyer of the Food and Agricultural Policy Research Institute at the University of Missouri for providing information on the procedure for multivariate stochastic simulation. This research is conducted by Project S4 of the Global Environment Research Fund of the Ministry of the Environment of Japan.

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Chapter 3
Impacts of Climate Change on Lakes and Reservoirs Dynamics and Restoration Policies

G.B. Sahoo and S.G. Schladow

3.1 Introduction

Global and regional climates have already begun changing. The World Meteorological Organization (WMO) (2006) has pointed out that "since the start of the 20th century, the global average surface temperature has risen approximately 0.7°C. But this rise has not been continuous. Since 1976, the global average temperature has risen sharply, at 0.18°C per decade. In the northern and southern hemispheres, the period 1997–2006 averaged 0.53 and 0.27°C above the 1961–1990 mean, respectively." The Intergovernmental Panel on Climate Change report (IPCC 2007) indicates that (1) there is high agreement and much evidence that, with current climate change mitigation policies and related sustainable development practices, global greenhouse gas (GHG) emissions will continue to grow over the next few decades; (2) continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the twenty-first century that would very likely be larger than those observed during the twentieth century; (3) even if radiative forcing (e.g., GHG-driven long-wave radiation) were to be stabilized, thermal expansion (i.e., expansion of seawater volume due to global warming) would continue for many centuries, due to the time required to transport heat into the deep ocean.

Meteorology is the driving force for lake internal heating, cooling, mixing and circulation, which in turn affect nutrient cycling, food-web characteristics and other important features of lake/reservoir limnology. Therefore, climate changes will affect the physical, chemical and biological attributes of lakes and reservoirs because of changes that include (1) the thermodynamic balance across the air–water interface, (2) the amount of wind-driven energy input to the system, and

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(3) the timing of stream delivery into a lake/reservoir. These processes can exert changes across the entire water column depth. These processes vary for different systems and their geographical location. Most existing water management and restoration plans, as well as water-supply and -drainage systems, are based upon historic climatic and hydrological records, and assume that the future will resemble the past. Although these systems may be sufficient to handle most changes in mean conditions associated with climate change over the next couple of decades or less, management problems are likely to arise if there is an increase in climate variability and the occurrence of extreme events due to climate change. The existing problems may be exacerbated due to such changes.

The broadening consensus about the inevitability of global warming and climate change is forcing both decision makers and researchers to evaluate the probable consequences for lakes and reservoirs. There is a growing concern that aquatic ecosystem function may also be affected. Lake Tahoe is an ultra-oligotrophic and sub-alpine lake renowned for its deep blue color and clarity. Due to concerns about progressive loss of clarity [i.e., 0.22 m per year, Tahoe Environmental Research Center (TERC), UC Davis], the lake has been the focus of major efforts by local, state and federal agencies and policy-makers to halt the worsening trends in clarity and trophic status. Records from the past 33 years (i.e., 1969–2002) also show that Lake Tahoe has become both warmer and more stable (Coats et al. 2006). With continued climate change, Lake Tahoe can be expected to continue to become more stable and, as a consequence, to experience water quality changes over time.

Meteorological predictions from a global climate model (GCM)—the national oceanic atmospheric administration (NOAA) geophysical fluids dynamic laboratory (GFDL) CM 2.1 model, downscaled to northern regional scales (Cayan et al. 2008)—were used to investigate the effects of climate change on Lake Tahoe. The changes in lake dynamics over time were examined using the lake clarity model (LCM). The LCM was developed to study the impacts of pollutant load on lake clarity as part of the science-based restoration plan, i.e. the Lake Tahoe Total Maximum Daily Load (Lake Tahoe TMDL). A TMDL is a water quality restoration plan required under the United States Federal Clean Water Act to ensure the achievement of water quality standards in impaired surface water bodies. Therefore, the objective of this study were (1) to examine the lake warming rate using LCM and GFDL-predicted meteorological variables, (2) to assess lake dynamics using possible climate change scenarios, and (3) to discuss possible effects on lake water quality and general lake management alternatives for restoration. Modeling of lake water quality changes under these changed climatic inputs is beyond the scope of the present contribution.

3.2 Description of Lake Tahoe

Lake Tahoe has long been known for its beauty and spectacular clarity. Millions of people visit Lake Tahoe every year. Lake Tahoe is a subalpine lake that was formed by a graben fault about 2 million years ago (Marjanovic 1989). Lake Tahoe is the 11th deepest lake in the world, with a maximum depth of approximately 500 m.

The average elevation of Lake Tahoe is 1,897 m from mean sea level, with an average depth of 303 m. The total area of the Lake Tahoe basin is 1,310 km^2, with 813 km^2 in the surrounding watershed area. The total volume of the lake is 158 km^3, with a hydraulic residence time of 650–700 years. Elevations in the Lake Tahoe Basin range from over 3,050 m at Mountain Rose down to 1,897 m at lake level. The basin consists of a total of 63 inflow tributaries and 1 outflow tributary. The Truckee River is the only outflow, and is an inland drainage, ending at Pyramid Lake, Nevada (Rowe et al. 2002).

3.3 Methods

To examine the impact of global warming and climate change on Lake Tahoe, the LCM was used as a tool to simulate lake dynamics. The LCM is a complex system of sub-models including thermodynamic, hydrodynamic, ecological, zooplankton, nutrient, particle, and optical sub-models, although for the present study only the thermodynamic and hydrodynamic modules were used. The conceptual design of the LCM is shown in Fig. 3.1 (Sahoo et al. 2007a). All the LCM sub-models operate inside the dashed line box in Fig. 3.1. The pollutant sources and amounts of inorganic particle loading from atmospheric deposition, groundwater, tributaries and various land uses (urban and non-urban) are shown above this box. Groundwater contributes only nitrogen and phosphorus for algal growth. The optical sub-model estimates Secchi depths based on scattering and absorption characteristics of particles, algae, colored dissolved organic matter (CDOM), and water itself.

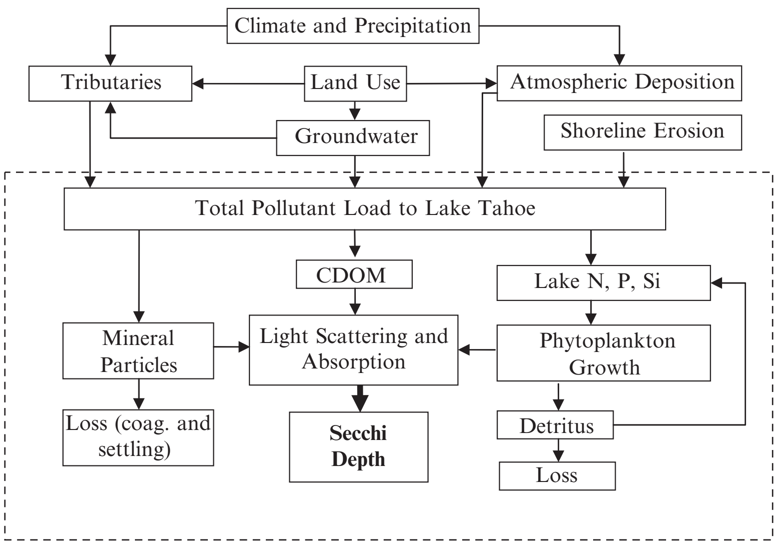

Fig. 3.1 Schematic representation of the lake clarity model (LCM). The *dashed line box* encloses all in-lake processes. *N* nitrogen, *P* phosphorous, *Si* silicon

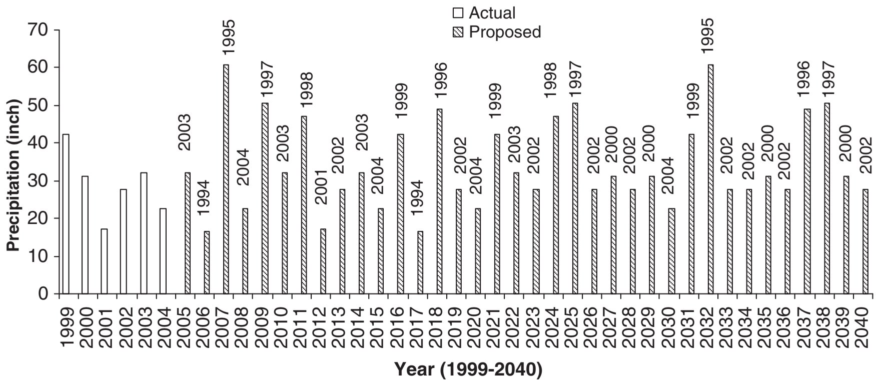

Fig. 3.2 Proposed annual total precipitation distribution for 1999–2040 for generation of the base case. The year used to supply input data for runoff and pollutant, and meteorological inputs, is indicated above each *bar*

To run the LCM, a series of simulation years into the future (a 40-year period, i.e., 2000–2040) was established. This time period was selected for example purposes only to examine the effect of global warming and climate change on Lake Tahoe. The loading simulation program in C++ (LSPC) watershed model (Tetra Tech 2007) provided stream inputs (i.e., inflow) for the period 1994–2004. Therefore, the precipitation information (and associated LSPC loading results) for these 11 years (i.e., 1994–2004) was used to populate the LCM runs for the period 2000–2040. The precipitation distributions used for LCM modeling during 2000–2040 are shown in Fig. 3.2. The proposed precipitation frequency distribution for the period 2000–2040 in Fig. 3.2 is similar to that of past years (i.e., 1965–2005). Sahoo et al. (2009) developed a subroutine to estimate stream temperature from air temperature and solar radiation.

The meteorological inputs to the LCM for the establishment of baseline estimates for the years 2000–2040 were set to the same as proposed for precipitation years. The lake dynamics will continues for the next 40 years if there is no change in the current status. Thus, the values obtained using these values are referred to as the base case.

Previously published monthly and seasonal air temperature and precipitation change data (Cayan et al. 2008), as shown in Table 3.1, were used to estimate the net change per year. The total changes during a specific period were spread progressively over the entire period, i.e., the net temperature change in a year during the period 2005–2034 is $\Delta T = (1.5/30) \times (2035 - \text{year})$. Similarly the net change in precipitation was estimated using Table 3.1.

GFDL CM2.1 model predictions indicate that shortwave radiation does not change over time. The stream water temperature was estimated using the air temperature and solar radiation values of the climate change scenarios. The change

Table 3.1 Geophysical fluids dynamic laboratory (GFDL)-predicted temperature and precipitation changes during the twenty-first century for A2 emission scenario and northern California (Source: Cayan et al. 2008)

	Mean	Change during the period relative to 1961–1990		
	1961–1990	2005–2034	2035–2064	2070–2099
Annual (°C)	9.30	1.5	2.3	4.5
Summer (°C) (JJA)	21.50	2.1	3.4	6.4
Winter (°C) (DJF)	−0.46	1.4	1.7	3.4
Annual (mm/%)	1,098	+0.3	−3	−18
Summer (mm/%) (JJA)	14	−29	−67	−68
Winter (mm/%) (DJF)	649	−1	+6	−9

Mean values are provided for historical (1961–1990) period, and changes relative to 1961–1990 between successive 30-year periods are shown in subsequent columns for the GFDL model and A2 emission scenario
JJA June, July, August; *DJF* December, January, February

of flows and pollutant loads, and delivery timing of each stream into the lake due to climate change is the subject of another study. This study presents lake dynamics where temperature acts the dominant variable. Pollutant load values are kept the same for both with- and without-climate-change scenarios except stream water temperature. Detailed water quality studies are currently underway.

3.4 Data Used

Required daily meteorological data for the LCM include solar short wave radiation (KJ m^2 day^{-1}), incoming longwave radiation (KJ m^2 day^{-1}), or a surrogate such as fraction of cloud cover and air temperature (°C), vapor pressure (mbar) or relative humidity (%), wind speed (m s^{-1} at 10 m above the water surface) and precipitation (mm, 24-h total). Data from 1994 and 2004 were collected at Tahoe City meteorological station SNOTEL gage located at 39.172°N latitude and 120.138°W longitude maintained by the United States Natural Resources Conservation Services. The hourly recorded data were then further averaged or integrated as necessary to obtain daily values.

In-lake vertical profiles of temperature, chlorophyll *a* (Chl *a*), dissolved oxygen (DO), biological oxygen demand (BOD), soluble reactive phosphorous (SRP), particulate organic phosphorus (POP), dissolved organic phosphorus (DOP), nitrate (NO_3) and nitrite (NO_2), ammonia (NH_4), particulate organic nitrogen (PON), dissolved organic nitrogen (DON), and concentrations of seven classes of particles collected at the mid-lake station (i.e., in the deeper part of the lake—460 m deep) were used for calibration and validation purposes and as initial profile for lake simulation. Flows and loads from all streams estimated using LSPC++ (Tetra Tech 2007) were used in this study. The values of groundwater discharge and nutrient loading to Lake Tahoe reported by the United States Army Cores of Engineers USACOE (2003) were used in this study. The values of nutrient and inorganic particulate matter estimated by Adams and Minor (2001) were used as shoreline erosion load. The California Air Resources Board (CARB 2006) conducted the Lake Tahoe atmospheric deposition study (LTADS) to quantify atmospheric deposition from nitrogen, phosphorus, and particulate matter loading into Lake Tahoe. Estimates of wet deposition came from UC Davis–TERC monitoring. Phosphorus deposition was also estimated by the UC Davis DELTA Group (Cahill 2006; Gertler et al. 2006) and the UC Davis–TERC (Hackley et al. 2004, 2005). Nitrogen deposition was estimated by the Desert Research Institute (DRI, Reno, NV), and UC Davis–TERC. Deposition of particulate matter was performed by CARB (2006). The nutrients and particulate matter loads from the atmosphere, groundwater discharge, and shoreline erosion were kept the same for all the simulation years because these are the best estimates available at present.

3.5 Results and Discussion

3.5.1 Lake Tahoe: Current Status

During late spring, summer, and early fall (June–October), Lake Tahoe becomes physically stratified into three identifiable layers—the epilimnion, metalimnion, and hypolimnion (Fig. 3.3). The epilimnion is the upper, warm layer, and is typically well mixed. Below the epilimnion is the metalimnion or thermocline region—a layer of water in which the temperature declines rapidly with depth.

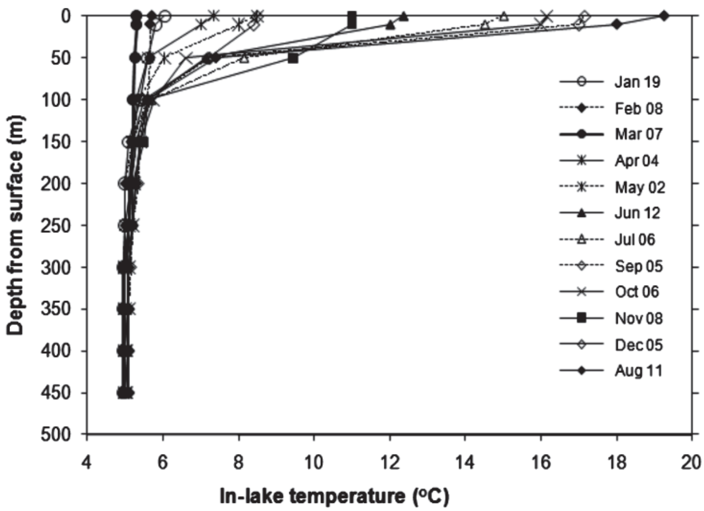

Fig. 3.3 Measured in-lake temperature profiles during the year 2000

The hypolimnion is the bottom layer of colder water, isolated from the epilimnion by the metalimnion. The change in temperature (thus density) at the metalimnion acts as a physical barrier that prevents mixing of the upper and lower layers for several months during the summer.

The depth of mixing depends on the exposure of the lake to wind. As the weather cools during winter (January–March), the epilimnion cools too, reducing the density difference between it and the hypolimnion (Fig. 3.3). As time passes, winds mix the lake to greater depths, and the thermocline gradually deepens. As the atmosphere cools, the surface water continues to cool, leaving it unstable. This cold water plunges in a turbulent plume, mixing with the water beneath. When surface and bottom waters approach the same temperature and density, winds can mix the entire lake; the lake is said to "turn over" (see Fig. 3.3 and March 07 line). Mixing distributes oxygen throughout the lake. Lakes that do not mix, or that have high oxygen demand, may have low oxygen levels in the hypolimnion. The cold water in the hypolimnion (bottom) can hold more oxygen than warmer water in the epilimnion (top). But if the lake produces an overabundance of algae, which fall into the hypolimnion to decay, oxygen becomes depleted. The steep temperature gradient of the metalimnion prevents any surface water with dissolved atmospheric oxygen from reaching the bottom waters.

Lake Tahoe's DO level never falls below 6 mg/l although there is seasonal variation of DO during the year (Fig. 3.4b). The surface DO during summer is low because the oxygen gas holding capacity of water decreases at higher temperatures and vice versa (Fig. 3.4a). In oligotrophic lakes like Lake Tahoe, low algal biomass allows deeper light penetration and less decomposition. Algae are able to grow relatively deeper (nearly 20–50 m below surface) in the water column (Fig. 3.4c) and less oxygen is consumed by decomposition because the mortality rate is low (Sahoo et al. 2007b). The DO concentrations may therefore increase with depth below the thermocline where colder water is carrying higher DO leftover from winter mixing (recall that oxygen is more soluble in colder water). In extremely deep, unproductive lakes such as Lake Tahoe, DO persists at high concentrations, near 100% saturation, throughout the water column in all years. DO concentration is high at a depth of 50 m below the surface during summer because algae release oxygen during photosynthesis.

The in-lake profile for the year 2000 is presented herein as an example to show some important features of lake dynamics such as the occurrence of a deep chlorophyll maximum (DCM) during summer, full or deep mixing events during winter, and high DO concentration year round throughout the lake. Note that the mixing depth, and hence lake dynamics, varies every year. However, with continued climate change, this pattern may change over time.

3.5.2 Lake Status Under Climate Change

The LCM was calibrated and validated using measured data from 2000 and 2001–2002, respectively. The measured in-lake profiles of temperature, DO, Chl *a*, nutrients, and

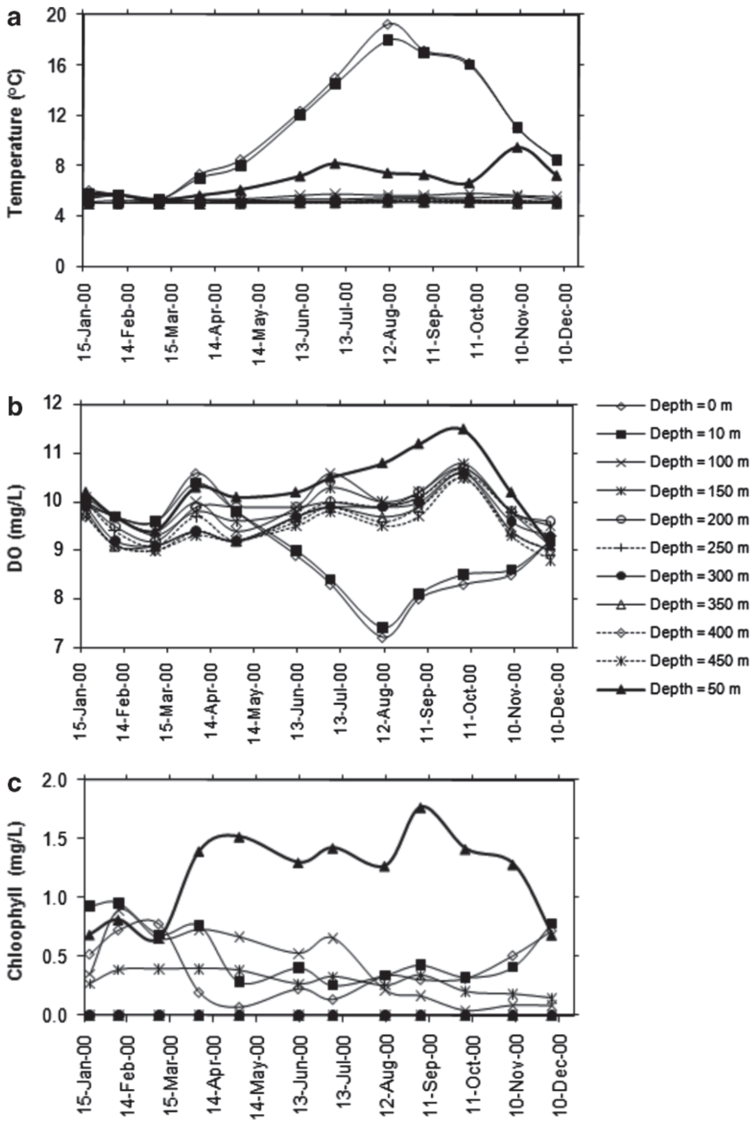

Fig. 3.4 Measured in-lake temperature, dissolved oxygen (DO), and chlorophyll *a* (Chl *a*) concentration at different depths

particle concentrations of the first month of 2000 and 2001 were taken as the initial profile for calibration and validation, respectively. Although the model runs in 1-h time steps, the boundary conditions of stream inflow, outflow, and meteorology are average/total daily values. The simulated time series–depth profiles temperature values were close to measured values (Sahoo et al. 2007a). This indicates that the LCM simulates lake dynamics well. In addition to temperature, the LCM was calibrated and validated for phytoplankton concentration, nutrient concentrations, particle concentration, and Secchi depths. Sensitivity analysis was carried out for the modeling parameters. The calibrated values of modeling parameters were found to be well within the ranges reported in the literature and the coefficient of variation (average value/standard deviation) of Secchi depth for a combination of a ±25% change of modeling values of three important parameters (coagulation rate, chlorophyll growth rate, and chlorophyll light scattering rate) was only 11%. The reader is referred to Sahoo et al. (2007b) for detailed results of calibration and validation. The calibrated LCM was used in this study to estimate effect of climate change on lake dynamics.

The LCM was run for 40 years using the data with and without climate change scenarios as described in Methods. There is no change in temperature and precipitation during the period 2000–2004, because actual measured data were used for these years. The results of daily volume–average lake water temperature for 2005–2040 presented in Fig. 3.5 show that the lake is warming up at 0.005°C per year, which is lower than the estimate of Coats et al. (2006) (i.e., 0.015°C per year). This indicates that other meteorological variables, such as longwave radiation and wind speed, may have an influence on lake warming. Using data from the 5th generation of Mesoscale Model (MM5) of the National Center for Atmospheric Research (NCAR), Coats et al. (2006) showed that the downward longwave radiation trend was upward during the period 1970–2000, while the trend of shortwave radiation did not change during this time.

Meteorological data for the GFDL CM2.1 model were downloaded from the website http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php. There is no monthly longwave radiation estimation available for the twenty-first century A2 scenario. Thus, the monthly net longwave radiation for A1 scenario and for Lake Tahoe (i.e., GFDL cell latitude 38.43°–40.45°N and longitude 117.5°–120.0°W) was estimated using

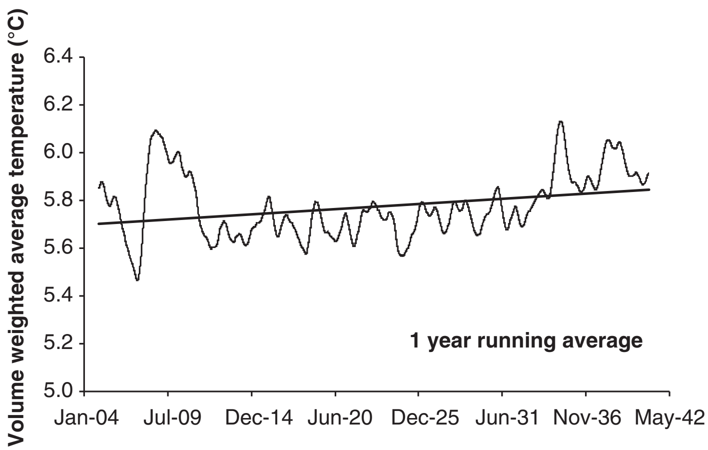

Fig. 3.5 One-year running average volume-average lake temperatures using geophysical fluids dynamic laboratory (GFDL) A2 scenario temperature change data reported by Cayan et al. (2008). *Thin black line* Volume average temperature, *thick black line* linear trend

the upwelling and downwelling longwave radiation data of the period 2001–2100. Figure 3.6 shows the upward trends for net longwave radiation. The slopes of the upward trend vary in the range 0.03–0.11 W m^{-2} during October–March (Fig. 3.6). The values of slopes for other months are less than 0.03 W m^{-2}. The important point to mention here is that deep mixing occurs only during winter. Figure 3.6 shows the increasing trends of net longwave radiation during winter. Thus, in addition to the change in air temperature and precipitation, the longwave radiation should be increased so that the warming rate approaches 0.015°C per year as estimated by Coats et al. (2006).

In addition to the change in air temperature and precipitation, the 10% progressive change in longwave radiation over the period 2005–2040 shows that the lake warming rate is approximately 0.015°C per year (see Fig. 3.7a), which is close to the value estimated by Coats et al. (2006). To cancel out the seasonal variations, 1-year running averages of daily values are presented in Fig. 3.7. Lake stability—the amount of work needed for a water column to overcome thermal stratification, and hence vertical density differences in order to completely mix—increases as shown in Fig. 3.7b. Schmidt stability is the amount of work needed to be done by the wind for a water column to overcome thermal stratification, and hence vertical density differences, in order to mix completely. Estimation of Schmidt stability requires surface area, area at each depth measured, the depth to the center of gravity for a stratified lake, total lake volume, and the density at each depth measured. Thus, lake stability increases and mixing reduces for increasing total and Schmidt work. Deep mixing has reduced as the weather continues to become warmer, as shown in Fig. 3.8. Each bar in Fig. 3.8 shows the maximum mixing depth occurring in that year. In the 40-year simulation period, the lake is expected to mix completely ten times if there is no change in climate (i.e., no base case). Figure 3.8 indicates that deep mixing will cease after 2019 with continued global warming and climate change. Note that the results presented herein are based on the assumptions considered in this study. Lake warming and mixing pattern will change if the assumptions made regarding the rate and magnitude of meteorological variables (air temperature, longwave radiation, wind speed etc.) change. Wind speed, which was not considered in this exercise, can change the mixing pattern. The reader should not take the findings presented herein as predictions and/or estimations, but rather should take the message that lake dynamics will change with continued climate change. The results presented are preliminary and detailed further study is required to verify these findings.

3.5.3 Possible Adverse Impacts on Ecology due to Climate Change in Lakes

The changes in Lake Tahoe's thermal structure reported herein are consistent with the findings of other researchers and other lakes around the world (Table 3.2). Analyzing in-lake measured data from 1969–2002, Coats et al. (2006) pointed out that (1) the volume average rate of warming in Lake Tahoe amounted to 0.015°C $year^{-1}$, and

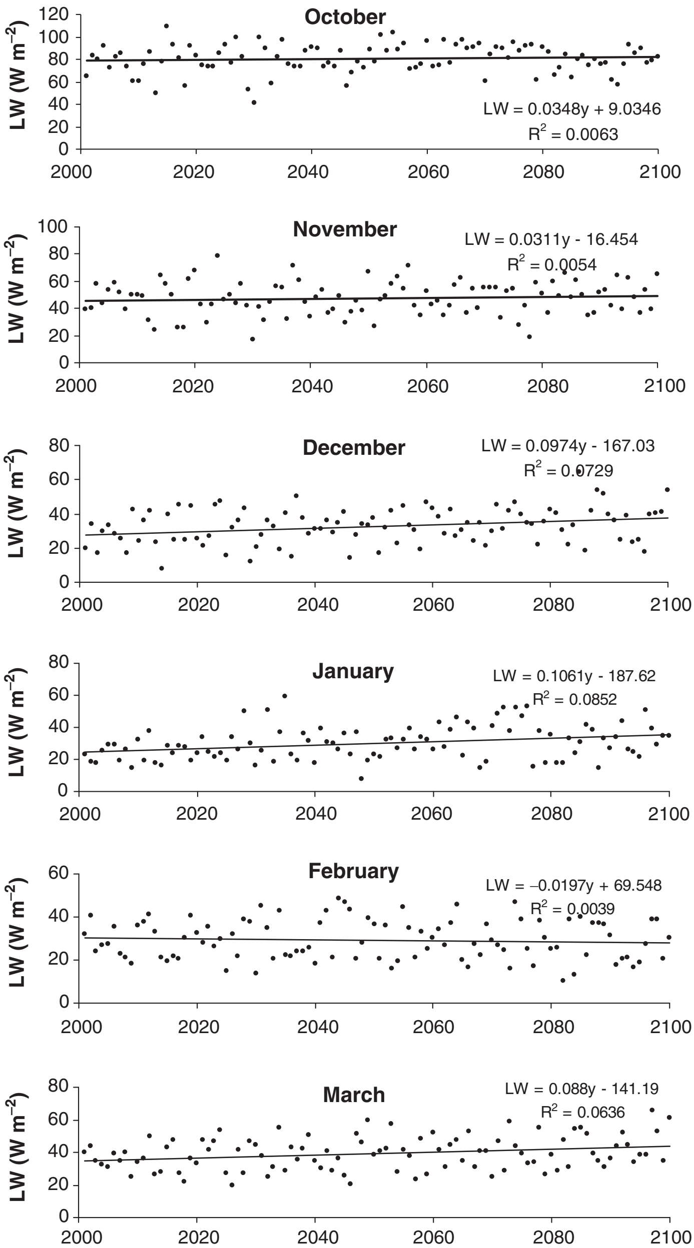

Fig. 3.6 Monthly net longwave radiation (W m^{-2}) for the period 2001–2100 using predicted values of GFDL CM2.1 climate model and A1 scenario. *Data points* GFDL CM2.1 model predicted values, *line* linear trend, *LW* longwave radiation, *y* year, R^2 coefficient of determination

Table 3.2 Warming trends in lakes around the world

Lake	Location	Period	Warming rate (°C/year)	Basis	Reference
Lake Superior	Canada and the United States	1979–2006	0.05–0.17	Sum wat temp	Austin and Colman (2007)
Lake Tahoe	California-Nevada	1970–2002	0.015	Vol-wtd ave	Coats et al. (2006)
Lake Washington	Seattle, WA	1964–1998	0.026	Vol-wtd ave	Arhonditsis et al. (2004)
Toolik Lake	Alaska	1974–1990	0.180	Sum wat temp	McDonald et al. (1996)
Lake 239	NW Ontario	1964–1998	0.108	Depth-ave	Schindler et al. (1996)
Lake Maggiore	Italy	1963–1998	0.030	Vol-wtd ave	Ambrosetti and Barbanti (1999)
Lake Zurich	Switzerland	1947–1998	0.016	Vol-wtd ave	Livingstone (2003)
Nine lakes	Signy Island, Antarctica	1980–1995	0.060	Mean temp	Quayle et al. (2002)
Lake Tanganyika	East Africa	1913–2000	0.004	Depth-ave	Verburg et al. (2003)
Lake Malawi	East Africa	1939–1999	0.010	Vol-wtd ave	Vollmer et al. (2005)

Vol-wtd ave volume weighted average, *Depth-ave* depth average, *Mean temp* mean temperature, *Sum wat temp* summer surface water temperature

(2) lake warming was associated with increased thermal stability and resistance to mixing. The findings of this study using the twenty-first century GFDL A2 scenario for Lake Tahoe are identical to the findings of Coats et al. (2006).

O'Reilly et al. (2003) reported that, along with increased temperatures, wind velocities in the Lake Tanganyika watershed have declined by 30% since the late 1970s. The combined effect increased lake stability and reduced mixing. They also reported that, because of reduced mixing, the loading of internal nutrients was reduced resulting in declining productivity. This reduction in internal loading and primary production allowed expansion of the anoxic water mass in Lake Tanganyika. O'Reilly et al. (2003) indicated that algal abundance declined 20% over the 80-year period for which data exists. This decline is a direct result of the reduction in lake circulation. Based on earlier studies on other lakes (Nixon 1988), a 20% decline in primary productivity would lead to a 30% reduction in fish stocks in addition to any possible effects of over-fishing. Reduced mixing and lake warming has also been reported in Lake Malawi (Verburg et al. 2003).

Austin and Colman (2007) reported that (1) the surface warming rate is about $0.11 \pm 0.06°C\ year^{-1}$, and (2) average wind speeds at the open water surface increased on the order of $0.05\ ms^{-1}\ year^{-1}$ during the period 1979–2006 in Lake Superior. They hypothesized that the increased wind speeds might have been caused by destabilization of the atmospheric boundary layer due to a decreased air density gradient (since the surface air temperature is becoming progressively warmer). Analyzing data for the period 1979–2006, they showed similar trends of surface water temperature, air temperature, and average wind speeds for Lake Michigan, Lake Huron, and Lake Erie. Applying a one-dimensional temperature model to Lake Michigan, McCormick (1990) showed that climate warming decreases summer thermocline depth, increases resistance to mixing, and could even lead to the evolution of a permanent deep-water thermocline.

From the 1950s to the 1990s, a high warming rate ($\sim 0.024°C\ year^{-1}$) in the uppermost 20 m (i.e., epi/metalimnion) of Lake Zurich combined with lower warming rates ($0.013°C\ year^{-1}$) below 20 m (i.e., in the hypolimnion) resulted in a 20% increase in thermal stability and a consequent extension of the stratification period by 2–3 weeks (Livingstone 2003). In several Swiss lakes, including Lake Zurich, a series of three consecutive warm winters (1987/1988–1989/1990, associated with an extremely positive phase of the North Atlantic Oscillation) with persistent stratification has been shown to have been responsible for the extremely low deep-water oxygen concentration (Livingstone 1997).

Coats et al. (2006) hypothesized that (1) decreased mixing helps retain small particle in the epilimnion, where they have maximum adverse impact on lake clarity; (2) reduced mixing will shut down the flow of oxygen to the bottom of the lake, and continued influx of increasing pollutants may cause hypoxia at the sediment surface in deep water triggering soluble phosphorus; (3) observed water quality in a large lake like Tahoe may response slowly in the short-term, although responses might be significant in decadal time; (4) the increased stability and decreased thermocline depth may affect the feeding behavior and population structure of zooplankton. It can also be hypothesized that decreasing transparency in the lake may decrease solar radiation penetration into the deep lake. The DCM may not occur and the lake may be strongly stratified in future.

Reviews of past literature and the current study show that there are positive upward trends in lake warming, stability, resistance to mixing and longer summer stratification periods. If the warming trend continues, lakes will be permanently stratified, resulting in low DO concentrations in the hypolimnion. The dynamics of many other important elements in lake ecosystems, such as phosphorous, nitrogen, sulfur, silica, and iron, are dominated by microbial activity, which is controlled primarily by DO concentration (redox potential), temperature, pH, and various concentrations of these elements. In general, increasing temperature accelerates reaction rates. Decreased redox potential caused by low DO availability affects many equilibrium reactions. The phosphorous (P) cycle is sensitive to DO concentration at the sediment–water interface. Even a short extreme anoxic period near the bottom can induce P mobilization from the sediment to the water body, and change the lake permanently to eutrophic. It is very difficult and expensive to reverse this development. Typically, if surface erosion from the catchment is increased, P input is also increased. The nitrogen (N) cycle is connected to the atmosphere, both through N fixation by blue-green algae and bacteria (source), and through denitrification (sink). With increasing temperature, the solubility of gases decreases and processes such as denitrification and nitrogen fixation are accelerated. Such changes will lead to many water quality problems in lakes.

3.5.4 Possible Restoration Managements

Total phosphorus (TP), total nitrogen (TN), Chl *a*, Secchi depth and, sometimes, suspended solids (SS) are the key variables used to evaluate the restoration of lakes (Søndergaard et al. 2007). To achieve lake restoration, the natural processes that allow a lake to assimilate the nutrient load it receives must be restored. However, it is hard to stop/reverse the effect of climate change on lakes since continued GHG emissions at or above current rates would cause further warming. Thus, efforts should be taken to reduce the load entering the lake by managing lakes and their watersheds.

Lake restoration is very broad and complex topic, and is very case specific. Some general alternatives that are not specific to any particular case are discussed herein. Specific strategies to address a lake's nutrient enrichment problems must focus on activities in the watershed and, if needed, in-lake restoration techniques. Lake management approaches fall into two categories, the "quick-fix" and long-term management. The quick-fix offers a short-term solution such as the application of algaecides to kill unwanted algae. This approach treats the biological symptoms of a lake's problem but does not address the underlying causes of symptoms.

Varis and Somlyódy (1996) proposed a variety of alternatives for lake water management (see Table 3.3), which are in wide use globally. External nutrient sources such as fertilizer use, pet wastes, stormwater runoff, septic system effluents, waterfowl, agriculture, and even rainfall can contribute nutrients to a lake.

Table 3.3 General alternatives for lake water quality management (source: Varis and Somlyódy 1996)

Water use	Water quality problems							
External action								
Treatment of wastewater and sewage	√	√	√	–	–	√	√	–
Manipulation of inflow	o	o	–	–	–	–	√	–
Land use in the catchments	o	o	–	o	o	o	o	o
Non-point source pollution control	√	o	o	–	–	√	o	–
Liming of lakes and catchments	–	–	–	–	√	–	–	–
Shifts in lake water volume or level	o	o	–	o	–	–	o	–
Flow regulation	o	o	–	–	–	–	o	–
Increased throughflow	o	o	–	o	–	–	o	–
Internal action								
Ecotechnology, biomanipulation	√	o	–	–	–	–	o	–
Chemical treatment of water (P inactivation, poising of algae, etc.)	o	o	–	–	–	–	o	–
Removal, treatment, or covering of sediment	√	√	–	–	–	o	o	–
Macrophyte harvesting	o	o	–	–	–	–	o	–
Aeration and mixing	√	√	–	–	–	–	o	–

E Eutrophication, *O* oxygen depletion, *H* hygienic problems, *S* salinization, *A* acidification, *X* toxic and cumulative substances, *M* turbidity and suspended matter, *T* thermal pollution, √ High influence, *o* low or occasional influence, – no influence

Lake management removes or modifies as many of these nutrient sources as possible, especially those sources shown to be contributing the greatest nutrient load to the water body. In-lake restoration techniques are necessary and they should be followed by, or occur simultaneously with, appropriate long-term management actions to control sediments, nutrients, and toxic inputs. A successful lake restoration program should strive to manage both external and internal nutrient sources. Many of them, particularly the internal action alternatives, are best applied, and in some cases can only be applied, to small lakes or on a local scale.

Anaerobic digestion of lake sediments is a much slower process than aerobic digestion. Whereas aerobic digestion can result in the control or reduction of organic sediment levels, anaerobic digestion almost always allows organic sediment levels to increase. During anaerobic digestion, bacterial enzymes and lack of oxygen make the nutrients in the bottom sediments soluble. The nutrients then return to the water column and are available to support new weed and algal growth. Anaerobic conditions at the lake bottom have a damaging effect on the food chain that supports fish populations as well as reducing or eliminating fish habitat, ultimately resulting in reductions in fish quality, size and quantity. Hypolimnetic aeration/oxygenation, which can be achieved by pure oxygen injection, or air injection (see McGinnis et al. 2004; Sahoo and Luketina 2006; Singleton et al. 2007), is an effective means of improving DO concentration in the water column. In the specific case of Lake Tahoe, however, injection of air or oxygen would be difficult due to the compression needs in overcoming the lake's great depth.

The current Lake Tahoe TMDL (1) quantifies the source and amount of fine sediment and nutrient loading from a variety of activities and land-uses within the major categories of urban watershed, forest upland, atmospheric deposition, stream channel/shoreline erosion and groundwater; (2) uses the customized LCM to link pollutant reduction loading to lake response; and (3) develops the framework for an implementation plan to achieve an annual average Secchi depth of 29.7 m, as required by existing water quality standards (Roberts and Reuter 2007). This is a positive response for lake restoration. Sewage disposal to Lake Tahoe was halted in 1972. In the case of occurrence of low DO concentration in the hypolimnion, the possibility of installation of an aeration/oxygenation system should be investigated.

3.6 Conclusions and Suggestions

The GFDL CM2.1 model shows that northern California air temperature is expected to increase by approximately 1.5 and 4.5°C at the end of 2034 and 2099, respectively, relative to 1961–1990. The model also indicates that net longwave radiation will increase by 3–11% during fall to winter at Lake Tahoe. The combination of both these factors will warm Lake Tahoe at a rate of approximately 0.015°C per year. Lake warming is associated with increased thermal stability at a rate of approximately 0.39 KJ m^{-2} per year. A review of the literature shows that lakes and reservoirs around the World are warming up because of global warming and climate change. Rising air temperatures account for only part of the recent warming of lakes. Other climate variables, such as changes in longwave radiation and wind speed, are also causes of lake warming. Lake warming has led to increased lake stability and resistance to deep mixing. It was shown that, at current rates of climate change, Lake Tahoe will stop deep mixing after 2019. However, this change depends on the future rate and magnitude of climate change. Reduced mixing in the lake may have significant adverse impacts on lake ecosystems. The possible scenarios are summarized as follows.

1. Reduced mixing in the lake helps retain fine particles in the epilimnion and may decrease penetration of solar radiation into the deep lake. This may contribute to a permanent stratification state.
2. Reduced mixing may limit the flow of DO to the bottom of the lake. Thus, continued influx of increasing pollutants may cause hypoxia at the sediment surface in deep water, triggering the release of soluble phosphorus.
3. Existing lake water quality problems may be exacerbated due to continuous lake water warming. Increasing temperature accelerates reaction rates. Decreased redox potential caused by low DO availability affects many equilibrium reactions. Such changes result in changes in lake dynamics in terms of nutrient cycling and primary productivity.
4. Future rates of lake warming depend on the rate and magnitude of climate change as well as on the success of on-going efforts to reduce the anthropogenic flux of nutrients to the lake.

The results shown here are not predictions and/or estimations. Rather, they are possible future scenarios. The results and findings would change if the rate and magnitude of the meteorological variables differ from the assumptions made in this exercise. Since climate change is inevitable, current lake management strategies should be integrated with new approaches and methodologies that can handle issues on water quality problems due to climate change. Research and development on lakes should focus on methodologies and approaches that can also handle extreme uncertainty.

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Chapter 4
Study of Fishery Ground Around Indonesia Archipelago Using Remote Sensing Data

Takahiro Osawa and Sigit Julimantoro

4.1 Introduction

The official estimate of the marine biological resources for Indonesia is 6.7 million tons/year (Ditjenkan 1999a). The fishery and other sea products have recorded a high of 3.61 million tons in 1997. The brackish and freshwater fish cultivation production totaled 0.66 million tons, and the public waters fishery production amounted to 0.3 million tons for the same year, thus totaling about 3.91 million tons. The fish export recorded a huge 574,419 tons with an income of US$1,686,168 (Ditjenkan 1999b).

The closing down of a number of fishery companies has resulted in a decline of the fishery industry. Also, the fish resources have been decreasing from a peak high in 1982.

Recent advances in remote sensing techniques allow more accurate estimation of potential fishing zones using parameters such as sea surface temperature (SST), chlorophyll-a (Chl-a), wind direction, and speed. SST is useful for demarcating the upwelling zones and fronts. Certain fish species are comfortable at an optimum temperature of the water. Fish are abundant in the front areas, which are indicated by SST variation. Chl-a is a basic parameter to measure the primary productivity (PP) of the sea. The fish abundance is always related to the abundance of Chl-a concentration.

For the above aim, the PP was calculated using the vertically generalized production model (VGPM) algorithm (Behrenfeld and Falkowski 1997a). The fish production (FP) and fish biomass (FB) were calculated from the PP by a formula proposed by Pauly and Christensen (1995). Finally, the fish production (fish biomass) derived from satellite data, and the total production (total fish catch) derived

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from the fishery data were correlated. This study considers the correlation between FP and fishery data in the East Indian Ocean from September 1997 to August 2000. Spatially referenced fishery data and satellite-derived fishery data have been examined using geographic information system (GIS) techniques.

4.2 Data and Method

4.2.1 Conceptual Remote Sensing Application to Fishery

Remote sensing technology is a useful tool for fishery science (Laurs et al. 1984). Being an optical system, it detects prominent oceanic phenomena such as SST, ocean color (refers mostly to the Chl-a concentration in the ocean), wind speed and direction (determined by scatter meter), and sea surface height (estimated by altimeter). Finally, the fishing ground is estimated from remote sensing data (Fig. 4.1).

4.2.2 Fishery Data

The total fish catch on-board PT Samudra Besar during September 1997 to August 2000 fluctuated similar to that of the monthly hook rate. The highest total fish catch was in May 1998 (about 127 tons) (with a monthly hook rate of 1.47), and the lowest

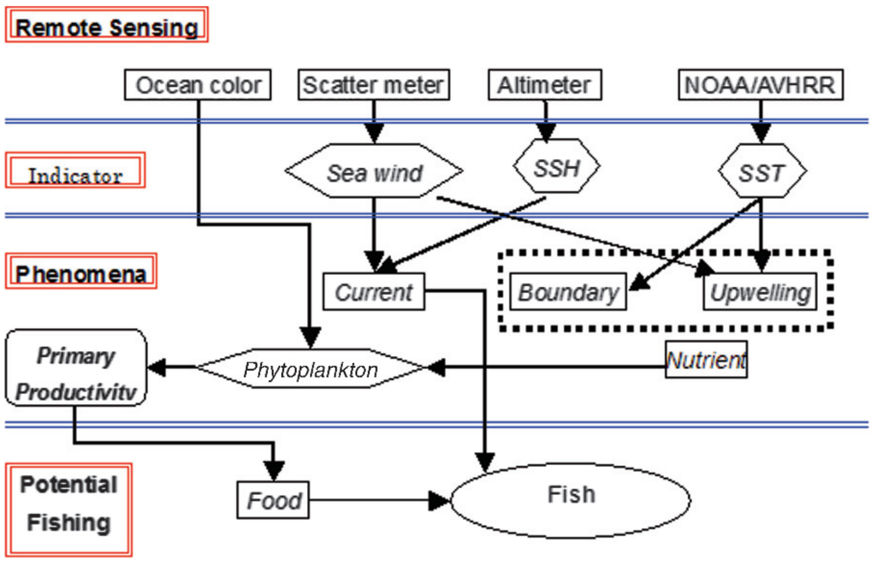

Fig. 4.1 Remote sensing application to fishery – conceptual diagram

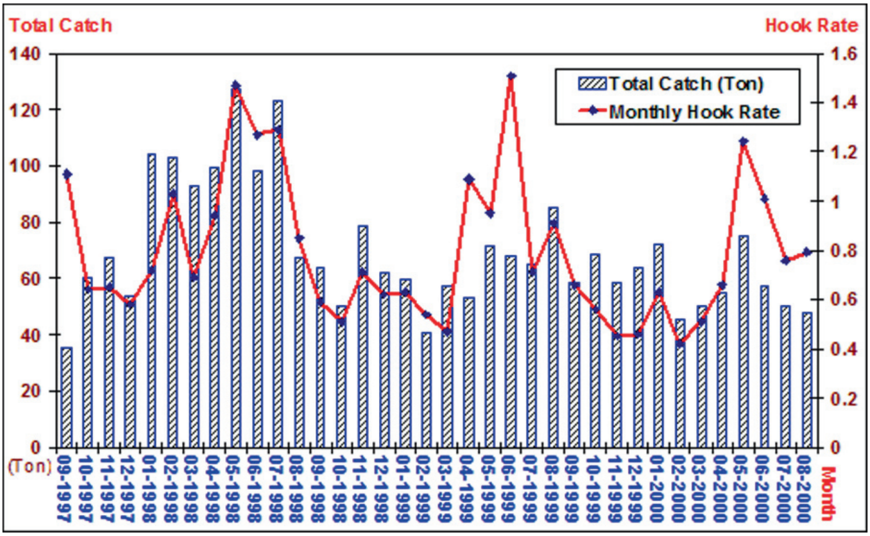

Fig. 4.2 Monthly fluctuation of total catch and hook rate of fishery data from PT. Samudra Besar Indonesia (September 1997–August 2000)

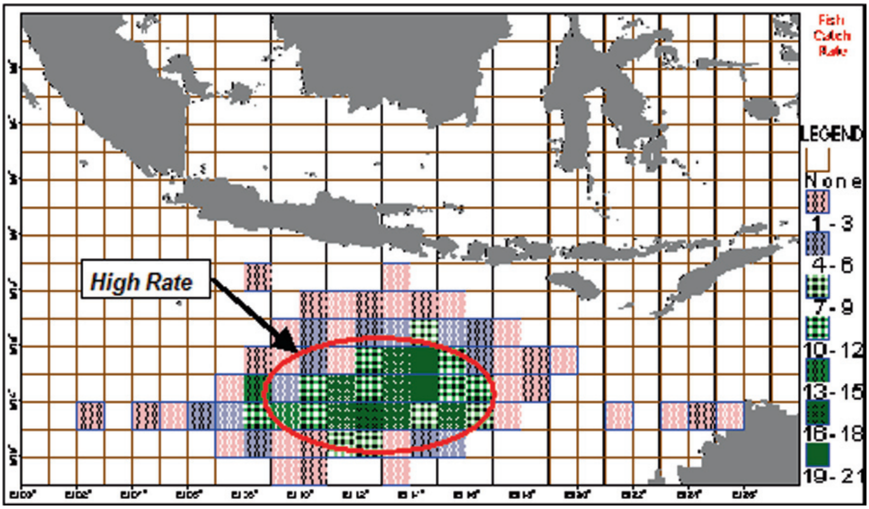

Fig. 4.3 Fishing ground (E112º–E115º and S12º–S15º) (see Color Plates, Fig. 4.3)

was in February 1999 (about 41 tons) (with a monthly hook rate 0.54), as shown in Fig. 4.2. The highest total fish catch was in the area between E112º–E115º and S12º–S15º (Fig. 4.3). The big eye tuna was the most commonly available fish during September 1997 to August 2000. It made up 67% of the total catch, followed by albacore 12.29% and yellow fin 9.34% (Fig. 4.4).

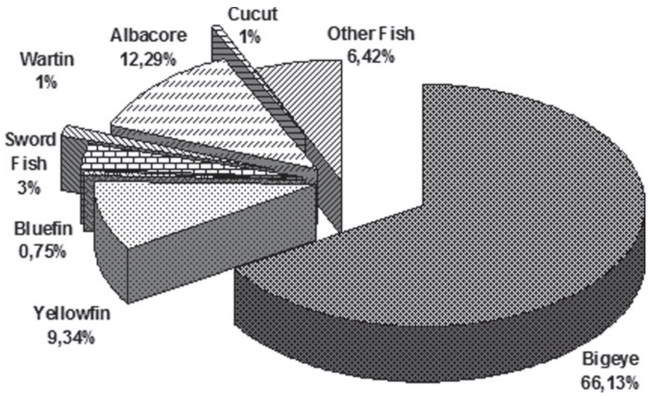

Fig. 4.4 Oceanic variables derived from percentage of species of fishery data from PT. Samudra Besar – Indonesia (September 1997–August 2000)

Table 4.1 Detail of data Source

No	Data	Source	Coverage	Available
1	Chl-a	NASA/GSFC SeaWiFS data processing center	Global area coverage	September 1997–August 2000
2	PAR	NASA/GSFC SeaWiFS data processing center	Global area coverage	September 1997–August 2000
3	SST	NASA/PO.DAAC AVHRR oceans pathfinder	Global area coverage	September 1997–August 2000
4	Wind speed	Halpern, F. Wentz algorithms, JPL (NASA)	Global area coverage	September 1997–August 2000
5	Fishery data	PT. Perikanan Samudra Besar	East Indian Ocean	1997–2000

4.2.3 Satellite Data

4.2.3.1 Oceanic Variables Derived from Satellite Data

Chlorophyll-a and photosynthetically available radiation (PAR) were estimated from the SeaWiFS satellite, the SST was studied from the NOAA-AVHRR satellite, and wind speed was studied from the SSM/I F13 satellite. All the digital forms of the data set were in Global Area Coverage (GAC) site, which were rectified and cropped as per research area. Fishery data comprise total production, the hook rate (defined as how many fish are caught by 100 fishing hooks with the log line method), and the percentage of species, among other factors. These tabular and spatial data are in analog form. All the data are quantitative. Details of the data source are shown in Table. 4.1.

4.2.3.2 Primary Productivity Model

By definition, PP is the amount of photosynthetically fixed carbon available to the first heterotropic level; and as such, it is the relevant metric for addressing environmental questions ranging from tropic energy transfer to the influence of biological processes on carbon cycling (Behrenfeld and Falkowski 1997b).

The values of PP are indicators of the environmental quality and ecological condition of the seawater. Moreover, the quantity of PP helps us not only to understand matter and energy bases of PP but also to predict bioresources, particularly fishery resources. The distributors of Chl-a, which is a basic parameter, used to measure PP are the phytoplankton, which help us understand the role of the ocean in the global biogeochemical cycle.

For a logical discussion of productivity models, an organizational system is required for distinguishing between basic model categories; yet such a system does not exist. The classification system for daily PP models was based on implicit levels of integration. Each category included a photoadaptive variable [i.e., Φ, φ, $P^b(z)$, P^b_{opt}] corresponding to the resolution of the described light field (Behrenfeld and Falkowski 1997b).

4.2.3.3 Vertically Generalized Production Model

The VGPM model shows the relation of the content of surface chlorophyll with integrated PP in water columns of the euphotic layer.

The original formula for GPM was (Behrenfeld and Falkowski 1997a),

$$PP_{eu} = 0.66125 \times P^B_{opt} \times \frac{E_o}{E_o + 4.1} \times C_{SAT} \times Z_{eu} \times D_{irr}, \tag{4.1}$$

where:

PP_{eu}: daily carbon fixation integrated from the surface to Z_{eu} (mg C/m^2)

P^B_{opt}: optimal rate of daily carbon fixation within a water column [mg C (mg Chl)$^{-1}$ h^{-1}]. P^B_{opt} can be modeled according to various temperature-dependent relations

$$P^B_{opt} = \begin{cases} 1.13, & T < -1.0, \\ 4.00, & T > 28.5, \\ P^B_{opt}, & \text{otherwise,} \end{cases} \tag{4.2}$$

$$\begin{aligned} P^B_{opt} = {} & 1.2956 + 2.749 \times 10^{-1} \times T + 6.17 \times 10^{-2} \times T^2 - 2.05 \times 10^{-2} \times T^3 \\ & + 2.462 \times 10^{-3} \times T^4 - 1.348 \times 10^{-4} \times T^5 + 3.4132 \times 10^{-6} \times T^6 \\ & - 3.27 \times 10^{-8} \times T^7. \end{aligned} \tag{4.3}$$

E_0: sea surface daily PAR (mol quanta/m^2/d)

C_{SAT}: satellite surface Chl-a concentration as derived from measurements of water leaving radiance (mg Chl/m^3). VGPM calculations of global primary production were based on monthly average C_{SAT}

T: sea surface temperature (ºC)

Z_{eu}: physical depth (m) of the euphotic zone defined as the penetration depth of 1% surface irradiance. Z_{eu} is calculated from C_{TOT}.

$Z_{eu} = 586.2 \times C_{TOT}^{-0.746}$, if Z_{eu} 102. Then

$$Z_{eu} = 200.0 \times C_{TOT}^{-0.239}. \tag{4.4}$$

C_{TOT}: total pigment and total Chl-a content within the euphotic layer, mg Chl/m^2.

$$C_{TOT} = \begin{cases} 38.0 \times C_{SAT}^{0.425} & C_{SAT} < 1.0 \\ 40.2 \times C_{SAT}^{0.507} & C_{SAT} \geq 1.0 \end{cases} \tag{4.5}$$

D_{irr}: daily photoperiod (in decimal hours)

4.2.3.4 Fish Production Model

Fish production was estimated from integrated production assuming a simple trophic chain with a fixed trophic efficiency and an average number of *trophic links*. The formula proposed by Pauly and Christensen (1995) to estimate PP necessary to support observed catch data was used, together with their value for efficiency (10%) and for the average number of trophic links for pelagic in upwelling regions:

$$FP = PP(EEF)^{(TL-1)}, \tag{4.6}$$

where *FP* (in grams of carbon) is fish production, *PP* is the primary productivity, *EFF* is transfer efficiency, and *TL* is the number of *trophic links* (for open ocean = 4, upwelling areas = 2.8). This approach implies that primary production is accessible to the fish in both time and space. As this is unlikely, it necessarily provides an upper limit of fish yield. The conversion between carbon to wet weight is a factor of 8, thus leading to a biomass (FB) to compare with landings:

$$FB = 8 \times FP, \tag{4.7}$$

where *FB* is expressed hereafter in millions of tons (MT).

4.3 Results

4.3.1 Variation of Ocean Parameters from Satellite Data

Results for Chl-a derived from satellite data and the detailed variability of CHL is shown in Fig. 4.5. Chl-a maxima for September 1997 to August 2000 is 0.07–5.0, and the highest values are located in the coastal regions of southern Java,

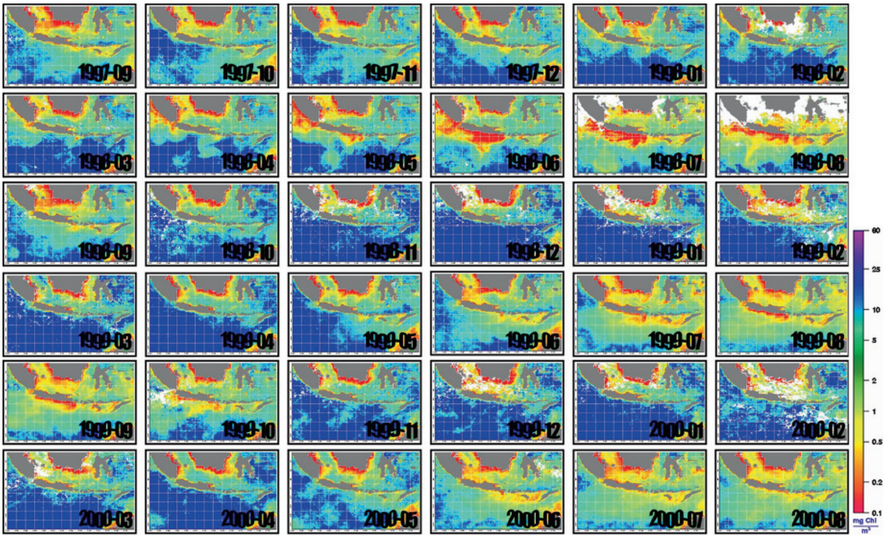

Fig. 4.5 Spatial distribution of Chl-a during September 1997–August 2000 (see Color Plates, Fig. 4.5)

Kalimantan, and North Sumatra. The southern coast of Java exhibits low Chl-a, about 0.08 mg/m^3, compared with minimum Chl-a of 0.01–0.7 mg/m^3. The highest difference between maximum and minimum Chl-a (about 2 mg/m^3) was seen in the southern coast of Java, except on the Kalimantan and Sumatra coasts.

From September 1997 to August 2000, the highest amount of PAR (about 45 Einstein/m^2day) was recorded off the western coast of Australia and in the offshore region of the Indian ocean, whereas the South China Ocean showed the lowest maximum PAR, compared with the maximum PAR from the complete research area (47–60 Einstein/m^2day (Fig. 4.6). The minimum PAR was 21–43 Einstein/m^2day, and the lowest value (21 Einstein/m^2day) occurred east of Sulawesi, whereas the highest value (43 Einstein/m^2day) occurred in the islands from Bali, Lombok, Sumbawa, to Timor.

Figure 4.7 shows the average SST for the study area. The southern Java and Sumatra coasts had the lowest value for SST (about 22°C), compared with minimum SSTs for the area of 22°–30°C. They had also the highest gap between the maximum and minimum SSTs (about 9°C). The lowest SST differences of 1°C were seen north of Sulawesi.

The highest SST value (>29°C) was found in the northern part of the research area, or near the Equator. The area between Timor Island and Australia had a relatively high SST value, in contrast, <29°C. The lowest SST occurred offshore in the southwest part of the research area. The west coast of Sumatra showed the greatest difference between the average and minimum SSTs (6°C.)

Figure 4.8 shows that during SE monsoons Chl-a was 0.25–0.3 mg/m^3, and wind speed was 7–8 m/s (relatively high). In contrast, PAR was 35–45 Einstein/m^2day

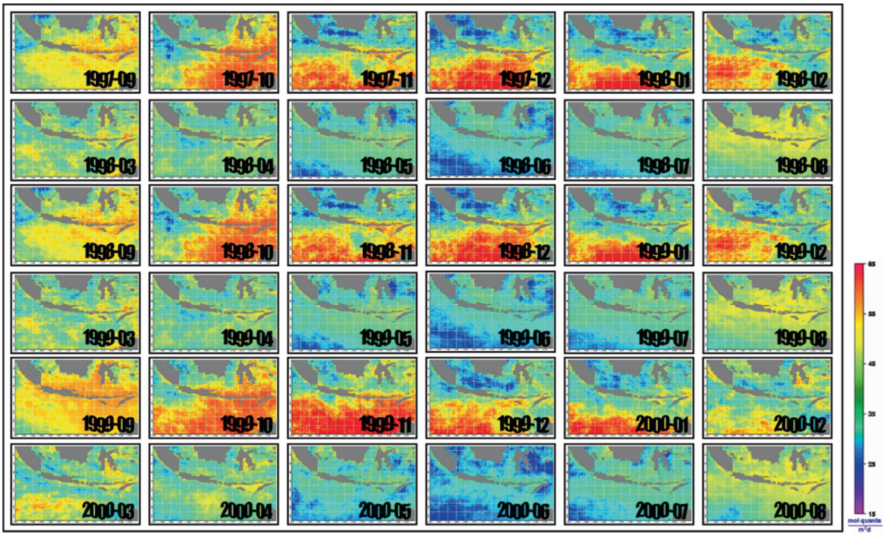

Fig. 4.6 Spatial distribution of PAR during September 1997–August 2000 (see Color Plates, Fig. 4.6)

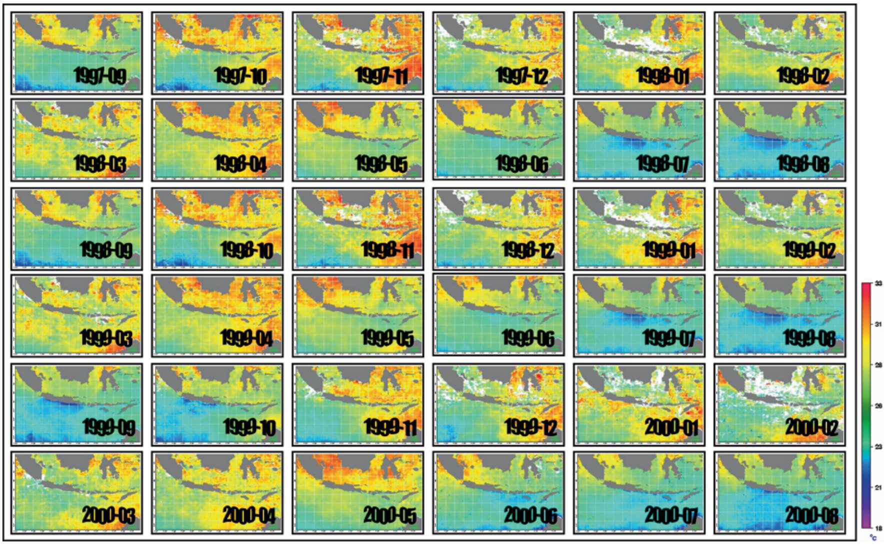

Fig. 4.7 Spatial distribution of SST during September 1997–August 2000 (see Color Plates, Fig. 4.7)

and SST was 26°–27°C (relatively decreased). Chl-a and wind speed were 0.09–0.12 mg/m^3 and 4–5 m/s (decreased), respectively, and PAR was 50–60 Einstein/m^{2}day and SST was 30°–31°C (increased).

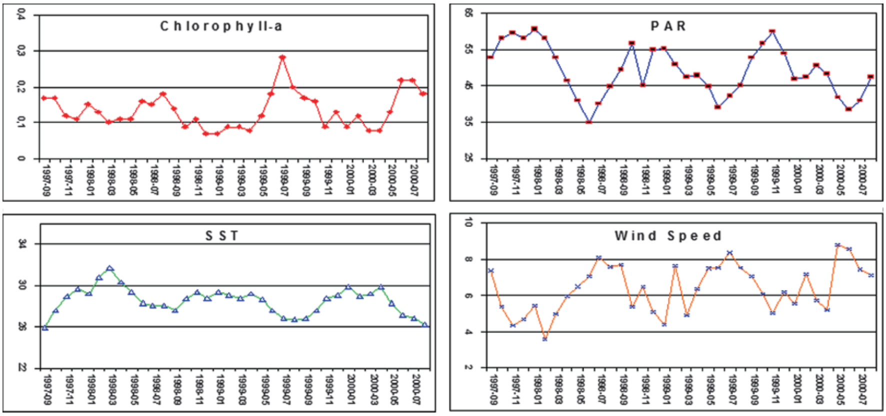

Fig. 4.8 Temporal variability of Chl-a, SST, PAR, and wind speed at 114ºE 13ºS

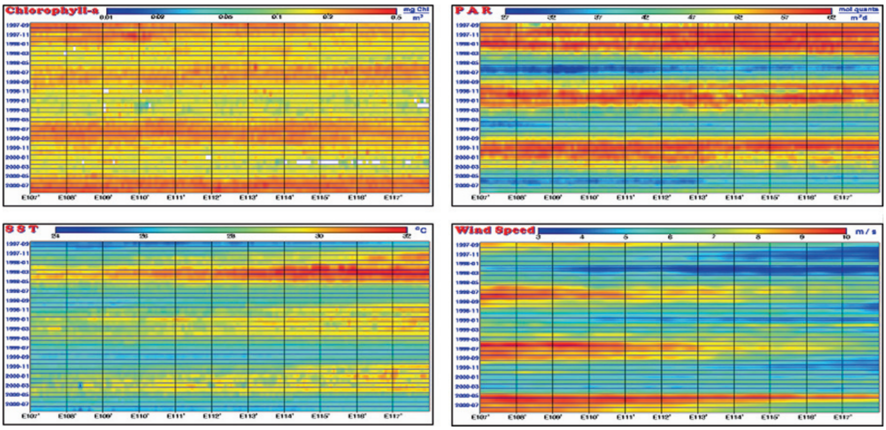

Fig. 4.9 Isopleths of monthly variations (SST, PAR, Chl-a, wind speed) in transect point (107ºE 14ºS–118ºE 14ºS) from September 1997 to August 2000 (see Color Plates, Fig. 4.9)

The time series of data from the transect line is presented in Fig. 4.9. The gray in the SST represents the high value; that is, extremely gray in the SST variation in 1997 in Fig. 4.9 appeared because of the El Niño phenomenon.

4.3.1.1 Fish Production and Fish Biomass

The VGPM was used for calculating FP. The FB was calculated using the FP results. FB increased during September to December 1997 along the Java and Sumatra coasts, to about 30–50 million ton; in contrast, it decreased 4 months later to less than 5 million tons. The coast of Kalimantan maintained a high in FB value of 10–30 million tons. The FB off the north and west coasts of Australia every June was between 5 and 10 million tons.

4.3.2 Correlation Map Between Fish Production and Fishery Data

The entire correlation map from January to December and the histogram are shown in Figs. 4.10 and 4.11. The gray area in the correlation maps and the higher number (value near 1) from the right to the left side in the histograms indicate a positive correlation. On the other hand, the black area in the correlation map and the higher number (value near 1) from the left side to the right side in the histogram indicates a negative correlation. A positive correlation was apparent in the months of January, February, and April; a negative correlation was observed in June, July, and December; the remaining months had no correlation.

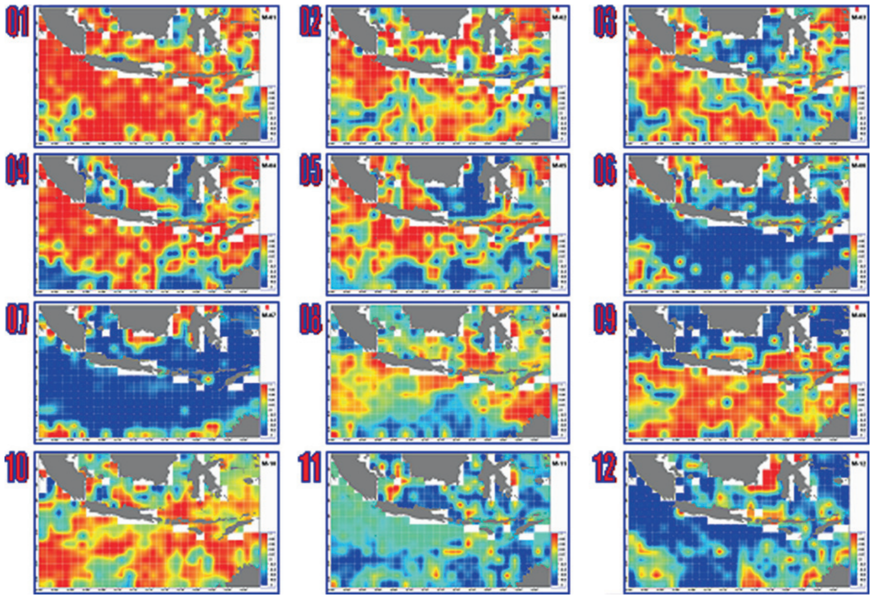

Fig. 4.10 Correlation map from January to December (see Color Plates, Fig. 4.10)

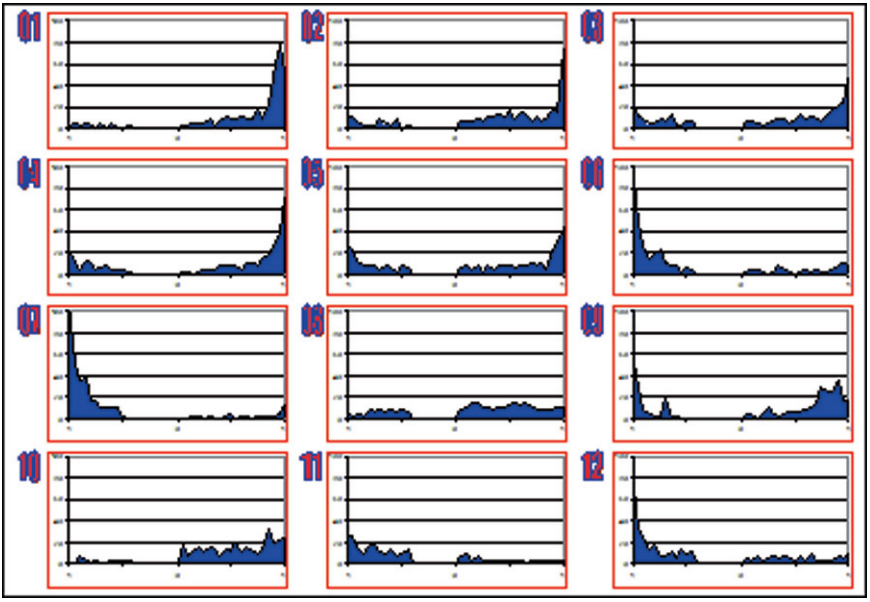

Fig. 4.11 Histogram of correlation map in January to December

4.4 Discussion

4.4.1 Variability of Fishery Data and Satellite Data

The highest total FP was in May 1998. There was an increase in Chl-a and wind speed from May to July 1998; in contrast, PAR and SST decreased relatively. Conversely, the lowest total production of fish was in February 1999. Chl-a and wind speed decreased from January to March 1999; whereas, in contrast, PAR and SST increased Therefore, more fish came to the area, as an indicator of highest production. Conversely, during NW monsoons, in the months of January to March, wind from the Asian continent caused increased SST and PAR. No fish came to that area, as they probably preferred a certain optimum temperature, and the area experienced high temperature and certain physiological characteristics. Hendiarti et al. (2004), showed that the variety in the fish catch decreased during NW monsoons when ocean water is transported into the Sunda Strait (December to March).

Satellite-derived Chl-a concentrations were higher than 0.8 mg/m^3 and SSTs lower than 28°C, indicating upwelling along the southern coast of Java (Hendiarti et al. 2004). The upwelling center with low SST migrated westward and toward the equator during SE monsoons (Susanto et al. 2001).

Large pelagic fish, such as big eye tuna, yellow fin, and albacore, constitute the primary catch by trawling line system (Haenawa method) in the East Indian Ocean during the period of September 1997 to August 2000; 67% of fish caught by PT Samudra Besar are the big eye tuna. This was because the SST and other environmental factors during the time were preferred by big eye tuna, more so than by other fish.

4.4.2 Fish Production Model

Fish biomass on the Java and Sumatra coasts showed the highest value; the coast of Kalimantan showed a high value each time; and the area north and west of the Australian continent showed high values relatively often. On the Java and Sumatra coasts, this is caused by the migration of an upwelling center due west with low SST and toward the equator during SE monsoons. The high FB on the coast of Kalimantan could be due to the discharged waters containing high concentrations of organic and inorganic materials from the numerous rivers and large mangrove regions. In the regions north and west of Australia, cooler temperatures and strong winds from the southern area are the reason for the high PP value.

Correlation maps were utilized to compare with the satellite-derived FP and fishery data. A positive correlation was shown in January, February, and April.

4.5 Conclusions

The trend of oceanic variables derived from satellite data (e.g., CHL, PAR, SST, wind speed) and fishery data showed that in the East Indian Ocean the SE monsoon season is the best time to catch fish, especially in the area between E112°–E115° and S12°–S15°.

The feasibility of calculating PP on a regional basis from satellite-derived data was examined. Two key issues were examined. First, the reliability of NOAA SST, SeaWiFS chlorophyll, and PAR were shown from 1997 to 2000. Second, PP and FP were calculated by the VGPM and FP model.

The correlation maps of FP derived from satellite data and fishery data were calculated. Positive correlations were shown in the months of January, February, and April (SE monsoons) and a negative correlation in June, July, and December (NW monsoons). During the remaining period there was no correlation.

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Chapter 5
Global Warming and Trans-Boundary Movement of Waterborne Microbial Pathogens

Nicholas J. Ashbolt

5.1 Introduction

Potential ramifications of climate change, as they relate to waterborne pathogens (primarily viruses, bacterial and parasitic protozoa), are the focus of this chapter. It seems clear that climate change will impact on waterborne pathogens in various ways (Rose et al. 2001), pertinent to transboundary issues are: (1) increases in intense storm events (increasing sewage/animal waste flows into waterways/aquifers) (Charron et al. 2004; Schijven and de Roda Husman 2005; Yang and Goodrich 2009; De Toffol et al. 2009; Richardson et al. 2009); (2) warmer surface water temperatures or salinity changes (for increased autochthonous pathogen growth) (Niemi et al. 2004; Koelle et al. 2005; Lebarbenchon et al. 2008); and (3) changes in food production, as most obvious in animal diseases (Lightner et al. 1997; Rapoport and Shimshony 1997), but also of concern with zoonoses and from changes in social behavior (Schwab et al. 1998; Nancarrow et al. 2008; CDC 2009a). When considering trans-boundary effects on waterborne pathogens, it is therefore the flow of pathogens in surface water (fresh and marine) and in groundwater, as well as in the varying ways water is used/reused in association with human activities (e.g., food production) that are the trans-boundary issues discussed in this chapter (examples in Table 5.1). Changes in infectious and vector-borne diseases associated with rising sea levels, losses of habitat, international travel etc. are not addressed in this chapter.

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Table 5.1 Examples of pathogen effects associated with climate change

Pathogen group	Agent	Food	Water	Indirect effects	Direct effects
Enteric viruses	Hepatitis A Enterovirus Norovirus	Shellfish	Ground water	Storms can increase transport from fecal sources	Survival increases with reduced temperature and sunlight
Bacteria Cyanobacteria Dinoflagellates	*Vibrio vulnificus*, *V. parahaemolyticus, V. cholerae* non-01	Shellfish	Recreation Wound infections	Enhanced zooplankton blooms	Salinity and temperature related growth
Parasitic protozoa	*Cyclospora Cryptosporidium Giardia*	Fruits and vegetables	Recreational and drinking water	Storms can increase transport from fecal sources	Temperature associated maturation of *Cyclospora*

Adapted from Rose et al. (2001)

5.1.1 Areas of Potential Impact by Climate Change

One of the largest effects of climate change is likely to be reflected in changes in water resource use, which will need to account for water's equally important roles in electricity production/greenhouse gas production (King and Webber 2008) and ecological service provision (Corvalan et al. 2005; Keath and Brown 2009) so as to provide more sustainable water services into the future. A likely consequence of these changed services is an increase in the use of water fit-for-purpose. For example, where there is municipal water supply, not treating all to drinking water quality, give that less than 10% is required in the home for that purpose (Rathjen et al. 2003). Rather, for other urban and irrigation needs, there will be increased use of recycled wastewater streams for toilet flushing, garden/crop irrigation and cloths washing, so reducing the demand on traditional urban water resources (possibly up to 70%) and keeping environmental water to support ecological services and reduce trans-boundary effects of water pollution.

At a regional scale and in developed regions, climate change is already having a profound impact on water decisions within Australia (WSAA 2008), and is expected to have major impacts in many other regions. For example, Californian water resources are projected to significantly change with respect to snowpack, river flows, and sea levels. By 2050, it is predicted that the Sierra snowpack will decline by 25%, which is an important source of urban, agricultural, and environmental water (California Department of Water Resources 2009). More variable weather patterns may also result in increased dryness in the southern regions of California. The sea level has risen about 7 inches at the Golden Gate Bridge in the last century, and continued sea level rise could threaten many coastal communities, as well as the sustainability of the Sacramento-San Joaquin Delta that supplies 25 million Californians with drinking water. As a consequence, water reuse has to increase, most likely via a second non-potable supply pipe to homes (Okum 2002) and/or through wastewater irrigation (direct or via aquifer storage and recovery) (Kracman et al. 2001; Dillon et al. 2009), which will open up new ecological niches for waterborne pathogens.

An example of the possible effects of climate change on waterborne pathogens in developing regions can be seen in the increases in diarrheal disease during El Niño periods in Peru. For each 1°C increase in temperature, hospital admission increased by 8% (95% CI 7–9%), with an additional 6,225 cases of diarrheal disease recorded (Checkley et al. 2000). In Fiji, diarrheal disease appears to increase by 3% (95% CI 1.2–5.0%) per 1°C temperature increase, noting also that a significant increase in diarrhea rates occurred if rainfall was either higher or lower than average conditions (Singh et al. 2001). Overall in developing regions, water, sanitation and hygiene-related disease currently account for some 5.5% of total disability adjusted life years (DALYs) lost (Prüss-Üstün et al. 2008). Changes in diarrheal disease has been the main metric used in WHO reports on possible climate change impacts related to waterborne disease (McMichael et al. 2004; Campbell-Lendrum and Woodruff 2006). What is not clear from most reports, however, are the trans-boundary effects, let alone the raft of other diseases unrelated to diarrhea (e.g., see Table 5.2 and

Table 5.2 Major potential pathogens/indicators in aquatic environments

Group of organism	Source(s)	Symptom(s)	Survival
Viruses			$T_{99.9}$
Adenovirus	Human feces	C Co F G H R	50 d
Astrovirus	Human feces	G	Unknown
Calicivirus (inc. Norovirus)	Human feces	G	Weeks–months
Coronavirus	Human feces	G	Unknown
Coxsackie A and B	Human feces	B C D E-M F H R S	2 d–46 wk
Echovirus	Human feces	C E-M F G R P.S	2 d–46 wk
Hepatitis A	Human feces	H	25 d at 25°C–677 d at 4°C
Hepatitis E	Pig/human feces[1]	H A	Unknown
Poliovirus	Human feces	C F E-M P R	2–130 d
Reovirus	Human feces	None known	>4 d
Rotavirus	An./human feces[1]	G	2–34 d
Bacteria			T_{90}
Aeromonas spp.	An./human feces	G S W	"Indigenous"
Campylobacter jejuni	An./human feces	G-F	Poor
Toxigenic *E. coli*	An./human feces	G, kidney failure	5 h–2 d
Thermotolerant coliforms/*E. coli*	An./human feces	Fecal indicator	2 h–2 d
Fecal streptococci	An./human feces	Fecal indicator	2 h–12 d
Legionella spp.	Biofilms/amoebae	R	"Indigenous"
Mycobacterium avium complex	Freshwater/ biofilms	R, weight loss	"Indigenous"
Mycobacterium marinum	Sea water	S W Granuloma	"Indigenous"

(continued)

Table 5.2 (continued)

Group of organism	Source(s)	Symptom(s)	Survival
Salmonella spp.	An./human feces	G-F	12 h–5 d
Shigella spp.	An./human feces	Bloody diarrhea	<15 to >70 d
Tropheryma whipplei	Human feces	G,	Unknown
Vibrio spp.	Seawater, feces	G W	"Indigenous"/<6d
Yersinia enterocolitica	An./human feces	Appendicitis-like G	Days–weeks
Protozoa			
Cryptosporidium parvum/C. hominis	An./human feces	Watery diarrhea F	Months
Entamoeba histolytica	Feces	G/dysentery	Unknown
Giardia intestinalis	An./human feces	G/bloating	Weeks
Helminths[2]			
Ascaris spp.	An./human feces	Roundworm	Weeks–months
Taenia spp.	An./human feces	Tapeworm	Weeks
Dinoflagellates			
Alexandrium spp.	Ballast/sea water	PSP	"Indigenous"
Gambierdiscus toxicus	Sea water	Ciguatera shellfish poisoning	"Indigenous"
Gymnodinium spp.	Ballast/sea water	PSP	"Indigenous"
Pfiesteria piscicida	Sea water	Fish kills and human illness	"Indigenous"

Adapted from McNeill (1985), Evison (1988), Hallegraeff (1992), Chung and Sobsey (1993), Gantzer et al. (1998), Fenollar et al. (2009), Lathrop et al. (2009)

[1]Enteric viruses from humans cause most waterborne viral infections (i.e., animal viruses from the same group/family do not infect humans and visa versa, with possible exceptions of porcine hepatitis E and bovine Rotavirus and Norovirus)

[2]Helminths are largely an issue for direct contact with fecal matter/fecally-contaminated foods and typically less important as waterborne pathogens

An. animal source, largely mammals/birds that may yield human-infectious strains

A abortion; *C* carditis; *Co* conjunctivitis, *F* fever; *D* diabetes; *E-M* encephalitis-meningitis; *G* gastroenteritis; *G-F* gastro + fever; *H* hepatitis; *P* paralysis; *PSP* paralytic shellfish poisoning; *R* respiratory infection; *S* skin infection; *W* wound infection

T_{90} or $T_{99.9}$ times for 1 or 3 $\log_{10}$ reduction in numbers respectively at 10–25°C

Niklasson et al. 1998; Blinkova et al. 2009). For example, given the increase in aquaculture produce from developing regions, what may be the impact on countries that purchase these products for increased diarrhea and other disease endpoints?

Globally, some 70% of environmental water withdrawals are used in agriculture (Millennium Assessment Board 2005). The need to reduce the total demand but feed the world is probably the biggest global water issue, and the Israelis are leading the world in demonstrating one solution via drip irrigation of treated municipal wastewaters (Oron et al. 2001). Given the globalization of food products, however, numerous disease outbreaks have been recorded for other situations when crops eaten raw are spray irrigated with poorly treated water (Rose et al. 2001; Jay et al. 2007; CDC 2009b). The latter is of particular concern with zoonotic pathogens in surface water (Bharti et al. 2003; Fayer 2004; Bednarska et al. 2007; Mattison et al. 2007; Moulin-Schouleur et al. 2007; Zell et al. 2008; Banyai et al. 2009; Robertson 2009; Rutjes et al. 2009), which includes viruses, bacteria and parasitic protozoa (Table 5.2).

5.1.2 Pathogen Dynamics and Problematic Identifications

Before going into details on the range of waterborne and water-based pathogens of concern, two points are important to note. Firstly, pathogens are dynamic in their ability to evolve and change in their potential to be human pathogens, as exemplified by seasonal changes in flu viruses. Secondly, as we use better methods (largely molecular-based) difficult to culture or non-culturable pathogens are being identified which were previously missed. Hence, it would be fair to say that there are many pathogens yet to be identified today (Rosario et al. 2009; Victoria et al. 2009), let alone what may evolve tomorrow, in part reflecting new environmental conditions.

As an example of the difficulty in describing human pathogens one can look at members of the important waterborne parasitic protozoan genus *Cryptosporidium*. Most human illness is thought to be due to *C. hominis* and *C. parvum* (cattle genotype), yet several other *Cryptosporidium* species or genotypes: *C. meleagridis*; *C. felis*; *C. canis*; *C. suis*; *C. muris*; *C. andersoni*; *C. hominis* monkey genotype; *C. parvum* (mouse genotype); *C. parvum* (pig genotype II) and *Cryptosporidium* rabbit genotype have caused human illness (Kváč et al. 2009). So how to target the right species? In a similar way but at the strain level within a species, *Escherichia coli* O157:H7 has been the focus of method development and study, due to numerous water- and food-borne outbreaks. Yet focusing on O157:H7 strains appears to be at the detriment of missing the even more important non-O157 shiga toxin-producing *E. coli* (Bettelheim 2007; Lathrop et al. 2009). The situation is further complicated in *E. coli*, which is probably better described as pangenomic (i.e. not a single isolated species, but one that shares many genes amongst a broader range of related members) that includes the six known pathovars, each of which may have separately inherited particular virulence factors (Rasko et al. 2008).

5.2 The Waterborne Pathogens

Waterborne pathogens are defined as disease-causing organisms excreted in feces/urine and ingested/inhaled with water. They are often referred to as being transmitted via the fecal-oral route (Ashbolt et al. 2001). All of these pathogens can persist to varying degrees in the aquatic environment, but rarely grow outside the host organism(s) they come from. Hence they are introduced and pass through the water environment as allochthonous members. Most waterborne pathogens that infect humans come from human excreta, other mammals or birds (Table 5.2).

In contrast to the fecally-borne pathogens, there are a number of water-based pathogens generally unrelated to fecal contamination, but loosely referred to as waterborne. Examples of these autochthonous or indigenous pathogens are various *Legionella*, *Mycobacterium* and *Helicobacter* spp. native to freshwaters, and *Vibrio vulnificus*, *V. parahaemolyticus* and *V. cholerae* in saline waters. The bacterium that causes cholera (*V. cholerae*) is a good example of a species with members that are transmitted by the fecal-oral route, but that also have a natural life-cycle associated with marine zooplankton (Blokesch and Schoolnik 2007). It also seems that *Legionella pneumophila* serogroup 1, and similar respiratory pathogens, are accidental human pathogens, with various amoebae possibly acting as their main environmental host (Lau and Ashbolt 2009). Unfortunately our lung macrophages are very similar host cells to amoebae, and these *Legionella*-like intracellular pathogens can also parasitize our lung macrophages (Thomas et al. 2008).

5.3 Changing Habitats

In diverse regions around the world, enteric (gastrointestinal) diseases show evidence of significant seasonal fluctuations, e.g.,

- In Scotland and Sweden, *Campylobacter* infections are characterized by short peaks in the spring (associated with snowmelt periods)
- In Bangladesh, cholera outbreaks occur during the monsoon season
- In Peru, *Cyclospora* infections peak in the summer and subside in the winter

Therefore, further extension of "seasonal" effects under climate change is likely to yield further peaks in waterborne diseases. Climatic-related peaks are also common with various autochthonous (indigenous) pathogens, such as marine *Vibrio vulnificus*. Highest concentrations of *V. vulnificus* and increases in shellfish-borne human disease have been recorded in Florida following heavy rainfall associated with El Niño events (Lipp et al. 2001). It appears that reduced salinity due to increased freshwater inputs rather than temperature is the key factor increasing the competitive advantage of *V. vulnificus*.

5.3.1 Which Water-Based (Autochthonous) Microbes Are Pathogens?

A common feature of the autochthonous (and allochthonous) bacterial pathogens, is that not all strains of pathogenic species are effective human pathogens. For example, in a three-year study of environmental and clinical *Vibrio vulnificus* isolates, the more important biotype 3 sub-species represented about 21% of the aquaculture pond isolates versus 86% of clinical cases (Broza et al. 2009). Huge quantities of aquacultural produce are now exported around the world for direct human consumption as well as animal feedstock – their global significance to disease is largely unknown. Indeed, it is often unclear where foodstock or feeds have come from.

However, what is clear is the uptake and release of ship ballast waters being responsible for the reintroduction of cholera into South America in the early 1990s (McCarthy and Khambaty 1994; WHO 2003), and ballast waters in general continue to be a problem for introductions of various toxic dinoflagellates (algae), cyanobacteria and *V. parahaemolyticus* (Myers et al. 2003; Tang and Dobbs 2007).

Identifying what are important biotypes is also at the heart of the issue with trying to determine the clinical significance of the common occurrence of *Mycobacterium avium* complex mycobacteria (Falkinham III 2009) and *Helicobacter pylori* (stomach ulcer and cancer bacterium) (Kawaguchi et al. 2009). Water appears to be a likely vehicle for the exposure of people to these pathogens, but it is currently unclear if water is the primary source or much less important. Interestingly, various mycobacteria seem to be selected in chlorinated waters, possibly due to their relatively slow growth rates and biofilm-forming habitat.

5.3.2 Transfer of Virulence and Antibiotic Resistance Genes

5.3.2.1 *V. cholerae* as a Model

Understanding the ecology of *V. cholerae* ; i.e., its ability to uptake virulence factors from bacteriophages (viruses to bacteria), growth in association with marine plankton and how it is impacted by climatic conditions, has served as a good model for trans-boundary waterborne pathogens and possible climate change impacts (Lipp et al. 2002). The marine life-cycle of *V. cholerae* is now well established and illustrated in Fig. 5.1.

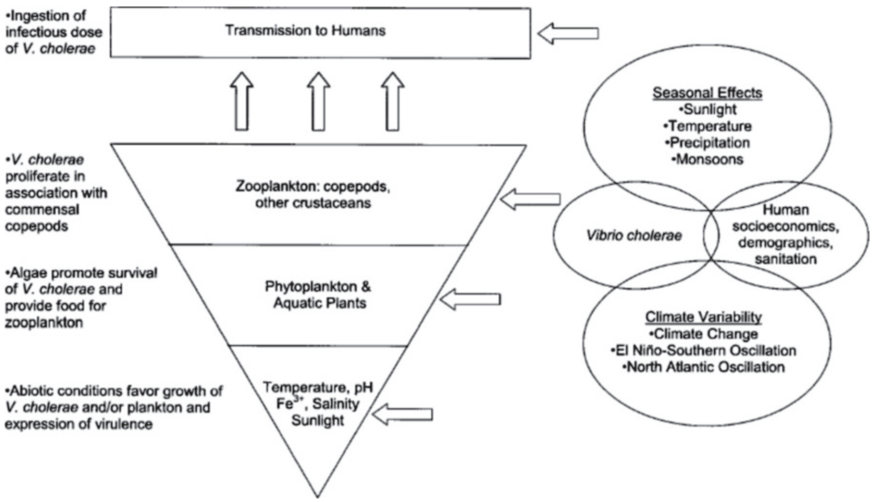

Fig. 5.1 Hierarchical model for environmental cholera transmission. From Lipp et al. (2002) with permission from the publishers

The cholera toxin (CT), which is responsible for the classic symptom of profuse diarrhea, is encoded by a lysogenic bacteriophage designated CTX Phi (includes six toxin genes which also occur on a plasmid) (Faruque et al. 1998). *V. cholerae*, requires two coordinately regulated factors for full virulence, cholera toxin (CT) and toxin-coregulated pill (TCP, surface organelles required for intestinal colonization and the site for phage attachment). Hence, the emergence of toxigenic *V. cholerae* involves horizontal gene transfer, in vivo gene expression and follows phage seasonality. In marine waters *V. cholerae* becomes resistant to the phage, yet in the intestine it remains susceptible and hence, maintains its virulence (Zahid et al. 2008). Also, *V. cholerae* is commensal to phytoplankton and their consumers zooplankton, notably copepods, as such it is also a vector-borne disease. Interestingly, growth of *V. cholerae* on the chitinous exoskeletons of copepods molts induces competence for natural transformation, a mechanism for intra-species gene exchange (Blokesch and Schoolnik 2007).

A further point of some controversy is that toxigenic *V. cholerae* are rarely isolated from the aquatic environment between cholera epidemics, due to their presumed presence in a dormant stage, i.e., active but nonculturable (ABNC) form (Colwell et al. 1996). Nonetheless, the aquatic biofilms rather than surrounding seawater, have proved to be a source of culturable *V. cholerae*, even in non-epidemic periods in Bangladesh (Zahid et al. 2008).

5.3.2.2 Integrons and Antibiotic Resistance

The last example of trans-boundary pathogen concern provided in this chapter relates to the insidious perfusion of antibiotic resistant genes in the environment. Most *β-Proteobacteria* (members of Gram-negative bacteria that includes many pathogens and non-pathogens) contain integrons. Class 1 integrons are central players in the worldwide problem of antibiotic resistance, because they can capture and express diverse resistance genes. In addition, they are often embedded in promiscuous plasmids and transposons, facilitating their lateral transfer into a wide range of pathogens and environmental bacteria (Gillings et al. 2008).

Hence, Gillings et al. (2008) have promoted the need to understand the origin of integrons as important for the practical control of antibiotic resistance and for exploring how lateral gene transfer can seriously impact on, and be impacted by, human activities. They have shown that class 1 integrons are common in nonpathogenic soil and freshwater *β-Proteobacteria* in the absence of antibiotic resistance genes, yet are almost identical to the core of the class 1 integrons now found in pathogens, suggesting that environmental *β-Proteobacteria* were the original source of these genetic elements. Because these elements appear to be readily mobilized, their lateral transfer into human commensals and pathogens was inevitable, especially given their intersect with the human food chain. The strong selection pressure imposed by the human use of antimicrobial compounds then ensured their fixation and global spread into new species (Hardwick et al. 2008; Gillings et al. 2009). Hence, changing food production practices influenced by population growth, water resources and climate change will further impact on our loss of efficacy in antibiotics. Newer treatment systems for wastewater are also not completely effective at removing resistance genes (Bockelmann et al. 2009) and intensive animal facilities are a likely hotspot for exchange of antibiotic resistance genes (Kozak et al. 2009; Toomey et al. 2009).

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Part II
Mitigation and Adaptation

Chapter 6
Designing Post-Kyoto Institutions: From the Reduction Rate to the Emissions Amount

Tatsuyoshi Saijo and Hiroshi Hamasaki

6.1 Introduction

In February 2007, the United Nations' Intergovernmental Panel on Climate Change (IPCC) observed that the average global temperature had climbed 0.74°C in 10 years from 1996 to 2005; they basically concluded that global warming is escalating owing to various human activities. If countermeasures were not taken, the panel warned that the temperature could climb a maximum of 6.4°C by the end of this century compared to the end of the twentieth century. With this in mind, the discussion regarding the post-Kyoto Protocol, an international framework concerning the reduction of greenhouse gases (GHGs) after 2013, has become animated. In January 2007, the European Union (EU) independently declared that it would reduce GHGs by at least 20% by 2020 (compared to the 1990 level). In May 2007, looking ahead to the June G8 summit in Germany, Prime Minister Abe and the Japanese government proposed the "Cool Earth 50" strategy.[1] Regarding the post-Kyoto framework, Prime Minister Abe proposed that all of the major emitting countries including the United States, China, and India aim to create a framework that will accomplish a 50% global reduction by 2050. The specifics of this plan, however, have not been realized, and what comes after the promised term of the Kyoto Protocol remains unclear.

In this chapter, we compared two alternatives – the United Nations Emission Trading Scheme (UNETS) and the Global Emission Trading Scheme (GETS) – with the Kyoto Protocol-type framework by using the Computable General Equilibrium model.

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[1] The entire speech can be found at: http://www.kantei.go.jp/jp/abespeech/2007/05/24speech.html

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6.2 Issues Surrounding the Kyoto Protocol

For a framework proposal for post-Kyoto, let us first look at the issues surrounding the protocol with simple numerical examples. Assume that the amount of GHGs emitted by country A in 1 year is 10 units, and for country B it is 2 units. Using this year as the base year, let us say that the protocol decided on a 10% reduction for country A and a 0% reduction for country B. Let us say also that at the end of the protocol term country A had produced 6 units and country B had produced 3 units of emission. Country A has realized the 20% reduction, whereas country B's emissions have increased by 50%. The major factors in country A's reduction are the end of subsidies for coal, a change to natural gas for fuel, and the outflow to other countries of major industries. On the other hand, let us suppose that country B is clearly still in the developing stages, and its increase in emissions was due to the export of products to country A and so on. Hypothetically, if country A were to sell 1 unit of emission to country B, both countries would have accomplished the goals of the protocol. If country A's emissions decline is almost entirely a natural reduction, it would enjoy greater economic profits by ratifying the protocol. Conversely, B would suffer a partial loss. If A is a country that has released massive amounts of GHGs throughout the twentieth century, could A and its 20% reduction be called a more environmentally advanced country than B and its 50% increase?

Hypothetically, let us change the above numerical figures to emissions per capita. Under the protocol promise, A would have the right to emit 9 units and B would claim 2 units. Though it has achieved a 20% decline, why would A's emissions limit be 4.5 times that of B's? What is the problem that lies within this logic-defying framework? The answer is the style of negotiation that focuses on the reduction percentage since the base year. What is most important in the discussion of stopping global warming, however, is not the reduction percentage from the base year but, rather, how much is being emitted relative to the rest of the world. At the completion of the promised period, A's emission is 8 units and B stands at 3 units. Should not the post-Kyoto principle be that each country takes responsibility for their respective emissions? In other words, it is necessary that the post-Kyoto framework not be based on reduction percentages but, rather, on taking responsibility for the actual quantity of emissions.

Hamasaki (2007) pointed out low coverage (the percentage of emissions of the countries bound to reduce emissions is low among total global emissions) and low efficiency (carbon leakage from the transfer of industries from countries engaged in reduction activities to countries that are not[2]) as problems with the Kyoto Protocol.

[2] Carbon leakage refers to, under the Kyoto Protocol, an increase in GHG emission from countries without reduction goals as a result of countries with reduction goals engaging in reduction activities. Carbon leakage occurs because of the following two reasons. (1) In countries with reduction goals, companies bear added expenses from energy reduction measures, etc. As a result, the production of energy intensive industries is shifted to countries where there are no reduction goals. (2) GHG reduction in countries with reduction goals leads to a decrease in the global demand for energy and a subsequent drop in the price of fossil fuels. This leads to stagnation of energy reduction measures in countries with no reduction goals, and a shift to a high energy consuming economic structure.

He emphasized the importance of a framework where major GHG-emitting countries such as the United States, China, and India would participate in the reduction programs. With the major emitting countries involved, it would be possible to resolve the problems of coverage and poor efficiency. Participation by these countries in a post-Kyoto framework would require that the framework be flexible and would consider the situation of each individual country.

6.3 United Nations Emission Trading Scheme

As an alternative to the Kyoto Protocol, we used UNETS[3] as a framework that would make it easier for major emitting countries to participate by having each country pay the expenses appropriate to their stage of economic growth, as well as bear the burden that is commensurate to emission amounts. Under the UNETS framework, decision-making will be conducted at the Conference of the Parties/ Meeting of the Parties regarding what kind of international emissions path to take to stabilize the climate. Research regarding an emission path at the IPCC would be helpful in this process.

Following this path, the United Nations and other designated institutions would sell emission rights to countries. Although the total amount of global emission is decided for a certain period, there is no limit on total emission for an individual country. Each country must purchase emission rights corresponding to the amount they emit from UNETS using an auction system. In practice, the purchasers of emission rights would be the upstream energy companies. These companies would purchase emission rights that are commensurate to the amount of GHGs produced from the energy they sell to a particular country; but they could not sell energy exceeding the amount of emission rights held. It is necessary to reduce the total global GHG emissions to stabilize the climate, and as a result the supply of emission rights would decrease; thus, purchasing these rights would come at a premium. Upstream energy companies would pass on the expenses incurred from buying the emission rights to the selling price of energy, and therefore companies buying energy would have to pay an even higher energy cost that reflects the price of emission rights. As a result, switching from coal to gas (in other words to energy with less carbon content), utilizing renewable energy such as wind and solar power, and investing in energy saving would be actively pursued – and a reduction in GHG emissions would be realized. In addition, this would lead to a mid- to long-term cost decrease in technology that will dramatically reduce GHG emissions of renewable energy; it would also jump-start research and development investment into innovative low-carbon technology.

UNETS would sell emission rights using an auction system and would receive the sales proceeds.

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[3] Here we place the UN in charge of the credit sales as an example. However, it does not necessarily have to be the UN as long as it is an appropriate third-party organization.

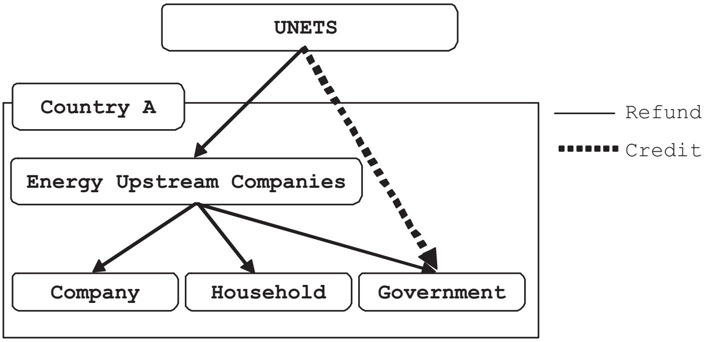

Fig. 6.1 Outline of the United Nations Emission Trading Scheme (UNETS)

Figure 6.1 illustrates the reallocation of proceeds to each country. Reallocation would involve two methods. The first is to refund a certain portion of the sales proceeds (e.g., half) and reimburse each country in proportion to the sales amount. To do this, countries would be divided into, for example, three categories: developed, semi-developed, and developing countries. Each country would receive a certain coefficient × amount of emission rights sales × the average sales price of emission rights. Regarding the certain coefficient (emission rights purchasing return rate), the rate of return decreases in proportion to the level of development of the country. The remaining half would, for example, be returned in proportion to another parameter with no direct relation with emissions, such as the gross domestic product (GDP). Here again, the more undeveloped the country the higher is the rate of return.

This would ensure that semi-developed and developing countries would not lose by participating in this system. In other words, by using the refunded capital it would become possible to contribute to the investment in global warming and poverty countermeasures. On the other hand, developed countries would have to bear an appropriate level of the burden. This could be called a system where developed countries such as Japan would bear a portion of the burden of GHG reduction activities and expenses toward adapting to climate change in developing countries. It would also be consistent with the United Nations Framework Convention on Climate Change (UNFCCC) basic principle of "shared but different responsibilities," as well as the principle of "a flexible and diverse framework that considers the individual situation of each country" proposed by Prime Minister Abe in his "Cool Earth 50." The level of refunding to each country would be a point of contention in international negotiation; but if developing countries were allocated adequate refunding, it would be possible for countries such as China and India to join the framework. The returned money would be channeled toward subsidies for areas such as research and development of technology to combat global warming and the introduction of wind power generation. It is also conceivable to have a portion returned to energy purchasers with the goal of reducing the burden on energy users.

The fluctuating part of the refund is as follows:

$$V(\mathrm{r}) = \alpha\ (\mathrm{r}) \times C\ (r) \tag{6.1}$$

where
$V(r)$ is the amount refunded to country r (fluctuating part),
$\alpha(r)$ is the fluctuating refund rate to country r;
$C(r)$ is the credit purchase amount paid by country r.
The fixed part of the refund is as follows:

$$F(r) = \beta(\mathrm{r}) \times \mathrm{GDP}(r) \tag{6.2}$$

where
$F(r)$ is the amount refunded to country r (fixed part),
$\beta(r)$ is the fixed refund rate to country r;
$\mathrm{GDP}(r)$ is the GDP in country r.

6.4 Global Emission Trading Scheme

Another framework that is dealt with in this research is GETS. It is an international emission trading scheme based on equal per-capita emissions permits. Under GETS, every single person is allocated the same amount of emission allowances, and each party must buy permits that are the same as the GHG emission of the party. International emission trading is allowed to equalize and minimize GHG abatement cost all over the world.

6.5 Overview of Model

Our research was developed using Global Trade Analysis Project (GTAP) as a base. GTAP is a general equilibrium model used widely in research related to global warming. GTAP-E refers to a GTAP[4] model expanded to conduct analysis of global environmental issues, which is greatly contributing to the impact assessment of global environmental policy, beginning with the Kyoto Protocol. Moreover, the databases and models have been made public, a point that is praised for making it possible for third parties to verify the results.

The GTAP-E model uses the GTAP-E database, which is the GTAP database with the inclusion of energy data. This model handles energy as a good that creates added value instead of an intermediate input good. One of its major characteristics is that a substitutive relation among energies has been added.[5] Under the GTAP-E model, industry, households, and the government, both regional and national, are the principal actors. Industry engages in production by using factors of production. Households and the government, which are the principal actors in consumption, are treated as principal trading actors known as regional households in a broad sense of the term. Households receive factor income by supplying production factors to industry, and

[4] For more information on GTAP, refer to Hertel (1997).

[5] For more detailed information on GTAP-E model, refer to Burniaux and Truong (2002).

the government collects tax revenue from households and industry. The factor income of households and the government's tax revenue would become the income of regional households, and so the expenditure of regional households would be the sum of private consumption expenditure and government consumption expenditure. It is assumed that there is perfect competition in the goods market and production factor market. This research assumes that the movement of labor and capital is free only among industries, not internationally. Moreover, labor and capital are used perfectly.

The production structure of the GTAP-E model is illustrated in Fig. 6.2. Each industry, with production amount as a given, decides on demand for intermediate input goods and production factors based on minimized costs and then engages in production. The GTAP-E model uses a multistage Constant Elasticity of Substitution (CES)-style

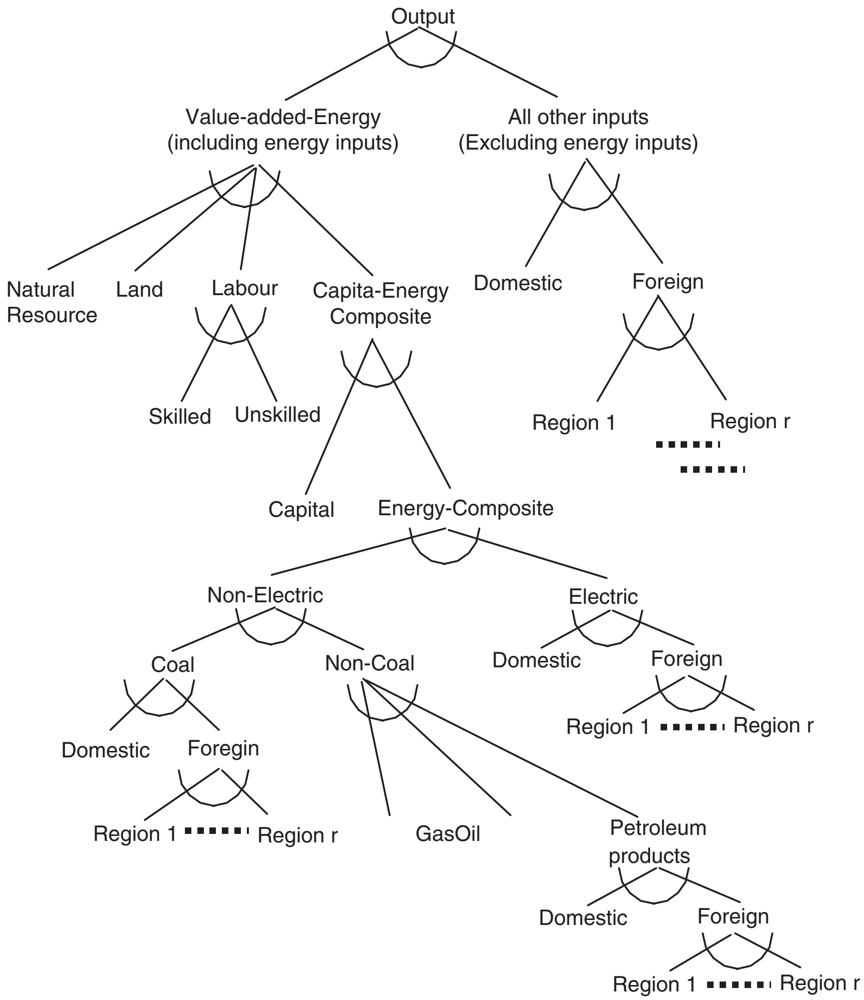

Fig. 6.2 Production structure of the GTAP-E model

function as its production function. Factors of production are capital, labor, land, and natural resources; and production factors and intermediate input (including energy) are linked with the CES-style production function. The top added value and intermediate input goods are linked by the fixed coefficient-type production function. Capital and the production of energy composite goods have a small multistage structure, and energy composite goods are comprised of fossil fuels (e.g., coal, crude oil, gas, oil products) as well as electricity.

In this research, GTAP databases Version 5[6] were used. As shown in Tables 6.1 and 6.2, analysis was conducted based on separating data by country and region as well as industry.

Table 6.1 Countries and regions

Code	Remarks
ANZ	Australia, New Zealand
CHN	China, Hong Kong
JPN	Japan
KTW	Korea, Taiwan
THA	Thailand
ASA	Indonesia, Malaysia, Philippines, Singapore, Vietnam, Bangladesh, India, Sri Lanka, South Asia
USA	United States of America
CAN	Canada
EU	European Union 15
FSU	Russia, other former republics of the Soviet Union
ROW	Other

Table 6.2 Industries

Code	Remarks
AGR	Agricultural crops, dairy, forestry, fishery
COL	Coal
OIL	Oil
GAS	Gas
GDT	Gas supply
P_C	Petroleum products, coal products
ELY	Electricity
MIN	Minerals
PPP	Paper, pulp, publishing
CRP	Chemicals, rubber, plastics
I_S	Iron and steel
MTL	Metals, metal products
VEH	Automobiles, automobile parts, transport machinery
OMN	Other manufacturing
TRP	Land, air, water, other transport
SERV	Water works, construction, distribution, transmission, financial, insurance, business services, leisure/entertainment, public services, housing

[6] Databases using 1997 as a basis.

6.6 Settings and Design of the Simulation Scenarios

In this research, we hypothesize that total global carbon dioxide emissions can be reduced by 10% from the current level. The simulation was conducted with the following two conditions.

In the UNETS simulation, returns are made using the fluctuating return rate and fixed return rate, as shown in Table 6.3. Regarding the fluctuating return rate, the less developed the country, the higher is the rate of return. The fixed return rate is also proportionally higher for developing countries. We assumed that the returns made to each country would be done through lump-sum returns to the entire region. The fluctuating return rate and fixed return rate (Table 6.4) were set under the principle that for developing countries an amount greater than the expenses to purchase emissions rights would be returned, whereas for developed countries an amount lower than the expenses to purchase emissions rights would be returned.

In the GETS simulation, it is assumed that every single person receives the same emission allowance. Each party must have permits that are the same as the GHG emission of the party. International emission trading is allowed to meet their targets.

In addition to the above two simulations, we have conducted simulations of the Kyoto Protocol Type framework (Kyoto), which sets GHG emission reduction targets for Annex I countries. Under the simulation, all annex countries have to reduce their emissions by 10% below the baseline, and international emission trading is allowed.

6.7 Simulation Results

First, we show the simulation results of UNETS. The simulation was done under the premise that 10% of the current amount of emissions would be reduced, and the price of emission rights would be US$24.5/carbon ton. Table 6.4 illustrates the net amount, the emissions rate compared to the current level, and the impact on the GDP.

Table 6.3 Return rate by country/region

	Fluctuating return rate α	Fixed return rate β
Australia, New Zealand	0.3	0.5
China	0.7	0.7
Japan	0.3	0.25
Korea, Taiwan	0.5	0.5
Thailand	0.5	0.7
Other Asia	0.7	0.7
USA	0.3	0.45
Canada	0.3	0.45
EU	0.3	0.3
Former Soviet Union	0.7	1.2
Other	0.7	0.7

Table 6.4 UNETS: Results

	Net return amount (US$ million)	Emissions rate compared to current (%)	Impact on GDP (%)
Australia and New Zealand	−476	92.2	−0.07
China	176	66.5	−0.47
Japan	−458	96.7	−0.01
Korea and Taiwan	−428	95.1	−0.05
Thailand	−137	94.3	−0.06
Other Asia	1,189	87.9	−0.14
USA	−1,491	92.6	−0.01
Canada	−650	95.0	−0.11
EU	−3,396	97.3	0.07
Former Soviet Union	−1,520	92.7	−0.21
Other	7,192	93.9	−0.08

The net amount of return is the difference after taking the amount of return received from the relevant country's amount of payment for emissions credit

As noted previously, UNETS returns an amount greater than the expenses to purchase emissions rights to developing countries and an amount lower than expenses to purchase emissions rights to developed countries. The net return amount to Japan is minus US$458 million, whereas the return amount to China is plus US$176 million. The country reducing emissions the most is China (33% reduction), following by "other Asia" (22.1%). On the other hand, the reductions are marginal in developed countries such as Japan (3.3% reduction) and the EU (2.7% reduction). Although the price for emission rights is consistent throughout the world, the opportunities for China, which has low energy prices, to raise energy prices is large compared to other countries, and as such energy-saving would be pursued actively. The fact that China's energy structure is centered on coal with a high carbon-containing rate should also accelerate energy-saving activities.

Regarding the impact on the GDP, whereas the return amount to Japan is minus US$458 million, the impact on the GDP is marginal at 0.01%. On the other hand, the impact on China's GDP is at −0.47%, a figure that is comparatively large compared to that of developed countries such as Japan, the EU, and the United States. The reason for this is, as previously mentioned, energy prices are held down at a low rate in China, and consequently the rise in energy prices is more pronounced in China compared to other countries. An increase in production prices hurts international competitiveness, and a hike in overall prices can lead to stagnant consumption.

Next, we discuss the simulation results of another proposed approach, GETS. Table 6.5 shows business-as-usual (BAU) emissions, allocated credits, and required reductions from BAU. Under GETS, high per-capita emission countries – generally developed countries – receive less credit than their BAU emissions, and low per-capita emission countries – generally developing countries – receive more credit than their BAU emissions. The United States is the highest per-capita emission country and as a result has to reduce emissions by 82.3%. On the other hand, China receives 43.3% more credits than BAU emissions.

Table 6.5 Credit allocations

	BAU emissions (million tons of carbon)	Allocated credits (million tons of carbon)	Required reduction (%)
Australia and New Zealand	95.2	22.3	−76.5
China	865.2	1,239.5	43.3
Japan	348.5	134.7	−61.3
Korea and Taiwan	191.5	68.6	−64.2
Thailand	46.3	60.4	30.5
Other Asia	439.0	1,644.7	274.6
USA	1,535.6	271.7	−82.3
Canada	143.7	30.2	−79.0
EU	937.8	396.6	−57.7
Former Soviet Union	584.1	314.0	−46.2
Rest of the world	1,127.6	1,500.2	33.0

BAU business as usual

Table 6.6 shows the major results of Kyoto, UNETS, and GETS. Under Kyoto, GHG reductions are achieved only in developed countries, although emissions in developing countries increase – so-called carbon leakage. Leakage of emissions could come about by relocation of carbon-intensive industries from countries with emission commitments to nonparticipating countries or by increased consumption of fossil fuels by nonparticipating countries in response to declines in global oil and coal prices. Under GETS and UNETS, major reductions are achieved in developing countries, which have many low-cost opportunities for carbon reductions.

The credit price is US$64.8/ton of carbon under Kyoto, which is much higher than the other two simulations (US$24.5/ton of carbon under UNETS and US$27.5/ton of carbon under GETS). As a result, the GDP decreases significantly in developed countries under Kyoto, except the United States, compared to the other two simulations. Table 6.7 shows the net value of international transfer payments for emission rights. Under Kyoto, the United States is the only recipient of transfers, and therefore the GDP of the United States increases while the GDPs of other developed countries decrease.

6.8 Conclusion

In this chapter, we conducted an assessment of the effectiveness of UNETS and GETS in comparison to the Kyoto Protocol framework (Kyoto) using a general equilibrium model.

Article 3 of UNFCCC defines the principle of common but differentiated responsibilities (CBDR). Under the Kyoto Protocol, the principle of CBDR has been translated to set quantitative mitigation obligations for developed countries and no emission mitigation obligations for developing countries. It is very costly to mitigate carbon emissions without the developing countries – which will be the

Table 6.6 Comparison between Kyoto, UNETS, and GETS

	GHG emissions in comparison to BAU (%)			GDP change (%)			Credit price (US$/ton of carbon)		
	Kyoto	UNETS	GETS	Kyoto	UNETS	GETS	Kyoto	UNETS	GETS
Australia and New Zealand	–22.2	–7.8	–8.3	–0.28	–0.07	–0.10	64.8	24.5	27.5
China	3.3	–33.5	–32.1	0.03	–0.47	–0.48	–		
Japan	–11.5	–3.3	–3.2	–0.10	–0.01	–0.01	64.8		
Korea and Taiwan	6.3	–4.9	–5.5	0.06	–0.05	–0.06	–		
Thailand	3.0	–5.7	–5.8	0.05	–0.06	–0.04	–		
Other Asia	5.8	–12.1	–11.3	0.09	–0.14	–0.09	–		
USA	–33.5	–7.4	–8.3	0.03	0.00	0.03	64.8		
Canada	–19.4	–5.0	–1.8	–0.48	–0.11	–0.31	64.8		
EU	–10.0	–2.7	–2.7	–0.07	0.07	0.05	64.8		
Former Soviet Union	–17.3	–7.3	–7.8	–0.31	–0.21	–0.38	64.8		
Rest of the world	8.6	–6.1	–6.3	0.07	–0.08	–0.08	–		

Table 6.7 International payments for emission rights (million US$)

	Kyoto	UNETS	GETS
Australia and New Zealand	−57	−476	−1,785
China	0	176	17,848
Japan	−2,597	−458	−5,559
Korea and Taiwan	0	−428	−3,091
Thailand	0	−137	461
Other Asia	0	1,189	34,460
USA	13,429	−1,491	−31,095
Canada	−363	−650	−3,037
EU	−7,812	−3,396	−14,173
Former Soviet Union	−2,600	−1,520	−6,175

major source of global emission increases in the coming decades – and have huge opportunities for low cost mitigation.

As alternatives to the Kyoto Protocol, the principles of CBDR are translated by reimbursing more revenue of emission rights sales to developing countries under UNETS and allocating more emission rights to developing countries under GETS. In both the UNETS and GETS cases, major reductions will be achieved in China and other Asian countries including India, whereas emission reductions in the EU and Japan will not be significant. These results bear out the importance of the participation of major GHG-emitting developing countries, as there are significant low cost carbon reduction opportunities in these countries. In addition, their participation will eventually solve competitiveness and leakage problems.

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Chapter 7
Mitigation Prospects and Challenges for India in Responding to Climate Change

Ritu Mathur and Suruchi Bhadwal

7.1 Introduction

Although India's per-capita energy consumption is still a fraction of that in countries of the developed world, its commercial energy use has increased considerably in absolute terms, growing at about 6% during the past two decades and making India the fifth largest country in terms of primary energy consumption. India is currently one of the fastest growing economies of the world, and implications of its levels and patterns of energy use and associated emissions have generated interest globally in the context of discussions related to efficient use of energy and lowering future carbon footprints. Although development is a key concern and a challenge for all developing countries, the magnitude of the challenge differs enormously depending on the existing level of socioeconomic development of the country and the global context it faces at various stages of its development.

7.2 Development Imperatives for India

The developmental challenge that India faces at present is especially formidable on several counts. First, about 72% of its population still resides in rural areas that often lack access to basic infrastructural requirements such as clean drinking water or adequate health and education facilities. Moreover, around 44% of the population does not have access to electricity (Census of India 2001). Several of these households continue to depend on inefficient traditional energy forms (e.g., firewood, crop residue, dung) owing to either a lack of access to modern fuels or their inability to afford them to meet their requirements. It is estimated that 27.5% of the population was below the poverty line in 2004–2005.

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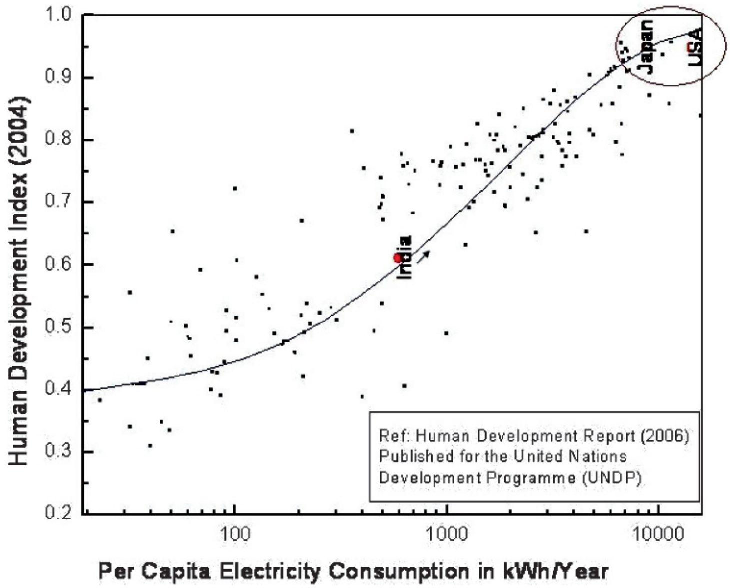

Fig. 7.1 Relation between per-capita electricity consumption and the human development index

Although India's human development index (HDI) has increased from 0.5 in 1990 to 0.6 in 2005 (UNDP 2007), its global position is still 128th. As the country attempts to provide more acceptable levels of well-being to all its people and improve the HDI, it is imminent that per-capita energy consumption would also rise given the strong positive correlation between energy use and human development (Fig. 7.1).

A country comparison of the Infrastructure Index (a composite index including road density and water and sanitation access) indicates that the level of infrastructure in India is significantly lower than that of the developed world (Fig. 7.2), and the country has a long way to go in terms of providing some of these basic infrastructural facilities to its population.

Recognizing the fact that rapid economic growth is an essential prerequisite to reducing poverty, the approach paper to the 11th Five-Year Plan (Planning Commission 2006a) emphasized the need to achieve economic growth of more than 8% over the next couple of Plan periods. Moreover, the Planning Commission has established targets that can be monitored for poverty alleviation for the Tenth Five-Year Plan and beyond, as indicated in Table 7.1. Achieving the targets' goals would require significant specific physical investments in creating new infrastructure and providing services. For example, construction of additional buildings and access roads for health and family welfare centers in both rural and urban areas would require significant energy inputs by the way of the indirect energy embodied in the materials used in their construction. Moreover, electricity would be required in these health centers for lighting, air-conditioning, and refrigeration among other needs, as well as fuel for ambulances used for referral transport.

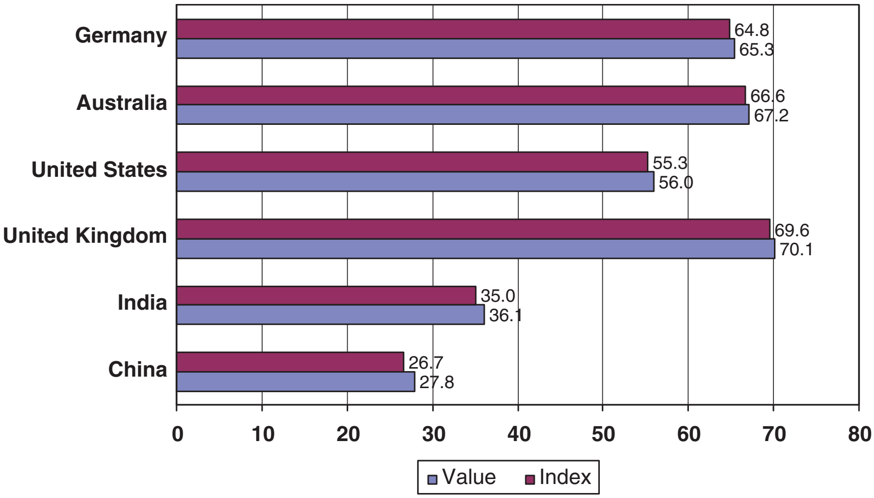

Fig. 7.2 Comparison of the infrastructure index among countries. Source: www.wttc.org/NU-compmon/Infrastructure.htm

Table 7.1 Monitorable targets for the Tenth Five-Year Plan and beyond

Reduction of poverty ratio by 5% by 2007 and by 15% by 2012
Providing gainful, high-quality employment as an addition to the labor force over the Tenth Plan period
All children in school by 2003; all children to complete 5 years of schooling by 2007
Reduction in gender gaps in literacy and wage rates by at least 50% by 2007
Reduction in the decadal rate of population growth between 2001 and 2011 to 16.2%
Increase in literacy rates to 75% within the Plan period
Reduction of infant mortality rate to 45 per 1,000 live births by 2007 and to 28 by 2012
Reduction of maternal mortality ratio to 2 per 1,000 live births by 2007 and to 1 by 2012
Increase in forest and tree cover to 25% by 2007 and 33% by 2012
All villages to have sustained access to potable drinking water within the Plan period

Source: Planning Commission (2002)

It is estimated that CO_2 emissions from the iron and steel, cement, and aluminum production sectors (key materials for infrastructure development) could increase by around 15 times the 2001 levels by 2031 to meet some of the country's developmental goals.

7.3 India's Future Energy Demand and Its Implications

In the context of its developmental objectives and plans for rapid economic growth, it is imperative that the country would require significant levels of energy and physical investments for the creation of adequate infrastructure and provision of

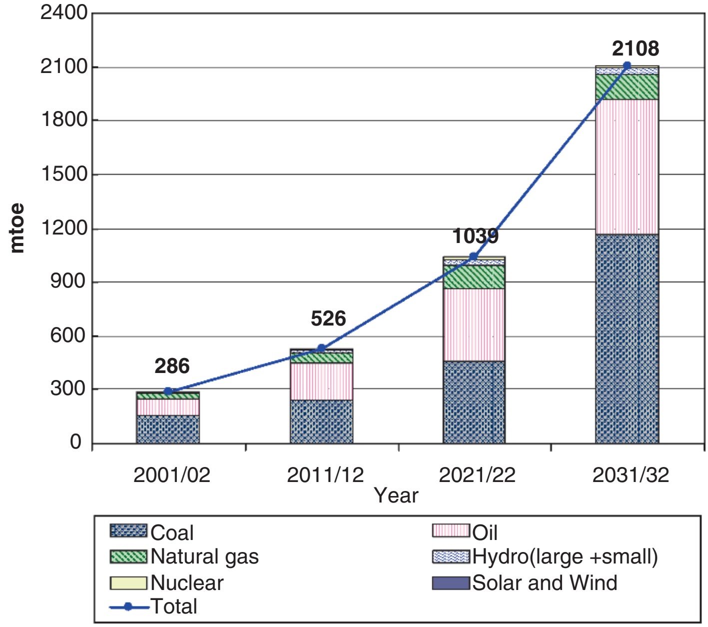

Fig. 7.3 Commercial energy supply in India: business as usual (BAU) scenario

services to its already large population base. Various estimates indicate that India would need to increase its primary energy supply by at least three to four times and its electricity generation capacity by five to six times of the 2003/2004 levels by the year 2031. The Integrated Energy Policy report brought out by the Planning Commission estimated that under an 8% gross domestic product (GDP) growth scenario, India's total energy requirements would be in the range of 1,536 million tons of oil equivalent (mtoe) to 1,887 mtoe by 2031 under alternative scenarios of fuel and technological diffusion (Planning Commission 2006b). As reflected in Figs. 7.3 and 7.4, TERI's analysis based on the MARKAL[1] (Market Allocation) model, indicated that under an 8% GDP growth scenario with current plans and policies of the government, commercial energy needs would increase to 2,108 mtoe by 2031/2032, and CO_2 emissions would grow by around seven times during this period (TERI 2006b). Moreover, it is estimated that coal and oil would continue to account for most of the energy requirements even by the year 2031.

In 2004/2005, the country imported around 120.9 mtoe of coal, oil, and gas (an import dependency of around 27%). Although India has depended on oil imports for several decades, imports of coal and gas have started only during the last decade.

[1] An integrated energy model for India using MARKAL modeling framework has been developed by TERI. It can be used to indicate various kinds of scenario analysis. The core research team of TERI, which developed this model comprised of Ritu Mathur, Pradeep Kumar Dadhich, Atul Kumar, Pooja Goel, Sakshi Marwah, Preety Bhandari and Leena Srivastava.

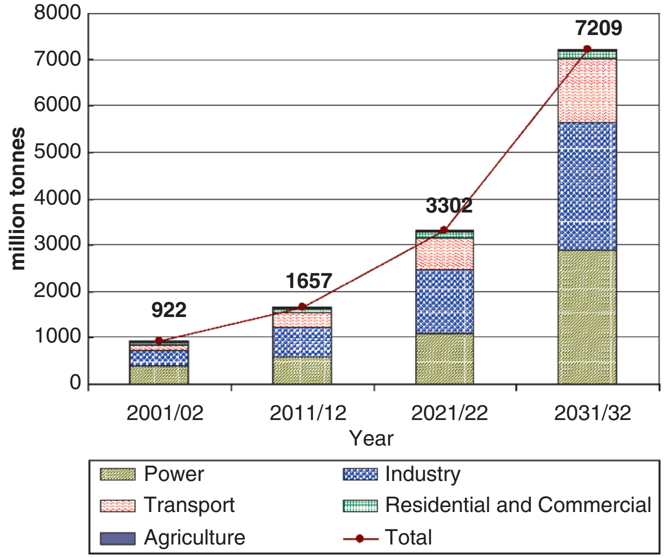

Fig. 7.4 CO_2 emissions from energy use. Source: TERI (2006b)

By 2031, TERI estimates indicate a dependency of 78% for coal, 93% for oil and 67% for gas with current estimates of future availability of indigenous energy (TERI 2006b). This is clearly an unsustainable trend with implications not only in terms of large monetary outflows but also in terms of the infrastructural requirements for port development, handling, and transportation of this energy. Future levels and patterns of energy use in India therefore raise concerns not only in the global context but also with regard to national concerns of energy security, infrastructural adequacy, and pressures on the local environment.

7.4 Reconciling Development and Sustainability: Achievements and Challenges

With regard to the government's development plans, although it is recognized that all people are entitled to achieve at least a minimum standard of living and that enhancing the level of human development would also help these people adapt better to the impact of climate change, there is apprehension with regard to the implications of higher per-capita energy requirements across a large population base that currently subsists at extremely low per-capita energy consumption levels. In this context, an analysis of consumption levels across countries indicates an inherently frugal nature of resource use in India. Despite the increasing trends of urbanization and industrialization, India's per-capita consumption of most energy-intensive goods and services continues to be low. It is estimated that, even in the year 2031,

Table 7.2 Comparison of per-capita annual consumption across various energy-intensive sectors

Sector	Current per-capita consumption	Estimated per-capita consumption in 2031
Iron and steel	India (30 kg) World average (135 kg) USA (426 kg) Korea (814 kg) China (111 kg)	India (272 kg)
Cement	India (110 kg) World average (273 kg) Korea (1,090 kg) Japan (540 kg) Thailand (300 kg)	India (847 kg)
Paper	India in 2003 (5.5 kg) One by ninth of world average (50 kg)	India (37 kg)
Electricity	India (559 kWh) USA (13,053 kWh) China (1,069 kWh) Japan (8,092 kWh)	India: (2,994 kWh including captive)
Motorized transport (per-capita annual passenger transportation)	In 1950: industrialized region (4,471 km), World average (1,334 km), USA (11,205 km) In 1997: industrialized region (16,645 km), World average (4,781 km), USA (24,373 km) India in 2001 (2,117 km)	India in 2031 (9,590 km)

Sources: WBCSD (2001), TERI (2006b), Statistics for Iron and Steel Industry (2001), IEA (2003a, b)

the per-capita consumption levels of some of the major energy-intensive products and services demand for India (e.g., cement, steel, paper, electricity, motorized transportation) would also be well below the current per-capita levels in several other countries, especially in the developed world (Table 7.2).

This analysis exemplifies the fact that India's future lifestyles and consumption patterns of materials and services need not be viewed with apprehension. On the other hand, the country is conscious of the need to reduce its carbon footprint. In the pursuit of sustainable development and well-being of its people and cognizant of the expected rise in absolute emissions of greenhouse gases (GHGs), the Indian government has already undertaken or planned several policies and initiatives that encourage sustainable energy growth – both in terms of both improved efficiency of use and the environmental implications. Several policies and measures have, for example, focused on improving energy efficiency, enhancing renewable and clean energy forms, bringing about power sector reforms, promoting clean coal technologies (CCTs), promoting cleaner and less carbon-intensive fuels for transport, and addressing environmental quality.

The Indian government has actively been pursuing a multipronged strategy for the promotion of renewable energy sources. Against a target of 3,075 MW, the country added 4,613 MW capacity based on renewables during the Tenth Plan. During the Eleventh Plan period, the Ministry of New and Renewable Energy (MNRE) aims to have 10% of grid interactive power generation installed capacity and 4% of the electricity mix based on renewables. There are several examples of efficiency improvements and technological leapfrogging in many of the large industry sectors. An analysis of trends in energy intensity not only reflect an improvement in the past but also indicate that the intensity is likely to improve further if the current plans and policies of the government are implemented, revealing the decoupling of energy and economic growth over time in the Indian economy (Fig. 7.5).

There has been steady improvement in specific energy consumption for cement production, with the manufacturing technology steadily changing from the wet process to the dry manufacturing process. By 2005, the dry process accounted for 96% of the total production capacity. As indicated in Fig. 7.6, heat and power consumption per unit of cement production has improved considerably, with several plants leapfrogging from the four-stage technology to the six-stage technology in recent years. The efficiency in the cement sector today compares well with the

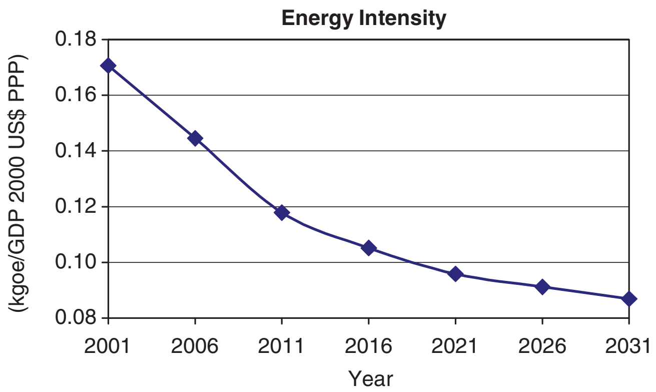

Fig. 7.5 Energy intensity trends. Source: TERI (2006a)

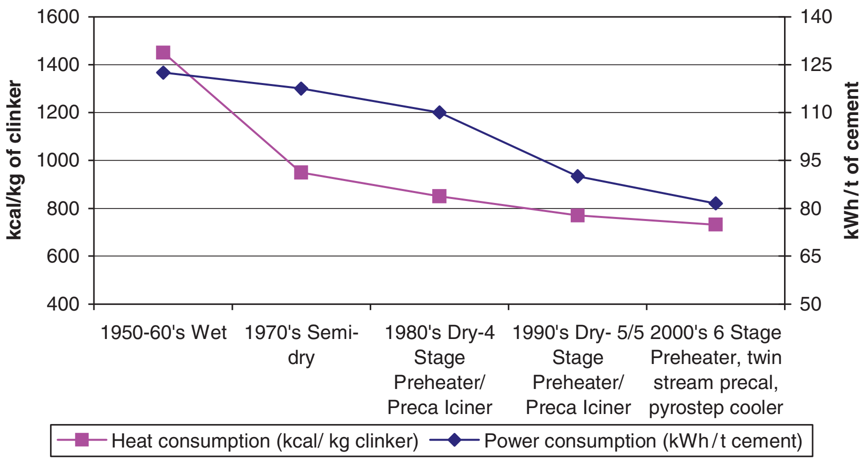

Fig. 7.6 Technological progress in the cement sector in India. Source: TERI (2006a)

world's best standards of heat consumption of 640 kcal/kg of clinker and power consumption of 66 kWh/ton of cement.

The production of blended cements such as Portland Pozzalana Cement (PPC) has been increasing during the last few years, reaching 57% in 2005. Moreover, policies favoring the use of fly ash from power plants for blending with cement are likely to have a further impact in terms of reducing the specific energy consumption for cement production. Similarly, in the steel sector, there has been a remarkable reduction of around 22%[2] in specific energy consumption by integrated steel plants during the period 1990/1991–2004/2005 (Fig. 7.7).The production of ammonia, which is the most energy-intensive process in fertilizer production, has also witnessed a remarkable improvement in average specific energy consumption, from a level of 13.7 Gcal/ton in 1985/1986 to 9.30 Gcal/ton in 2002/2003 (a reduction of 32%[3]). The best ammonia plant in India has a specific energy consumption of 7.3 Gcal/ton compared with 7.0 Gcal/ton in the world's best plant at present. The Fertilizer Association of India has targeted to achieve a specific energy consumption of 6.5 Gcal/ton of ammonia within the next 15 years.

The net efficiency of coal-based power generation improved from a level of 23% during the 1970s to 29% during the 1980s; it is currently around 35% for the new subcritical power plants. The new ultramega power projects (UMPPs) are adopting supercritical power-generating technologies with significantly higher efficiencies.

Such examples of technological progress clearly exemplify the fact that India is progressing in the right direction in terms of inducing energy efficiency and

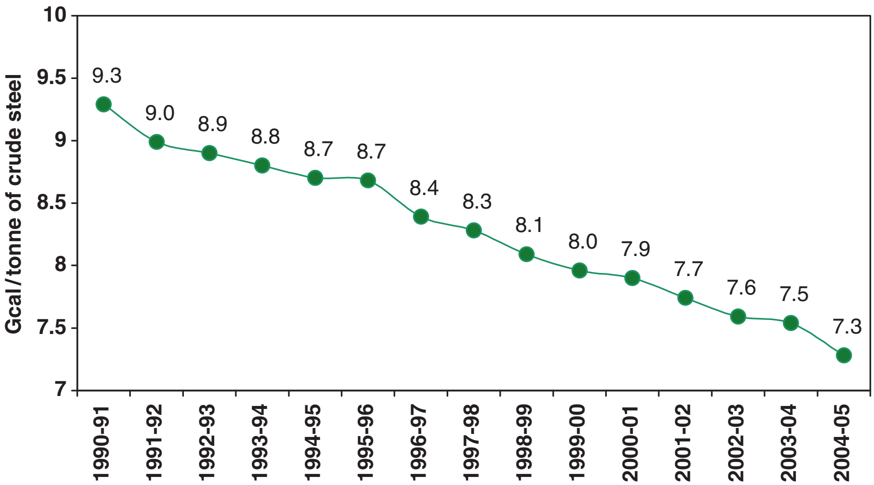

Fig. 7.7 Specific energy consumption in integrated steel plants in India. Sources: Statistics for Iron and Steel Industry (2001), TERI (2006a)

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[2] Steel Authority of India Limited.

[3] Fertilizer Association of India.

incorporating environmental concerns into its plans and policies. However, there is considerable scope for further improving energy and emissions intensity by enhancing efficiency improvements and further diversifying the fuel and technology mix to include low carbon options into the future energy system. Sustainable energy pathways – apart from contributing to enhanced energy security, reduced infrastructural pressures, and monetary outflow as well as benefiting the local environment – would also have co-benefits in terms of CO_2 emission reduction.

7.5 Mitigation Potential and Opportunities for India

Although India at this juncture does not have the luxury of choice among alternative energy forms, it needs to make every effort to harness the maximum possible potential of options available to it during the next couple of decades. On the basis of current knowledge about technology diffusion and resource availability, it is estimated that India has the theoretical potential to reduce substantially its total final resource consumption and to change the fuel mix to include a larger share of relatively cleaner and efficient fuels and technologies. Apart from efficiency improvement potential across the various end-use sectors, the power, transport, and industry sectors have a large potential to further reduce CO_2 emissions.

Figure 7.8 provides the sectoral CO_2 emission levels under a business-as-usual (BAU) scenario, which assumes that current trends and policies will continue, and

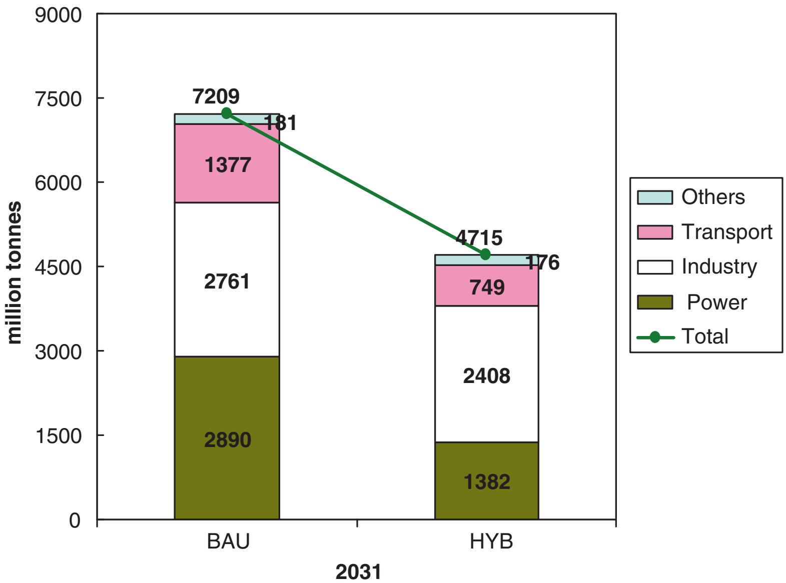

Fig. 7.8 Sectoral CO_2 emission reduction potential in 2031: BAU and hybrid (HYB) scenarios)

a hybrid (HYB) scenario that considers enhanced exploitation of policy and technological measures primarily geared towards social and economic development objectives on the energy demand as well as supply sides. While indicating the scope for emission reduction across various sectors, this also depicts that sustainable development policies and measures addressing social and economic development can play a significant role in addressing climate change concerns.

Although energy efficiency across various sectors can play an important role in reducing the total energy requirements, nuclear, renewables, and adoption of CCTs in power generation can go a long way in proving low carbon growth paths.

7.6 Potential for Energy Efficiency Options

In the residential sector, the use of compact fluorescent lamps for lighting instead of incandescent bulbs and the use of efficient refrigerators, air conditioners, and other efficient appliances hold considerable potential for energy savings. Efficient building design is also estimated to contribute in a big way to achieving a reduction in energy requirements of the residential and commercial sectors.

The scope for conservation improvements in the industry sector is also large. Whereas most of the large industry subsectors have adopted efficient technologies, the smaller units in these sectors and in the small-scale sectors continue to use rather inefficient technologies. Here again, the scope for energy saving through technological change is significant. Adoption of combined heat and power technologies in the cement, pulp and paper, iron and steel, and textiles sectors is estimated to reduce energy intensity by 15–30% (TERI 2006b).

In the power sector, renovation and modernization of coal-based thermal power can improve energy efficiency by 5–7%. Furthermore, auxiliary power consumption can be reduced from 9.5 to 6.5%. Reducing transmission and distribution (T&D) losses to around 12% would also go a long way in improving energy efficiency in the power sector.

Although efficiency improvements (i.e., conservation measures generally) indicate substantial scope for reductions, there are several barriers (financial, socioeconomic, technical) to the adoption of these options.

7.7 Role of Renewables in Reducing Energy Intensity

India still has a large untapped potential of renewable energy sources of energy (e.g., solar, wind, biomass). Although the share of renewable energy generation (based on wind, solar, biomass, and small hydro) is unlikely to be higher than 4–5% of the total generation according to current estimates, its importance should not be underestimated, as these options hold great promise for remote and difficult-to-access areas in terms of providing decentralized power.

In 2006, with a wind-power-installed capacity of 5,340.6 MW, India ranks fourth in the world after Germany, the United States, and Spain. Wind power is one of the most viable renewable technologies for power generation in India, and its potential is currently assessed at 45,000 MW (MNRE 2006). At locations where wind speeds are good enough (i.e., minimum 3 m/s), small wind generators with battery storage (wind battery chargers or aero-generators) can be installed. An aggregate capacity of 464.25 kW of photovoltaic (PV)/wind hybrid systems has already been installed.

The potential of small hydro power is estimated at about 15,000 MW (MNES 2004/2005).

Apart from the use of solar thermal energy in the generation of grid-based power, solar PV systems have emerged as useful power sources for applications such as lighting, water pumping, telecommunications, and power for meeting the requirements of villages, hospitals, and hotels, for example. Furthermore, solar thermal energy has considerable potential in industries where boilers (using coal, lignite, or furnace oil supply) process heat in the form of either steam or hot air up to a maximum temperature of 150°C. These industries include dairy, food processing, textiles, hotels, edible oils, chemicals, marine chemicals, bulk drugs, breweries, and distilleries.

Additionally, India has a vast potential for bagasse-based co-generation given that India is the largest producer of sugar in the world, producing around 17.5 million tons of sugar (Economic Survey 2001/2002).

Biomass gasifiers for power generation offer great potential for decentralized applications in rural areas, where either it is expensive to extend the grid or the power demand is low. Moreover, dual-fuel electric power generators (biomass gasifier coupled with diesel) offer a good opportunity for fuel saving and decentralized power generation in industries that are generating and using their own captive power based on diesel because of poor reliability of the grid.

As per estimates of the MNRE, about 115,000 tons of solid waste per day and 6,000 million m^3 of liquid waste – equivalent to about 1,700 MW of power – are generated every year in urban areas in India. The estimated potential of energy recovery from municipal solid waste is expected to increase along with the growth of economy and may reach 304,000 tons/day (5,200 MW of installed capacity) by 2017. Similarly the estimated potential for recovery from industrial wastes is about 1,000 MW of energy, and the estimated potential is expected to increase to about 2,000 MW by 2017 (MNRE 2005).

The main barrier to the uptake of renewable energy technologies is the high development cost associated with most of these technologies.

7.8 Clean Coal Technologies for Power Generation

Despite efforts to diversify the country's energy mix, India will need to rely significantly on its coal resources, with coal accounting for more than 40% in the commercial energy mix at least for the next two to three decades. Indian coal is of poor quality, with a high ash content (up to 50%) and low calorific value. Although there are some limited prospects for cleaner coal supplies (mainly through methods such as coal washing), the real opportunity for cleaner power generation using Indian coal is in the advanced coal-based generation technologies. Commercially available, advanced generation technologies, such as the supercritical and the ultrasupercritical steam cycles, compared to prevalent subcritical steam cycle systems, can be adopted in the near future. This step has already been taken by the National Thermal Power Corporation (NTPC), and for the five ultramega power plants of 4,000 MW each by the government of India (MoP 2007). This technology has not yet been adopted by state- government-owned utility companies.

Technological leapfrogging to these technologies is a highly promising option. Although the currently adopted subcritical technology has a net efficiency of 32%, and new plants can achieve efficiencies of 35%, leapfrogging to supercritical (38% efficiency) and integrated gasification combined cycle (IGCC) technologies (39–46% efficiency) should be the clear choice (TERI 2006b).

Studies conducted by Bharat Heavy Electricals Limited and NTPC in India and USAID/Nexant Consultants in the United States have proved that IGCC technology based on pressurized fluidized bed gasification is the optimal choice for the high-ash Indian coal, but this technology must still be demonstrated as successful for Indian coal. This calls for indigenous development of this technology while obtaining expertise on some subsystems of the plant from abroad. The second barrier for introduction of IGCC technology is the high capital cost of these plants. A method for subsidizing the incremental costs for such plants should therefore be worked out. If this becomes possible, it could be feasible to set up power plants with IGCC technology demonstrated abroad, using good quality imported coal. This, in itself, would be a significant step toward introducing improved efficiency power generation.

The power sector also holds considerable scope for emission reduction by switching to alternative energy forms (to the extent possible) and simultaneously moving toward more efficient generating technologies using coal. Figure 7.8 provides a comparison of the likely generation technology mix under a BAU scenario (representing the government's current technology plans) and the HYB scenario (representing higher penetration of the advanced power-generating technologies, rapid diffusion of alternative energy forms, and higher penetration of efficient end-use options) for 2031.

Although efficiency improvements on the end-use side indicate the possibility of about a 12% reduction in generation capacity (95 GW), the simultaneous aggressive pursuit of alternative fuels and technologies for power generation could lead to a 54% reduction in CO_2 emissions (compared to the BAU scenario) from electricity generation alone. The introduction of efficient coal and gas technologies would play a key role in achieving these emission reductions, and they can reduce fossil fuel requirements as well as meeting the challenge of rapidly increasing GHG emissions.

7.9 Role of Nuclear Power

Other than coal, nuclear power is India's only other large intermediate-term energy supply source. India's nuclear power program should be scaled up as soon as practicable to displace as much as possible of the coal-fired power generation additions.

India has the capability to build and operate nuclear power plants that observe international standards of safety. The installed capacity was only 3,310 MW in 2006/2007, so the government plans to increase the nuclear capacity to 6,780 MW by 2010 and to 21,180 MW by 2020 (Kakodkar 2004). India has a clear three-stage nuclear program. Stage I is designed to exploit 10,000 MW of nuclear power generation based on pressurized heavy water reactor technology using indigenous uranium. It is proposed that stage II be based on fast breeder reactor (FBR) technology using plutonium derived from extraction of the spent fuel in stage I. Stage III is planned to be based on the thorium cycle. Although India has limited availability of uranium resources (about 70,000 tons), it has one of the world's largest resources of thorium (around 360,000 tons). With the thorium–plutonium fuel cycle (advanced FBRs), a nuclear generation capacity of around 530 GW is envisaged; although current trends suggest that enough plutonium is unlikely to be generated to commission the advanced FBRs during the next 25 years. Nuclear generation capacity could, however, be enhanced to around 70 GW by 2031 by importing enriched uranium if the country pursues nuclear generation aggressively.

7.10 Scope for Energy-Saving Options in the Transport Sector

A TERI analysis indicates that the growth in CO_2 emissions is likely to be most rapid in the transport sector, with emissions likely to increase at more than 9% per annum during the period 2001–2031 under a BAU scenario (TERI 2006b). Although the power and industry sectors have progressed toward efficiency improvement, trends in the increasing use of personalized vehicles and a higher share of road-based freight movement are estimated to contribute adversely to energy efficiency in the transport sector. With limited options for fuel switching, efficiency in the transport sector is likely to remain policy driven in the medium term.

There is significant scope for reducing the consumption of hydrocarbon fuels and thereby reducing CO_2 emissions related to the transport sector through fiscal and policy interventions to increase the use of public transportation, promoting rail-based freight movement and providing a boost to the use of alternative fuels such as biodiesel. Such a reduction would, however, require institutional and regulatory reforms in the transport sector. These reforms should inter alia include a national transport policy to integrate various modes of transport for the movement of freight and passengers and an integrated urban transport policy to promote safe and sustainable transport in India's populous cities. There is also a need to establish institutional mechanisms at the central government level for coordination among the various modes of transport and at the state level among the various departments that deal with transport.

Apart from the large increase in the quantum of fuel required for transportation services, there is concern about the availability of alternative fuel options in this sector. Although clean options such as compressed natural gas, ethanol, and biodiesel exist, the role that these alternatives can play in the next couple of decades may be limited.

7.11 Developing Country Perspectives to Climate Change

Although there are several options that could theoretically be adopted by the country in the context of energy security from the national viewpoint as well as in the context of emission reduction from the global dimension, policymakers in developing countries such as India are faced with the even more basic and urgent need of providing at least minimum levels of infrastructure and development to a large section of its population.

One of the major barriers to options that may be economically viable in the long term is the high up-front investment that is generally required. A quick analysis indicates that providing infrastructure for a few select development objectives such as those related to providing primary education and health facilities would require additional investment requirements of the order of US$25 billion (at 2001 prices), which is of a similar order of magnitude as the fiscal support currently being provided for meeting social and environmental development targets (Fig. 7.9). This indicates that the budgetary choices that policymakers in countries such as India have are by no means easy. They require resources to be generated and other barriers to be eased to facilitate a move to the options that are cleaner or more efficient – but in general more expensive as well.

It has become increasingly clear that even with the currently agreed regimen of emissions control, concentrations of GHG are likely to rise over the next few decades and over the millennia. Consequent changes in the climate will have a huge impact on all life forms on earth, varying across regions and populations within regions, emphasizing the need to build adaptive capacities, thereby reducing the vulnerability to climate variability and change in future. Adaptive capacities are also known to vary widely across countries, with developing countries being more vulnerable given the limited resources to their access and the lack of adequate technical and financial resources to assist them (IPCC 2007). With its large agrarian-based society, India's vulnerability in this context is well explained.

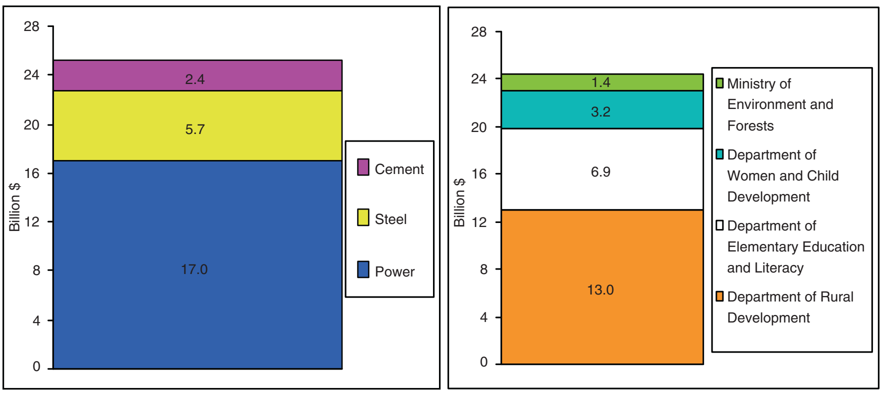

Fig. 7.9 Additional investment requirements (2012–2017) for transition to a low carbon path, vis-à-vis select development outlays of the government of India (GoI, 2008) for the Tenth Plan

Crucial sectors in India such as agriculture, water resources, health, forestry, biodiversity, and coastal regions will be affected. There are huge losses predicted, emphasizing the need to undertake measures that can help reduce the associated risks. Adaptation thus becomes a necessary strategy by all means. The nature of the impact (largely cross-cutting in nature) across different sectors calls for a rather more structured approach wherein the risk reduction strategies can be integrated into a country's national development framework (GoI 2008). A two-pronged approach can be suggested wherein adaptation measures are integrated into the current development process as well as integrated into the plans being developed in the future. Inclusion of climate risks in the design and implementation of development initiatives help promote climate-resilient development.

Although there are no specific initiatives in India that have been taken or can be highlighted on adaptation, there are a number of programs and schemes that are being implemented by the government of India that do have a bearing on adaptation and aim to achieve livelihood security. These schemes are spread across various sectors with a focus on enhancing research and development in relevant fields to promote effective management of resources. The total expenditure on these schemes has increased significantly over the years, and the expenditure as a proportion of the GDP has increased from 1.6% in 1997–1998 to the scale of 2.6% in 2006–2007. However, these schemes do not address the additional risks imposed owing to a changing climate; and they require further strengthening either in the form of introducing new elements or enhancing or scaling up some elements within them, which would in return have an effect on the costs.

There are various initiatives being undertaken to address climate change concerns at the international level. Whereas the developed countries are bound by targets specified under the Kyoto Protocol, developing countries can play a role through nationally appropriate mitigation actions supported and enabled by technology transfer, finance, and capacity building. These measures should largely be in alignment to achieve the sustainable development goals of the country in addition to realizing the full potential of market opportunities and exploring the scope for the use and spread of environmentally sustainable technologies (ESTs) for both mitigation and adaptation purposes.

There is also a need to recognize the common but differentiated responsibilities of parties. Whereas the developed countries – as per their greater historical responsibility and abilities – need to push the frontiers of technology and adopt a less resource-intensive lifestyle, the developing countries need to put in place policies and measures as well as adapt technologies so they are accessible to achieve higher resource efficiencies. The point of convergence for any committed action should be fixed on a per-capita basis. Moreover, resources to address technology and financial needs in developing countries for GHG abatement and adaptation to the effects will be required to address effectively the concerns relating to climate change.

India is greatly concerned about containing future GHG emissions through adoption of sustainable energy-efficient methods. The Prime Minister of India has reiterated India's determination of not allowing India's per-capita GHG emissions to exceed those of developed countries while pursuing policies of development and economic growth. At the national level, the Prime Minister's Council on Climate Change provides overall strategic guidance on mainstreaming climate change in regard to the development of measures to address the changes, identifies key intervention priorities, and monitors the implementation of these interventions.

7.12 Conclusion

There are formidable challenges facing India to ensure enough energy for the nation's development and that it is provided in an environmentally sustainable manner. Although there is no single response to the challenges, adoption of advanced coal generation technologies, enhanced exploitation of renewable energy options, policy reforms that promote the use of efficient technologies, and policy changes in the transport sector are some of the key initiatives that are envisaged to make India's development pathway more sustainable. Investment in research and development for more exploration and better exploitation of indigenous resources are crucial for energy security.

The developed world has a key role to play with regard to technology transfer and financing so efficient options are made available across each of the consuming sectors. This requires environment-conscious diplomacy on all sides. Global environment facility funding and the clean development mechanism (CDM) could play a major role in encouraging the adoption of these options.

Moreover, adaptation is a priority given the extent of dependence on climate-sensitive sources. It emerges as a crucial intermediate response strategy with the potential to reduce the adverse effects of climate change, although it may not be able to prevent all damages in entirety. To avoid the risks so associated, there is a strong need to integrate adaptation concerns into the development framework that takes into account risks associated with a changing climate both in the current context and from a future perspective.

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Chapter 8
Challenges to Substantial and Sustained Reductions in Greenhouse Gases: Opportunities for the United States from the Bottom-Up

Stephen R. Connors

8.1 Introduction

National leaders are calling for substantial reductions in anthropogenic greenhouse gas (GHG) emissions from industrialized nations in order to avoid dramatic climate change. Doing so raises significant challenges in technology, policy and organizational realms, and at international, national, regional and local scales. While the current debate is focused on national and international policies to reduce greenhouse gases, such as cap-and-trade and R&D in low-carbon technologies, reduction targets on the order of 80% will also require significant parallel capacity building at local and regional scales. Cost-effective, rapid deployment of efficient and low carbon technologies requires both localization and the leveraging of economic and environmental co-benefits. This chapter outlines a three part strategy that builds upon an understanding of local energy resource and demand dynamics, essential to cost-effectively achieve climate and other sustainability goals.

8.2 Challenges to Achieving Substantial and Sustained Reductions in Greenhouse Gases

The current policy debate – internationally and in the United States – has focused mainly on the mitigation of greenhouse gas (GHG) emissions, although discussions of adaptation to climate change have begun. In the United States there have been numerous state targets and federal legislative proposals over the past several years calling for GHG reductions of 50–80% from 1990 levels by 2050, with interim targets of reducing emissions to 1990 levels to 10–20% below 1990 by 2020 (Pew 2008). International negotiations, whether the United Nations, European Commission,

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G8 or other groups, are using similar numbers for both GHG reductions, renewable electricity and fuels, and efficiency improvements, with the European Commission's 20% by 2020 being the most notable (EC 2008). Surrounding these targets are the negotiations involving tradable credits, emissions taxes, participation and technology transfer mechanisms with developing and emerging economies, as well as work on low carbon technology development and demonstration, including carbon capture and storage (CCS). While it is recognized that emissions reductions are needed everywhere, current participation in cap-and-trade mechanisms have focused almost exclusively on large emitting industries.

Whether 50 or 80%, these are targets that – if met – will require a transformation of the way we use and supply energy – locally as well as globally. Furthermore, any reductions in the near- to medium-term must be sustained as the world's population continues to grow, and standards of living improve. Climate change is only one of several global environmental threats. Similar transformative challenges regarding water, land use including urbanization and sustainable agriculture (food and fuel), fisheries management, as well as numerous other areas will be needed. Opportunities for economic development, improving balances of trade, health and well-being, and other non-environmental goals must also be "designed in" to these long-term sustainability initiatives.

Often overlooked is the need to clearly quantify the co-benefits associated with GHG reduction strategies, since strategies focused on GHG reductions alone represent "cost added" measures, where adoption will likely be slow. Fortunately, policymakers are already aware of many of the synergies among climate change and other challenges, such as energy security, and the need to expand, replace and upgrade existing energy infrastructures. What we learn, and the mechanisms we put in place to track and reduce fossil fuel consumption should help us adapt to climate change.

Such dramatic reductions also suggest that "emissions reductions happen everywhere." Direct emissions reductions, whether centralized nuclear or CCS, or distributed renewables such as wind, solar, geothermal and biofuels, may face significant "Not in My Backyard" (NIMBY) opposition. Similar adoption challenges, in the area consumer behavior, should be anticipated for alternative modes of transportation, and types of energy efficiency. Identifying local and regional dynamics and thresholds will be essential to achieve rapid, cost-effective deployment of "low carbon" technologies. Examples include age and efficiency of the building stock, and the balance between retrofit and replacement of residential and commercial buildings to reduce energy consumption as well as the age and topology of power grids and the need to invest for an aging and growing power system. Large scale penetration of location-specific renewables such as hydropower and wind require this level of detail. Dynamics also exist for transportation, whether people or packages, linking the age and composition of the vehicle fleets, the age and sophistication of the road network system, the structure of the city, and growth and changes in fleets, fuels, urban form and the economy over decades.

Not yet identified are the thresholds at which "cap-and-trade" becomes just "cap." At what point along the pathway to an 80% reduction do your neighbors, globally, regionally and/or locally have no surplus reductions to sell you? Long-term, we will likely need to source a majority of our reductions "at home," and a detailed understanding of local energy service needs, and local energy resources, will be essential for achieving substantial and sustained reductions – globally.

The localization of energy demand and supply is an essential component of long-term sustainable energy system design. Recent research to quantify the avoided emissions of renewable generation in the United States has helped move this thinking forward, and identified both opportunities and challenges for getting the most out of renewables (Connors et al. 2004a). For example, the displacement of fossil generation in Texas using solar indicates that the daily emissions benefits are roughly equal in summer and winter. While photovoltaic (PV) system output on summer days is much higher, it displaces natural gas generation used to meet mid-day air conditioning needs, while lower PV generation on winter days displaces "dirtier" kilowatt hours such as coal. Understanding these dynamics from the "bottom-up" informs the design of technology and policy options, and identifies measures which target both energy consumption and alternative supplies with the greatest potential impacts. These dynamics themselves are multifaceted, in both space and time. Daily, seasonal and inter-annual trends, which themselves may be influenced by climate change, must be factored into the design of future energy and sustainability pathways. This represents an essential shift from the "technology choice" models of the past, to "technology utilization" models of the future, including their use in the design, planning, implementation and operation of our future energy infrastructures.

It is important to remember that energy is not an end-product, in and of itself, but serves the needs of society. Figure 8.1 illustrates the diverse energy service needs of

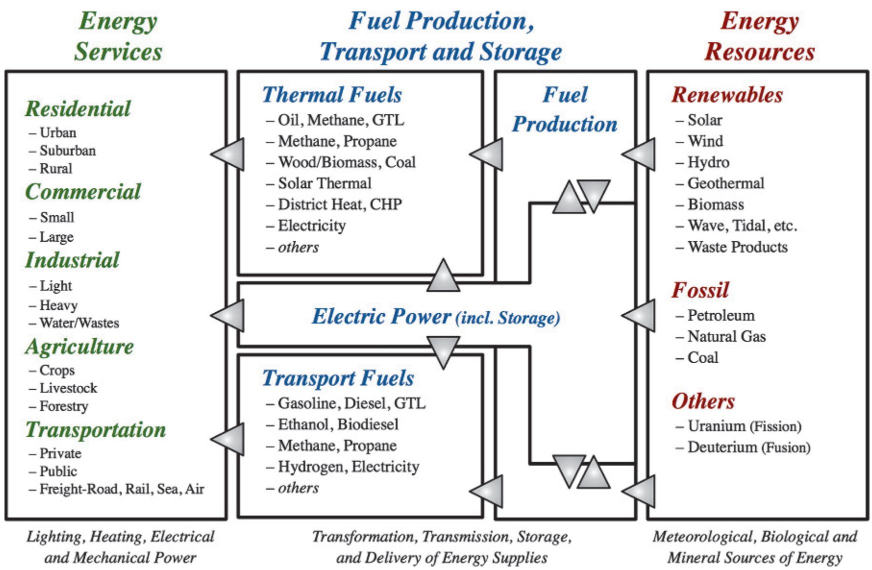

Fig. 8.1 Energy demand and supply – energy services, carriers and resources

the economy in the form of electricity, thermal and transportation fuels, and the various energy resources, renewable and non-renewable, used to produce those energy carriers. Each region's mix of energy service needs is different based upon its economy, demographics, weather and climate, and existing infrastructures, as is its local endowment of renewable and non-renewable resources. A detailed understanding of the current "demand and supply" dynamics of local and regional energy infrastructures and how they are evolving, along with an understanding of future alternatives, provides a solid foundation for designing a sustainable energy future.

8.3 A Three Part Strategy for Designing Pathways to a Sustainable Energy Future

While each locality or region may be unique, a common approach to designing a robust long-term strategy can be identified. Collaborative work among partners of the Alliance for Global Sustainability, including projects in the United States, Europe, Japan, China and Mexico have helped develop these insights. These insights have been distilled into three key components, which can be summarized as follows:

- First, move aggressively to improve the efficiency of local energy services. An aggressive end-use efficiency strategy reduces the demand for energy and extends the usefulness of the energy delivery infrastructure, while simultaneously reducing emissions and fuel imports.
- Second, greatly diversify the energy resources tapped by the local and regional energy sector to meet its domestic energy needs. A large component of this diversification is a shift away from reliance on global fuel markets, to domestic energy resources including multiple renewables and low/no-carbon alternatives such as nuclear and CCS.
- Third, modernize local and regional energy infrastructures by which those energy resources/supplies are transformed and delivered to consumers. This has near-, medium-, and long-term dimensions when we look at growing and aging pipeline and transmission systems, increased imports of oil, gas and coal, and the challenges of meeting large post-Kyoto GHG reduction targets.

Each of these three components is discussed in detail below. However, there are some notable underlying themes of the three part approach. Greater localization implies greater decentralization. Energy demand has always been highly decentralized. Before the "fossil age" began in the early 1800s, so were energy supplies. However, we can only go forward, not back, to decentralized energy supplies, given the huge expansions of populations, populations centers, transport, industry, and agriculture of the last century and a half.

Also notable is the increased role of information technologies in the design and operation of future energy systems. Whether smart houses or cars, or smart grids and transportation systems, the substitution of information for energy is a strong and essential underlying component of future energy systems. Energy demand will become more dynamic with the application of information and communication technologies (ICT). High penetration rates of variable renewables will make supply more dynamic in the case of renewable electricity, and more punctuated with respect to the growing and harvesting schedules of crops for renewable fuels. Modernized energy networks will be required to balance these dynamics at different time and spatial resolutions.

Finally, diversity is inherently "anti-efficiency." Fossil fuels, for all their environmental drawbacks are extracted in a form close to their final fuel properties. Associated gas is removed from methane sources and the natural gas is burned. Crude oil is heated up and cooled down to produce light oils, gasoline, diesel and heavier fuels. Coal is pulverized and burned, with only the poorer grades requiring some removal of non-combustibles before use. Alternatives such as biofuels and hydrogen do not enjoy such close chemistry. While ethanol, biodiesel and hydrogen can be made from a diversity of feedstocks, and be used to supply a multitude of end-uses, they require many more processing steps to convert the hydrogen and carbon atoms into the desired fuel. Whether corn, sugar cane or cellulosic feedstocks for bio-ethanol, or water plus electricity for hydrogen, these net-zero carbon fuels have additional process losses, plus the extra cost of the equipment needed to bridge the gap between chemical feedstock and fuel. Aggressive end-use efficiency is needed to free up the energy overall budget, in both cost savings and reducing total energy demand, in order to afford a greater diversity in renewable energy supplies, and modernizing the energy networks that connect the two.

8.3.1 Aggressive Energy Efficiency

Strategies which radically reduce an economy's energy use and intensity go a long way to meeting a region's combined energy security and environmental goals. If aggressive efficiency strategies can be crafted to reduce imported and/or high carbon content fuels first, then a strategy with an aggressive energy efficiency component can make substantial, early gains in increasing energy security and reducing GHG emissions.

Reduced energy consumption has both technology investment and utilization dynamics. For example, fossil fuel use can be reduced in personal transportation by promoting more fuel efficient vehicles, by "diluting" fossil fuel consumption with ethanol or biodiesel, by reducing distances commonly traveled from home to work, by reducing traffic congestion, and by improving the quality and frequency of public transportation.

Such a strategy is much more than just the replacement of older energy consuming devices with newer, more efficient lamps, heating systems, vehicles, etc. It also requires a detailed understanding of energy use patterns, and how those consumption patterns can be modified, or met with advanced technologies – including information technologies.

Aggressive end-use efficiency at this scale requires a re-definition of "energy efficiency" in policy, and in public perception, as well as from a technological standpoint. Today's efficiency comes in three types:

Energy conversion efficiency. The most common of the three types of efficiency, this refers to the energetic efficiency of a device "when it is on." Common examples include compact fluorescent lights, variable speed motors, better insulation in houses, refrigerators, etc. Efficiency standards, and energy audits for houses and businesses, are essential to promoting energy conversion efficiency improvements. However, they usually require paying the entire replacement cost of the equipment, so unless the performance of the new device is substantially better than the existing device, the forced introduction of energy conversion efficiency measures can be costly. Targeted programs commonly focus on the acquisition of the more efficient technology when the older device is due for replacement, incurring only the incremental cost of the new item as the investment cost impact of the efficiency improvement.

Energy utilization efficiency. This type of energy efficiency refers to the "efficiency of turning things off," and is becoming more common as electronic controls and information technology becomes integrated into automobiles, appliances and buildings. The best example is the advanced vehicle (not necessarily a hybrid) that turns the car's engine off when stopped in traffic, or reduces the number of cylinders in the engine getting fuel when cruising at constant speeds. Programmable thermostats for houses, and sleep modes for computers and other electronic devices are other common examples. While increasingly common within devices, the real hidden opportunity for improving utilization efficiency is through distributed monitoring and control of linked devices. Smart meters which sense when a house in unoccupied and turn off select appliances and adjust temperature and humidity controls is one such application. Another is in road network monitoring and the re-routing of private and public transportation due to congestion, accidents, etc. Energy utilization efficiency builds upon an understanding of the duty-cycle of buildings and equipment, and the driving-cycle of vehicles, individually and in combination, to reduce operational time thereby reducing costs, energy consumption and emissions.

Compared to energy conversion efficiency, energy utilization efficiency has a very large retrofit potential, since the core energy consuming equipment need not be replaced. What is easier and more cost-effective? Purchasing new office equipment used on an occasional basis or putting in a sensor that turns it off for the 90% of the day it is not in direct use?

In addition to the application of ICT for the direct monitoring and control of devices, is "behavioral" energy efficiency. Behavioral efficiency relies upon people to implement more efficient practices. Instead of a smart meter turning down the heat, it instead displays information on cost, energy consumption and/or emissions, to which building occupants respond. Similar are the displays in hybrid vehicles which inform drivers of their real time fuel economy, due to traffic conditions and driving style. Advanced systems my offer suggestions for corrective action. More general public education efforts are also considered a way to promote behavioral energy efficiency, such as the fuel economy benefits of driving less aggressively or taking public transportation. How consistently individuals shift their behavior, and for how long, due to these new sources of information, both real time and occasional, is an area of active research, and will determine the balance between automatic versus informational applications.

Integrated energy efficiency. This type of efficiency refers primarily to cogeneration or "combined heat and power" and is already established practice in energy intensive industries such as chemical and power, especially where there is continuous operation and a need for lower grade heat. Applications outside of industrial applications are increasing, but still very situational. In areas where there are large seasonal needs for heating and cooling, combined heat and power (CHP) applications are possible. As technology performance improves, and costs of implementation drop, CHP applications may grow. These are generally referred to as "thermal following" applications, as electricity is generated as the co-product of a large thermal energy demand. New, smaller systems are coming into the marketplace, where small electric generators operate as needed, either to provide electricity in expensive hours or as a by-product of occasional heating requirements, such as residential hot water. The institutional environment for the expansion of integrated energy efficiency remains a challenge. Most applications have been within a single organization, or small number of partners. More open systems, especially retrofitting city centers for distributed heating and/or cooling, have occurred in some US cities, but are difficult to set up.

While the benefits of energy efficiency are well known, so are the challenges. Recent reports by the World Business Council for Sustainable Development (WBCSD 2009) and McKinsey (2009) have looked at the opportunity of, and barriers to, end-use efficiency especially in buildings. In "Unlocking Energy Efficiency in the U.S. Economy" McKinsey estimates that "NPV-Positive" measures could reduce stationery energy consumption by ≈23% from their 2020 Business as Usual case (McKinsey 2009), although both reports highlight the long-standing challenges of overcoming poor consumer and construction industry perceptions and valuations of energy efficient buildings, poor transparency and fragmentation in the industry, and the need for more proven, off-the-shelf integrated smart building designs and systems.

To achieve the ≈80% reduction in emissions by mid-century, how much of each type of efficiency can a region rely on? This can only be answered by detailed work at the local level, and is highly dependent on the age and efficiency of the building, appliance and vehicle stocks, as well as the structure of both building ownership, and the building construction and repair industry. While energy conversion efficiency and smarter individual devices can be promoted on the national level with appliance efficiency standards, and select targeted "cash for clunkers" programs that promote earlier vehicle and appliance turnover, the local and regional regulatory, institutional and organizational landscape also plays a very important role. Decisions about efficiency remain primarily with the local decision maker, whether building owner or occupant, or vehicle purchaser or driver. Knowing up front the actual cost, emissions, comfort and other benefits of improving efficiency will help both design local efficiency programs, and provide consumers motivation for their adoption and use.

How transferable are these technologies and policies to developing and emerging economies, especially given the rapid, often unplanned, growth of developing country cities? This remains a major challenge across many sectors, including buildings, transportation, industrial activity, water, waste and sewage. Knowledge sharing, so that best practices from elsewhere can be adopted, along with a concurrent investment in local human capacity building, must be a central part of a region's long-term strategy. These efforts must be aimed at both the private and public sectors if rapid adoption is needed. Well designed and targeted policies that create new "market niches" for low-carbon technologies, will ultimately need to be coordinated with changes in local land-use planning and zoning including transportation, as well as the development of the requisite skill sets in the labor force so that prospective employers can deliver advanced, aggressive and efficient energy services.

8.3.2 Diversify Domestically

Diversifying the local and regional energy mix (electric power, thermal and transportation fuels), through the increased and responsible use of domestic energy resources, further reduces a local economy's exposure to tightening global markets for petroleum and natural gas. While some of these energy options can be large centralized facilities (nuclear generation, CCS), most are more geographically distributed, with significant daily, seasonal and inter-annual variability.

Tapping a much greater proportion of renewable resources, whether for power generation, or as a feedstock for alternative fuels (ethanol, biodiesel, hydrogen), requires a detailed understanding of the size, temporal and spatial variability, as well as quality of each renewable resource. Such dynamics may compensate or compound when different portfolios of renewables are examined. For example, a portfolio reliant on hydropower and bioenergy (fuel crops) will be vulnerable to droughts. Are wind-hydro, or solar-hydro portfolios equally vulnerable? These dynamics need to be well understood, and then factored into the design of long-term energy strategies. This is especially important as we look for very high penetrations of renewable energy, both for electricity and fuel.

Here the need to "design for the dynamics" is critical if the future energy system is to meet local energy needs when the system is stressed. Modern society is increasingly dependent on commercial fuels and power, and design for energy and environmental adequacy is necessary, but must also include operational reliability, resilience and robustness of the integrated energy system. This links directly with the next section on energy networks, but the design of the system will increasingly be based upon the combined quantity, quality and variability of its local renewable resources. Planning for how those resources (as well as demand for energy) may shift with climate change means planning for both mitigation and adaptation.

For renewable electricity, understanding the dynamics, especially the variability in those dynamics is essential. In the United States, California's hydropower is heavily linked to the snowpack of the Sierra Nevada mountains. Successive years of drought, and reduced snowfall, have reduced both hydropower and water supplies of California residents. Reduced hydropower means increased fossil generation.

Fuel crop agriculture, and by extension biofuels production, will have similar challenges. This is in no way an argument not to pursue renewables, simply that these dynamics must be designed into the solution as we currently do for food production. For both food and fuel, tracking how these dynamics may shift will become increasingly important as we manage both GHG emissions, and the impacts of climate change.

Operating on shorter time scales are renewables such as solar and wind. Solar is rather well behaved with the predictability of the revolution of the earth and its orbit around the sun, worrying mostly about cloud cover and temperature (which affects PV efficiency). Wind however is another story. A little more wind is a lot more wind energy, and micro-siting of both with farms, and individual turbines within farms can significantly impact annual production. Wind is also very seasonal, with winter being the season of the most production in northern latitudes. Figure 8.2 shows the monthly output over twenty years of an offshore wind site, off the U.S. Northeast coast (Berlinski and Connors 2006). Note both the seasonal and inter-annual variability in electricity production. Just like heating degree days in winter, and cooling degree days in summer must be tracked for understanding the potential energy efficiency, "the weather" must be tracked for energy production purposes as well.

Ongoing work in Portugal, and especially with the mid-Atlantic islands of the Azores, points to the need for even higher resolution energy systems design where coastal zones and topography rapidly influences temperature, humidity, sunshine, precipitation and wind. Here a few kilometers difference can dramatically change the renewable resource potential, as well as the need for energy. Similar design challenges may be needed for cities based upon the building age, type, and tree cover for different neighborhoods within cities. Therefore, depending on the region in question, resolutions down to the hour on the time scale, and micro-climate on the geographical scale will need be factored into the design, and ultimately operation, of the energy system, especially as we move to higher penetrations of renewable electricity. This will be even more important as we begin to use carbon-free generation to supply transportation as well as more traditional electric powered end-uses.

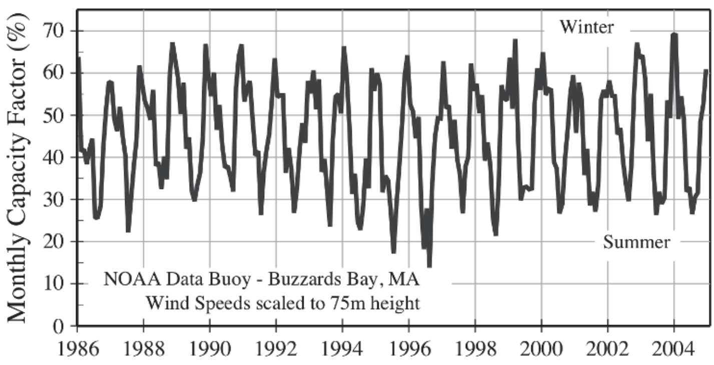

Fig. 8.2 Twenty year monthly offshore wind energy output

8.3.3 Modernize Energy Networks

The third component connects the first two, and focuses on upgrading the energy delivery network, on both an energy delivery and information basis to handle the combined dynamics of efficient and responsive energy demands, and diverse and changeable supplies of energy. The degree to which the energy infrastructure requires modernization – the so-called "smart grid," is directly linked to our understanding of the quantity, quality and location of domestic energy supplies, and opportunities presented by making energy services, including microgeneration, more responsive to "system state" and "market conditions."

The existing energy transformation/delivery network has evolved over time to deliver essentially bulk, uniform energy supplies (electricity, natural gas, petroleum fuels) to relatively non-price-responsive customers. Is this topology sufficient to deliver the more diverse, more domestic, and lower GHG energy supplies that we think we will need? Probably not, especially as we look at more dispersed/decentralized, and intermittent/variable renewable energy resources.

Currently the term "smart grid" is being used to describe a broad range of technology applications receiving a large influx of US government support, ranging from smart meters/smart loads that may be used for load reduction, as well as load balancing, to medium and high-voltage transmission lines and grid integrated energy storage to maximize the use of renewable and other generation, especially remote windpower. The transformation of the energy sector to one more reliant on local energy resources will require an upgrading of energy delivery systems – not just power – to handle the regionalization of renewable energy resources. Trends such as the inter-regional transfer of centralized nuclear generation and remote and/or offshore wind to load centers, and the collection and transportation of diverse, voluminous biomass energy feedstocks to "bio-refineries" must also be part of the design. Intelligent expansion of energy networks should enhance, not degrade, the overall operational reliability and robustness of fuel and power networks.

In electric power these dynamics are generally well understood. The power network must be extended so that diverse and often remote generation (wind, ocean, etc.) can serve local and regional populations. Power and fuel distribution networks must be upgraded if the benefits of microgeneration, whether local combined-heat-and-power, or power distribution network support, are to be realized. These enhancements need not happen everywhere at once. In fact, staged deployments, where past experiences and technology improvements can be incorporated into successive phases of deployment, constitutes a wise strategy.

Of particular note are the potential benefits of grid modernization to get the most out of the existing fleet of fossil and non-fossil generators. Figure 8.3 shows historical hourly electricity demand, and the actual hourly operation of several fossil generators in Southeast New England for 2 weeks in both January and July of 2002. Also shown is the modeled hourly output of a PV system and wind generation at two near-shore offshore wind sites (Connors et al. 2004b). Note that although there are different dynamics for why fossil generators go up and down (regional power system coordination) versus renewables (the weather), the overall up-and-down rates are similar.

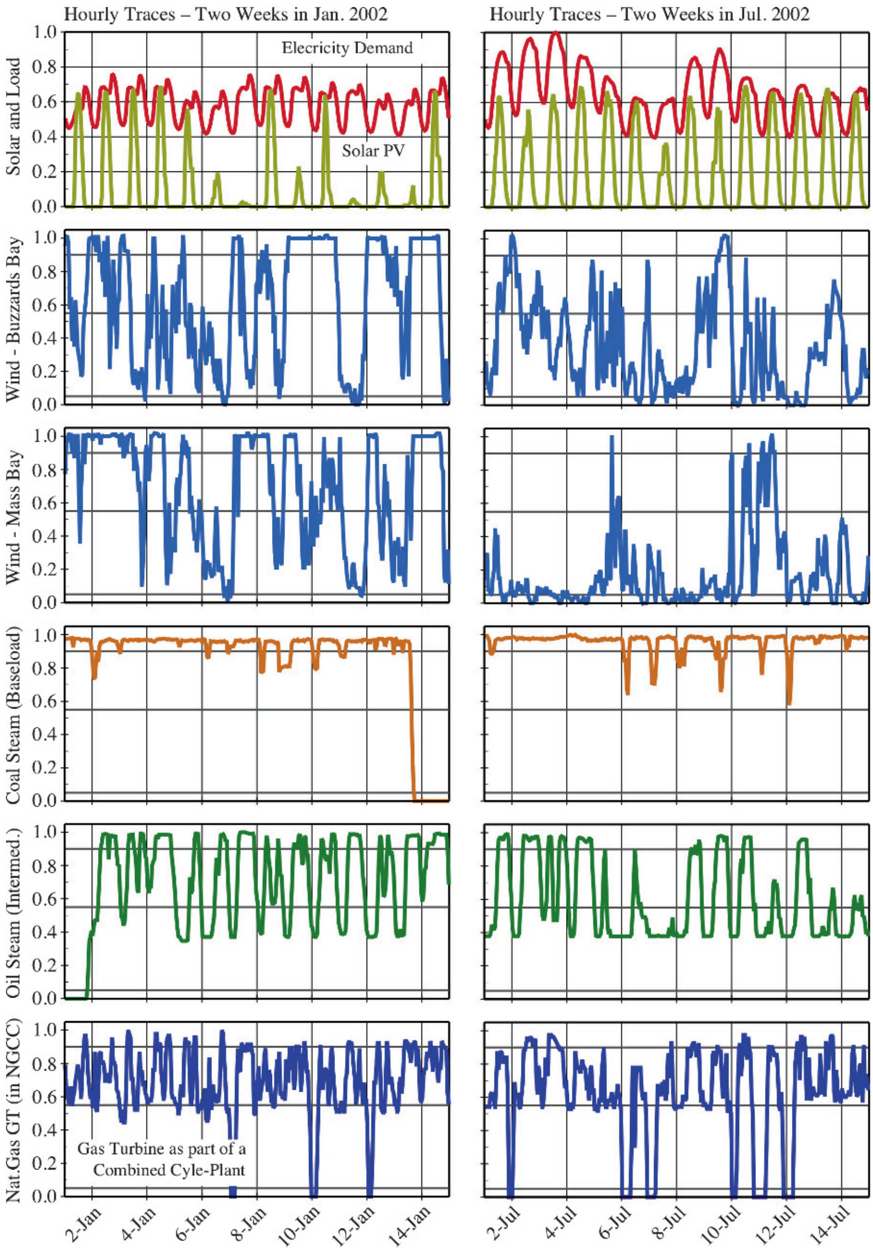

Fig. 8.3 Hourly operational dynamics of fossil and renewable generation (Connors et al. 2004b)

The figures show several other important dynamics. First is that fossil generators have their own unique duty cycles based upon their technology type and fuel, and place within the regional power system's "dispatch order." Baseload generation, like the coal-fired steam power plant, generally does not respond to system state and remain generating at high levels, while the oil and gas-fired units ramp up and down frequently, often operating at very low levels in overnight hours. In the broader analysis it was discovered that in US regional power systems without enough hydropower to respond to changes in demand, fossil units spent roughly a quarter to a third of their operating hours at 50% or below of their rated output (Connors et al. 2004a). This suggests two things. First, is that there is sufficient existing fossil baseload generation to charge a large number of electric vehicles (plug-in hybrids and battery electric vehicles) and as reported by EPRI and the NRDC (EPRI-NRDC 2007) charging automobiles using existing fossil generation may not only reduce oil consumption, but may actually reduce GHG emissions compared to a standard hybrid vehicle. So, co-evolution of the electric power sector, to charge electric vehicles using renewables, nuclear or fossil with CCS is necessary. Second is an operational dynamic. Due to their size and other technological considerations, no or low-carbon generation technologies such as nuclear, coal gasification with carbon capture, and geothermal are true baseload technologies and have difficulty cycling up and down. Investment in electric transportation, electricity storage and/or the ability to shift loads to overnight hours may be necessary in order to invest these types of generation beyond minimum load (baseload) levels of a given power system.

Transmission system modernization, including “smart grid” technologies, will need to address these and other dynamics. However, transformation of the high voltage grid takes years if not decades. Understanding emergent nodes and modes of power system operation is essential for a smooth and cost-effective transition. One example where renewable generation may make the transmission system more vulnerable – and where investment might need to be targeted – is windy nights, where lower, inflexible energy demand coupled with large renewable generation can make the system more difficult to control. Similar dynamics exist on the lower voltage distribution system. In addition to accepting large amounts of local renewable generation, a smart distribution grid also allows dynamic demand response – automatically turning select customers’ equipment on and off to balance supply and demand. These types of smart grid investments should first target local reliability “hot spots,” thereby capturing the multiple benefits of improved reliability and the deferment of larger distribution system investments, as well as improving local energy utilization efficiency.

8.4 Biofuels, Transport and Mobility

In discussions of low-carbon energy systems, much time is spent discussing the electric sector, but as shown in Figure 8.1, fuels – both transport and thermal fuels are also large energy carriers, especially when we consider industrial uses and inter-regional freight whether road, rail, sea or air. For biofuels, much of the dynamics are in the acquisition of the feedstock, whether fuel crop or waste stream. Studies of the net-energy and life-cycle benefits of biofuel production have highlighted how farmland agricultural productivity (crop yields), use of fertilizers and other agricultural inputs, feedstock transport, biofuel production processes, and indirect land use changes all impact the degree that biofuels may – or may not – reduce GHG emissions (Groode and Heywood 2008).

For reducing emissions from transportation, distance and speed is as important as vehicle technology changes. In designing emissions reduction strategies for Mexico City, improving vehicle fleets was important, but those gains were only temporary if improvements in public transportation and road network management did not keep pace, especially to serve growing informal settlements on the city's periphery. Urban form, in Mexico, in the United States, and in growing developing country cities is an important structural issue. Without good planning, cities are becoming larger, but less dense, which means longer commutes along with its increased energy use and emissions, and underutilized infrastructure investments (WBCSD 2004).

8.5 Informational Challenges to the Transformation

The three interrelated strategic energy policy themes – aggressive efficiency, domestic diversification, and network modernization – have some common challenges. Foremost, they all require a detailed understanding of how energy is used, sourced, and supplied, from short-term dynamics and how they interact, to long-term potentials and how quickly they might be tapped and brought "to market." Recent work by the Global e-Sustainability Initiative (GeSI) looking both globally, and in the US and Europe, has characterized the potential benefits of using information and communications technology, highlighting four areas where ICT can provide the greatest climate benefits: smart grids, road transport, smart buildings and travel substitution through virtual meetings (GeSI 2008).

Energy services in the United States and elsewhere vary region-by-region, season-by-season, and hour-by-hour. This includes both stationary and transport-related energy needs. Similarly, energy resources vary by region, season, and time-of-day, especially as we look to utilize more domestic and/or renewable resources. Attempts to find a common solution may cause localities to overlook some of the most targeted, and cost-effective solutions closer to home. This suggests that significant capacity building, both human and information gathering, is needed to design and implement sustainable energy pathways.

Developing the requisite information, knowledge and insights to tap renewable resources responsibly will require upgrading the participation of government agencies. For example, a region's meteorological office's data collection activities could be extended to include direct and diffuse solar insolation measurements to help promote the integration of solar energy. Higher resolution collection of wind speed data, especially at wind turbine "hub-heights" will help both wind farm developers and grid operators understand – and design for – the daily, seasonal and inter-annual variability of wind energy production. Agricultural bureaus will need to collect similarly focused information on the potential – and risks – to farmers, soils, and watersheds of increased fuel crop production. Understanding consumer behavior at home and on the road is also important. Real time traffic data is already captured in most major cities. How can this information be used by numerous actors? Research on carbon capture and storage has called for large scale demonstrations, not to prove the CO_2 scrubbing technology, but to understand what really happens in geologic structures when huge quantities of CO_2 are injected into them (MIT 2007). The need for detailed information goes on. The devil is not in the details. Having the details, and using them to appropriately design future energy systems is fundamental to meeting the climate challenge.

8.6 Investment Challenges to the Transformation

The three components for dramatically reducing GHG emissions outlined above identify the need for strong governmental action encouraging investments in the fuel and power delivery networks, as well as increased innovation in energy markets for the development, deployment, and use of novel energy services, on both the demand and supply side.

Such investments in new technologies and their potential application are a necessary, but not necessarily sufficient, prerequisite to the transformation to a secure, low-carbon energy economy. These advances will need to be backed up by policies which give confidence to both the energy and financial sectors, to move forward with the sizable outlays necessary to transform the energy sector over the coming decades. It is important to remember, there are no "low investment" energy strategies. All energy infrastructure investments are large, it is just that some like end-use efficiency improvements, non-fuel renewable facility development, and energy network investments tend to have greater up-front costs. This is a fact of life. Governmental policies will need to be developed which encourage, rather than discourage, these types of projects.

The word "infrastructure" implies a degree of over-capacity, as developmental lead times are long, and the need to physically deliver energy in difficult but foreseeable situations requires some amount of "surplus" capacity. As the energy sector transitions to more domestic, but geographically dispersed and variable energy resources, ensuring some degree of "minimum excess capacity" in the network is beneficial. For industrialized economies, it has been shown that the costs of interruptions are very large, and easily comparable to the "insurance cost" of investing in adequate energy supplies (USDOE 2006). This is another component of a "vision for a secure and environmentally responsible energy future" for which policies can then be designed and implemented.

Governmental policies which reward "infrastructure companies" to upgrade their systems to handle a more diverse and dynamic set of supplies and loads are a likely component of this "vision." Similarly, local, regional and national policies which recognize the broader benefits of a diverse energy mix must be developed and put into place. Market and other incentives which encourage the deployment of new, domestically sourced, low-carbon energy supplies need to be included.

This includes streamlined, but locally responsive, siting of new facilities, be it large nuclear power, distributed wind and biomass renewables, or fuel processing, storage or distribution facilities.

8.7 Conclusion: All Energy is Local

In the nearly two decades since the UN Framework Convention on Climate Change (UNFCCC) was signed in Rio de Janeiro in 1992, both climate science and technological opportunities for reducing GHG emissions have progressed significantly. This is especially true for energy applications that use information technology – distributed monitoring and control, to understand the dynamics of energy supply and demand, manage it to reduce emissions and costs, and to improve overall performance.

While UNFCCC negotiations have focused on reduction targets and policy mechanisms to reduce emissions at national and international levels, states, cities, industries and firms have been looking at what can be done closer to home. Recent work on "bottom-up" regional energy strategies has identified a three part approach to identify and implement local energy pathways for substantial and sustained reductions in fossil energy consumption and its associated GHG emissions. This strategy of aggressive end-use efficiency, diversification of energy supplies using local energy resources, and a modernization of electricity and fuel supply infrastructures will help local regions meet both global and local sustainability goals.

While a majority of the policy debate has focused on targets and trading, significant local capacity building, which collects the requisite information to design, implement and operate a low-carbon energy system is an area that desperately needs attention. A lot of this information is already collected in more aggregate form, including near real-time weather and traffic data, as well as annual vehicle fleet, use and emissions information.

As we begin to feel the impacts of climate change, superimposed on increasingly volatile global energy markets and other impacts of globalization, the information and systems we are developing to dramatically reduce GHGs will help us adapt not only to climate change, but an economically smaller and more interconnected planet as well. With mid-century GHG reduction targets of $\approx$80%, energy solutions will become increasingly local. But then, the real impacts of climate change have always been local. The development of technologies, information, and human and institutional capital will truly help us to "think globally, but act locally" by designing solutions from the bottom-up.

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Chapter 9
Scope and Roles of Adaptation to Climate Change

Nobuo Mimura

9.1 Introduction

Effects of climate change have become more and more apparent in various forms in the world. An important issue is how to address climate change and its adverse impacts both today and in the future. In the international arenas, many political initiatives have been established, including the G8 Summit, that are much more serious and intensive than before.

The impetus to accelerate such movement was the publication of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (i.e., IPCC AR4) (IPCC 2007). The report warned that warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. It is also said that the global mean temperature would increase 1.8°–4.0°C by 2100, and that the magnitude of the temperature increase varies with the development paths that control the emission of green house gases (GHGs). If such warming takes place, a wide range of impacts on water resources, natural disasters, terrestrial and marine ecosystems, agriculture, and human health, among other areas will be intensified.

To address global warming, there are two basic countermeasures: mitigation and adaptation. *Mitigation* means measures to reduce the emission and strengthen the absorption of GHGs, and *adaptation* is measures to increase preparedness for the adverse effects of climate change. So far, many efforts have been made for mitigation, mainly in the developed industrialized countries. In the face of the emerging impacts of climate change in many countries, people now recognize the necessity and importance of adaptation. Therefore, this chapter focuses on adaptation as a response strategy to climate change.

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9.2 Two Countermeasures Against Climate Change

As mentioned above, there are two countermeasures to climate change: mitigation and adaptation. We can understand the basic role of the two countermeasures from Fig. 9.1, which shows the global surface warming projection presented in the IPCC WGI (2007).

One of the features of Fig. 9.1 is that the global mean temperature increases at a rate of 0.2°C per decade up to around 2030 regardless of the emission scenarios. This means that the GHGs such as CO_2 already existing in the atmosphere will remain for decades, causing such a temperature rise during the next 20–30 years. In other words, the earth's atmosphere already has the inertia for global warming. However, this does not mean that we do not need mitigation initiation efforts now; on the contrary, today's effort to reduce the emission of GHGs determines the fate of long-term global warming because the average retention time of CO_2 in the atmosphere is about 70 years. Starting the mitigation 30 years later may cause delayed stabilization of the GHG concentration and further acceleration of global warming.

From the above observation, we can draw some conclusions about the countermeasures. First, adaptation is particularly important for the next 30 years because the effects of mitigation efforts will not be realized for a few decades. Second, mitigation is of fundamental importance to stabilize global warming in the long run. Therefore, the countermeasures against global warming should be a portfolio of mitigation and adaptation.

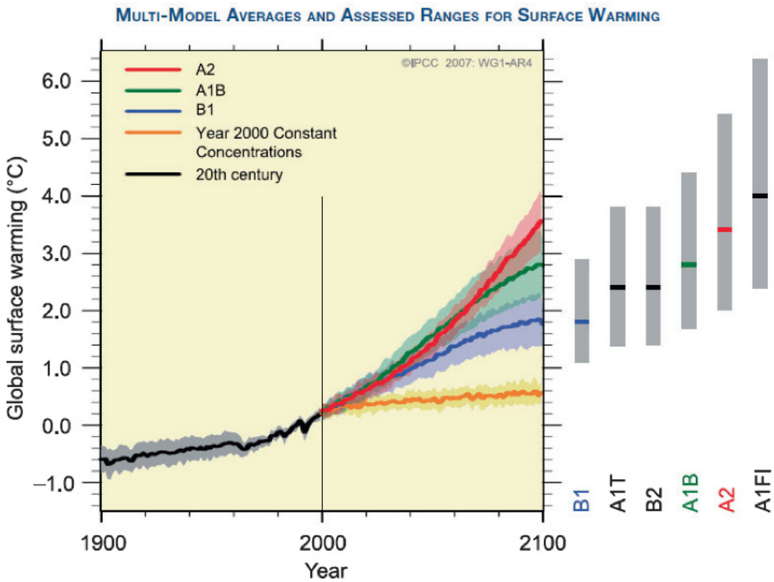

Fig. 9.1 Projection of the future increase in global mean temperature (IPCC WGI 2007). Legends such as B1 and A1 indicate socioeconomic scenarios given by IPCC SRES (IPCC 2000) (see Color Plates, Fig. 9.1)

Regarding the countermeasures, mitigation has been the focus so far. However, in the twenty first century, violent impacts of climate change and extreme events have been occurring, such as the heat wave in Europe in 2003, Hurricane Katrina in 2005, recent droughts in Australia, and floods and heat waves in many other countries. If the global mean temperature increases 0.6°C per 30 years, people in the world may face more severe threats. In particular, the effects would be more serious in developing countries, which lack infrastructures to prepare against natural disasters and provide lifelines to support people's everyday life. These countries include small islands, such as Tuvalu, Kiribati, and Maldives, and countries situated on low-lying deltas such as Bangladesh. As the amount of GHG emission is very little, the major countermeasures for these countries should be adaptation.

9.3 Vulnerability to Global Warming: Susceptibility, Resistance, and Vulnerability

The impacts of global warming can be divided into two areas: direct physical impacts (primary effects) and indirect effects (secondary and higher-order effects). Direct impacts cause changes in the physical environment, such as droughts due to less rainfall and coastal inundation caused by sea-level rise. Indirect impacts propagate into the socioeconomic system and the natural environment as a result of the direct impacts. For example, migration of inhabitants occurs as a result of flooding; restructuring of industries and conversion from agriculture may occur due to yield decreases; and infrastructures become dysfunctional under the changed climate. Developing countries will be highly susceptible to these indirect effects.

On the other hand, industrialized countries will take necessary measures to avoid or reduce adverse impacts if they face such problems. They may raise coastal dikes to protect lands against sea-level rise and improve water resource management to prepare for droughts. In many cases, private companies will also implement measures to avoid risks. Such measures, either public or private, entail financial costs, which means that society as a whole bears the cost of avoiding risks associated with climate change. Even if there is substantive damage, victims are covered by insurance. In this way, developed countries – with a well-developed social system – have the capacity to redirect, or share, the damage costs .

However, developed countries cannot always avoid, redirect, or distribute all physical impacts. As estimates of climate change have a degree of uncertainty, external forces, such as torrential rainfall and severe droughts, may become too devastating and thus exceed the design criteria of infrastructural facilities. Other socioeconomic systems may also suffer from large-scale impacts if disaster-prevention facilities are damaged. For example, the flood disaster in the Tokai area, Japan, in 2000 (JSCE 2000), the torrential rainfall in Tokyo in 2005, and Hurricane Katrina in 2005 showed that flooding of city centers could cause tremendous disruption of many societal activities. A large number of underground facilities, such as underground malls, subway stations, and information networks, could suffer from major disruption in the event of flooding.

Such considerations suggest that the onset of damage due to climate change is determined by several factors. They can be classified as follows: (1) *climatic stimuli*: the degree and extent of external forces; (2) *susceptibility*: the weakness of an exposed system to particular influences; and (3) *resilience*: the ability of the system to resist damage (also called *adaptability*). *Vulnerability* can be defined as a combination of these factors. We can consider vulnerability in various spatial scales (e.g., global, national, regional), and in sectors as well. Although vulnerability has been defined in several ways, the following definition is commonly acceptable: "the susceptibility of a system to adverse effects from external forces, and the ability of the system to change and adapt to or utilize those effects" (IPCC WGII 2001).

This definition implies that vulnerability is not merely passive damage to an exposed system but a balance among the factors causing the damage and the system's ability to handle them. We can express this relation as follows (Mimura 2006).

$$\text{Vulnerability} = \frac{\text{External force}}{\text{Resilience} - \text{Susceptibility}}$$

This relation shows that the vulnerability of a system increases with external force and susceptibility and decreases with resilience. Therefore, if the degree of the external force (climate change, extreme events, sea-level rise) is constant, we need to increase resilience to decrease vulnerability. It is the basic role of adaptability to increase the system's resilience.

9.4 Role and Factors of Adaptation

Adaptation can be defined as the process of developing, formulating, and implementing a strategy and policy to alter the effects of climate change and adapt to it. The basic concepts of adaptation can be summarized as follows (Hay and Mimura 2006).

1. Avoidance and reduction of the risks of harmful impacts

This means taking preventive measures against the anticipated effects, such as regulation of development in vulnerable areas and improvement of disaster-prevention systems.

2. Mitigation of damages

This involves measures to diminish damages that have already occurred. Examples are measures to relieve adverse consequences of a disaster and support recovery from the damages.

3. Dispersion of risk

The concept behind this measure is to lessen the costs of the damage by dispersing them among many people or over a longer period of time rather than concentrating damage within a short period of time. Insurance is a typical example.

4. Acceptance of risk and doing nothing

This means doing nothing at a particular time and accepting the risk of harmful effects.

For the classification of adaptive measures, there are several factors involved, such as the exposed societal sectors, intentionality, and timing of implementation (Mimura and Yokoki 1998; Kubota 2006). Adaptation involves a range of sectors, including agriculture and food production, water resources, disaster prevention, health, energy, industry, and the natural environment.

Let us take the coastal zone as an example of an exposed sector, as it is among the most susceptible to climate change and sea-level rise. In fact, adaptive measures for coastal zones have been intensively studied since the beginning of climate change studies. Even in its first report, the IPCC proposed three categories: planned retreat, accommodation, protection for coastal zones (IPCC WGII 1990). These categories comprise the countermeasures listed in Table 9.1. In the earlier stages of discussions, planned retreat was promoted mainly by Western developed countries. However, the importance of protective measures has remerged since the Indian Ocean tsunami in 2004 and Hurricane Katrina in 2005.

Regarding intentionality, there is a difference between autonomous and planned adaptation. Autonomous adaptation is a reactive response with no proactive intervention, whatever the actor happens to be, natural ecosystem or human society. Planned adaptation, on the other hand, is intentional actions aimed at predicting effects of climate change and mitigating their adverse consequences. At the same time, adaptation can be divided into reactive and proactive types according to the timing of implementation of the measures.

Table 9.1 Options for adaptation of coastal areas (after Harasawa et al. 2003)

Classification of adaptive options	Options
Retreat	Development regulations for disaster-prone coastal areas Land use and regional planning Evacuation from highly vulnerable coastal areas Subsidies for relocation
Accommodation	Proactive planning to avoid harmful impacts Changes of land use patterns Protection of coastal ecosystems such as mangroves Strict regulations in disaster-prone areas Disaster insurance
Protection	Protection through hard structural measures • Disaster-prevention: dikes, seawalls, floodgates • Antierosion measures: jetties, detached breakwaters • Water resource management: weirs, walls against saltwater intrusion • Protection through soft technologies • Antierosion measures: beach nourishment, protection of sand beaches • Conservation of coastal ecosystems: protection of marshes, afforestation • Early-warning systems • Evacuation systems

Source: After Harasawa et al. (2003)

Table 9.2 Classification of adaptation: reactive and proactive

System		Reactive measures	Proactive measures
Natural environment		Change of growth period Change in species in ecosystem Migration of plants Migration of habitats	
Human society	Individual	Change in cultivation methods Installation of air-conditioners	Insurance Elevating house foundations Migration to safer areas
	Local and national government	Improvement of water management system Improvement of dikes Antierosion measures Beach nourishment Subsidies Compensation for damage	Information dissemination Early-warning systems Change in building codes and design criteria for facilities Land use and regional planning

Sources: After Klein and Tol (1997) and Harasawa et al. (2003)

Table 9.3 Controlling factors of adaptability

Factors	Contents
Financial resources	Amounts of available capital and other economic resources
Human resources	Human capacities, such as skill, experience, and educational level
Knowledge and awareness	Fundamental knowledge for understanding environmental changes and their effects and implications
Information management	Personal and collective ability to understand and process information on impacts and adaptation
Technology	Ability to utilize the appropriate technologies and have access to the necessary information on them
Social institutions	Status of social systems for ensuring access to information and supporting decision making
Community	Human networks to respond to impacts collectively in the social community
Risk management	Framework and capacity for sharing and distributing risks among people

Sources: Klein and Tol (1997), Yohe and Tol (2002)

Table 9.2 shows adaptive measures classified based on the criteria mentioned above. The affected systems are divided into natural and human social systems. All adaptation by natural systems is reactive in its nature. However, this does not mean that it is impossible to decrease the impacts on natural systems. For example, landward migration of mangrove forests may be a natural adaptation to sea-level rise, but it can maintain its area if an evacuation corridor is created landward behind it to support its autonomous adaptation.

As mentioned above, adaptation to climate change occurs at various levels, ranging from the national to community, family, and individual. The adaptive capacity required by each is determined by many interrelated factors. Major factors indicated in Table 9.3 are financial resources, human resources, scientific knowledge, information accessibility, technology, institutional systems, and infrastructure (Smit and Pilifosova 2001; Yohe and Tol 2002; The World Bank 2006). These factors can be roughly classified into resource availability, scientific knowledge and its acceptability, and levels of institutional arrangement. Because the adaptability of each country is determined by its comprehensive abilities, it is not easy to promote them. Even if an infrastructure system, such as disaster-prevention facilities, is constructed with foreign aid, such facilities cannot continue to function without capital, awareness of residents, and institutions to support it. In this sense, building adaptability means building long-term social capacity.

Furthermore, it should be noted that the impacts of climate change and adaptation differ greatly among countries. Because water availability, frequency of natural disasters, and agricultural patterns vary markedly with the geographical and social conditions of a region, adaptive measures cannot be formulated without taking these conditions into consideration. In the development of adaptation, it is essential to strengthen the resilience of the country by enhancing the traditional knowledge, technology, and social institutions (Barnett 2001).

9.5 Mainstreaming Adaptation and Adaptive Capacity

It is obvious that adaptation has the ability to reduce the adverse impacts of climate change and to utilize its favorable effects. There have been intensive discussions on the concept and implementation of adaptation, mainly focusing on developing countries (e.g., Huq et al. 2003; Hay and Mimura 2005; Parry et al. 2005; Hay and Mimura 2006; IPCC WGII 2007). Countermeasures against current meteorological extreme events, such as droughts and floods, are also effective as adaptive measures to address future climate changes. Because the projections of future climate changes entail uncertainties, major adaptive options are "no-regret measures," which are effective at improving today's preparedness for hazards. Furthermore, the costs of adaptation are usually less than those of damages imposed by the impacts, and therefore adaptation is more cost-effective than reactive responses.

Mainstreaming adaptation is another emphasized point. This means incorporating the adaptation considerations in major policies – such as disaster-prevention plans, water-resource management, agricultural and food security policies, and environmental management – rather than highlighting the adaptation in isolation. Only this can ensure effective adaptation to climate change. The importance of the mainstreaming can be supported from another aspect. Adaptation to climate change and sustainable development share the same direction of socioeconomic development. Strengthening adaptive capacity includes many activities – reducing human pressure on resources, management of environmental risk, social resilience to hazards – that are essentially the same targets of sustainable development. Eventually, adaptation is seen as an important component of sustainable development.

Regarding the lead time of responses, it has been argued that adaptation can have an immediate effect, whereas a considerable lead time is required for mitigation (i.e., reduction of GHG emissions). However, this is not necessarily true. For example, Japan accelerated improvement of its coastal protection facilities after the devastation created by the Ise Bay typhoon in 1959 and the Chilean earthquake tsunami in 1960, but it took 30–40 years to increase safety throughout the country. It will be difficult for developing countries to increase their safety against natural disasters to a satisfactory level quickly. It should be noted that some adaptive measures require considerable lead time for implementation.

The success of adaptation depends on the adaptive capacity of each country, region, or exposed sector. This is because the adaptive capacity to climate change relies on various factors, such as financial and human resources, scientific knowledge, access to information, technology, social institutions, and infrastructure. As mentioned above, a community's ability is important to its adaptation on the ground.

Finally, we consider differences in vulnerability and adaptability between developed and developing countries. Vulnerability of developed countries is relatively low because they have developed multiple safety nets consisting of social institutions and infrastructure. In addition, developed countries can use their financial and technological capacities to reduce damaging effects when they face climate change. Although they sometimes suffer severe damage from extreme events, the major impacts will appear as a form of additional social costs rather than crude damages.

On the contrary, developing countries in the Asia-Pacific region are highly susceptible to the impacts of climate change because many are located on low-lying deltas, small islands, and areas prone to tropical cyclones. For these countries, the impacts of climate change could appear in more devastating direct damage. In addition, the Asia-Pacific region is expected to undergo high economic growth and a rapid increase in population. Mega-cities are growing in the coastal zones. These factors may increase the vulnerability of the region. On the other hand, the economic growth may enhance its adaptive capacity by increasing technological capabilities, economic strength, and social safety nets. However, it is uncertain how much fruits of the economic growth can reduce vulnerability.

9.6 Conclusions

Although adaptation is one of two major responses to climate change, no concrete policy movement has emerged on how to strengthen the adaptive capacity of developing countries or how to incorporate adaptation into major policies. To overcome this problem, several tasks can be proposed for future studies.

Because adaptation is a set of policies that will be formulated and implemented, it needs technologies and policy options as its elementary tools. Guidelines and a menu of technologies should be prepared for adaptation in each field and sector. Because adaptation is highly dependent on the geographical, environmental, social, and cultural conditions of each country, these conditions should be carefully considered when developing guidelines and the menu of technologies. To develop relevant adaptation, it is important to understand the resilience of each region and to assess its traditional and indigenous knowledge and technologies. At present, many research institutions around the world have launched studies on adaptation along this direction.

The success of adaptation depends on the adaptive capacity of each country and local community. Studies are necessary to identify the roles of factors that can strengthen the adaptability, particularly for community-based adaptation. This aspect has increasingly attracted international attention. In communities, traditional mutual cooperation and consanguineous networks are important. In addition, it will be a major challenge to incorporate the traditional knowledge and technologies of the communities in modern science and technology. So far, the policies of central and local governments have rarely considered the local situation properly.

Global warming is not the only issue facing our society. Human society also faces other problems, such as environmental pollution, loss of biodiversity, and changes in land use due to economic development, population growth, and economic globalization. It is important to address these pressures in parallel with global warming. The real world is under multiple stresses, and sustainable development can be achieved by solving these problems in a holistic manner. This approach may pave the way to sustainable development.

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Chapter 10
Adaptation of Fishing Communities in the Philippines to Climate Change

Maria Rebecca Campos

10.1 Introduction

The Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC 2007) declared that few studies have been conducted on the possible impact of climate change in Southeast Asia despite the fact that commercial and subsistence marine and freshwater fisheries and aquaculture are important for the food security and the economies of many countries in the region. In the Philippines alone, fisheries account for 4% of the gross national product (GNP). The fisheries sector employs approximately a million people, about 26% of whom are engaged in aquaculture operations, 6% in commercial fishing, and 68% in marine and freshwater municipal fishing (i.e., artisanal, small-scale, or traditional fisheries). The Intergovernmental Panel on Climate Change (IPCC) concluded that: (1) in the low latitudes of the tropics, many wet areas will get wetter and many dry areas will get drier, aggravating drought and flood tendencies; (2) weather events will become more extreme, creating more variability in water supplies that drive agricultural and hydrological systems; (3) rising water temperatures may reduce the upwelling of food supplies that fish in the upper layers depend on, and increased carbon dioxide in the atmosphere will increase the acidity of water bodies, adversely affecting shellfish and coral reefs; and (4) coastal areas and islands will be particularly hard-hit by the combination of rising sea levels and more intensive oceanic storms such as typhoons and hurricanes (IPCC 2007).

Although fisheries will be severely affected by many of these changes, they can contribute solutions as well. The flooded areas that can no longer be used for crop production can be used to cultivate fish using adaptive technologies and management systems. Moreover, reservoirs and ponds used to store water to moderate the

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swings between flood and drought can be simultaneously used for fish farming (WorldFish Center 2009). In addition, governance bodies and institutions need to increase their capacity to help people adapt to climate change.

In the Philippines, one of the major government institutions that can be tapped is the Quedan and Rural Credit and Guarantee Corporation (Quedancor) of the Department of Agriculture (DA). Quedancor has the critical responsibility of providing and improving credit assistance to fishers. It also has the task of helping its beneficiaries meet the repayment obligations of their loans. One reason for defaults is the devastating impact of natural calamities. Schemes in place are still insufficient to help safeguard lending programs and operations from nonrepayment of loans due to production losses and damage to personal properties.

Natural calamities include the uncertainties and vagaries of weather and climate that bring about typhoons, floods, and droughts; earthquakes; and volcanic eruptions – as well as pests and diseases – that affect the productivity of fisheries. When natural calamities occur, small fishers are unable to pay back their loans from Quedancor; moreover, they have difficulty renewing their loan applications from Quedancor or accessing credit from other sources. Failure to access credit could prevent them from continuing with fishing activities and could eventually jeopardize the welfare of their entire households. The inability of borrowers to pay back their loans and meet their obligations also impair, to a large extent, the financial operation and viability of the lending institutions. The risk management schemes currently employed include price stabilization measures, targeted relief to victims of typhoons and droughts, and crop insurance programs, to name a few. Some of these schemes are becoming very expensive to implement. Moreover, they fail to enable fishers to regain sufficient resources so they may continue production.

10.1.1 Objectives

The purpose of this study was to analyze the impact of natural risks and risk management practices of Quedancor on fisher borrowers and to propose appropriate measures to mitigate these adverse impacts on income and welfare.

10.2 Methodology

The study was undertaken in two stages. The first stage was the quantification of risks or expected losses to help determine the appropriate interventions to strengthen Quedancor programs. It involved an analysis of the biophysical and economic aspects of the agricultural production systems (e.g., fisheries and aquaculture), particularly those relevant to Quedancor, to estimate agricultural commodity losses and to determine the impacts of natural calamities at the national or regional level and, best, at the provincial level. Secondary data and statistics on historical production (yield and costs of production) and on historical occurrence of natural calamities were collected and used. The second stage was identification of the effective mitigating measures and coping strategies to manage risks. The analysis was more on a microlevel using survey data to evaluate the vulnerability of the different agricultural production systems; assess risk characteristics and their impact on farmer-borrowers and their households as well as their impact on credit repayment and needs; identify specific coping mechanisms and guidelines for managing agricultural risks by commodity (e.g., fish/aquaculture); and develop common guidelines for determining the best and suitable crop or agricultural commodity mixes that can be adopted in areas covered by the Quedancor programs.

The results of the analyses were used as inputs when rationalizing the decision options of Quedancor, especially in relation to its lending operations. The resulting characterization provided the information needed to determine the features and coverage of the bridging fund scheme. With the availability of a new credit window, Quedancor clients and stakeholders could have better chances of continuing and sustaining agricultural production in the event such livelihood activities are affected by typhoons and other calamities. The identified mitigation measures and coping strategies will help fishers minimize the risks in production brought about by the occurrence of natural calamities. At the same time, these measures would help secure Quedancor's lending operations.

The study involved field surveys and field data verification and validation. It also included consultation with local Quedancor program field implementors and Quedancor member-borrowers who have experienced natural calamities and other stakeholders including other fishers, local government units (LGUs), and nongovernmental organizations (NGOs), among others.

10.2.1 Quantification and Evaluation of Risk

- *Risk* is defined as the average or expected value of economic losses of the commodity due to the occurrence of the natural calamity. It comes in various types and from various sources. It is usually expressed or measured in weight or value of product (e.g., kilograms or tons; pesos per hectare). Analysis of risks involves an evaluation of the hazards associated with the calamity as well as the vulnerability of the agricultural crop or commodity to the hazard. Risk is location-specific and time-dependent and may vary from one commodity to another. This is primarily due to the fact that the probability of occurrence and the relative strength of natural calamities usually vary from location to location and usually occur only during certain periods of the year. For example, the occurrence of typhoons during the rainy season is more frequent in areas along the typhoon belt than in areas near the equator.
- Only risk associated with the occurrence of natural calamities was considered in this study. Risk due to the occurrence of natural calamities was determined as the product of four factors: (1) probability of the occurrence of the natural calamity; (2) probability of the hazard associated with the occurrence of the calamity; (3) degree of vulnerability of the commodity or agricultural enterprise; (4) the level of exposure of the commodity in the area.

10.2.2 Sources of Risk

Risk can be differentiated in terms of its source, some of which are natural phenomena, causes, and events (e.g., weather and climate variability, natural calamities such as typhoons, floods, and droughts; pests and diseases) and socioeconomic-political factors (e.g., price fluctuations, changes in demand, trade). Fisheries and aquaculture production are intrinsically risky activities, and natural calamities are the major sources of risk. Depending on the strength and duration of these calamities, they can lead to total loss of production, which in turn can have a devastating effect on the welfare of small fishers. For some calamities, the speed of occurrence is so fast that fishers are left unprepared to face the aftermath. Risks from other sources can also lead to losses in agricultural production, but their speed of occurrences is not usually as fast. In such cases, fishers could possibly devise some measures to reduce any expected negative impact.

10.2.3 Data Limitations for Assessing Risks

The extent of the output of this study vis-à-vis its objectives has been primarily influenced by the availability of the secondary data in the areas covered and the completeness and accuracy of the primary data collected. Agricultural commodities covered are those that currently have a significant share in Quedancor's loan portfolio.

10.3 Results and Discussion

The commodities covered by this study are classified under aquaculture, which is the leading fish-producing sector in the Philippines, contributing 44% (1,717,026.7 mt) to the total fish production of 3,926,173.3 mt in 2004. Aquaculture registered the highest growth (18%) followed by municipal fisheries (2.4%), and commercial fisheries (1.6%). In terms of employment in 2003, aquaculture and fisheries provided employment to around one million, or 5%, of the total labor force of the country; in aquaculture, 26% (258,480) aqua farmers were engaged in various culture methods. To date, Quedancor has provided about half a million small fishers with credit facilities. The above-mentioned figures make aquaculture a highly promising industry when viewed in relation to the decreasing catch from natural sources due mainly to rapid population growth.

The summary of technical information presented below on aquaculture production for each species surveyed did not include information from respondents giving unreliable data/information to some of the items sought during the survey.

10.3.1 Production and Profitability

The survey results are shown in Table 10.1, which summarizes the average production and net income per cropping season of the commodities produced by the Quedancor fisher borrowers sampled.

Tilapia. Tilapia grower borrowers harvested about 3.5 t/ha, on average. This gave them a net income of PhP 91,290 when they sold their produce at PhP 35/kg farmgate price to middlemen and traders.

Bangus (milkfish). The average harvest of milkfish in Pangasinan is only 725 kg/ha compared to the national average of 1.75 t/ha/year (or 1,750 kg/ha). At PhP 37 per kilogram (kg), the 2005 farmgate price, the net income is PhP 15,900/ha. The respondents blamed the low yield on the occurrence of disease during the previous harvest seasons. The milkfish growers mostly marketed their harvest (95%) to traders and middlemen, and the rest were either consumed or given away.

Seaweeds. Seaweeds grown in Zamboanga del Norte command a price of PhP 27/kg on average, which provides the respondents a net income of PhP 91,600/ha with a total harvest of 4.9 tons/ha. The complete harvest is purchased by middlemen or traders.

Grouper. Grouper is a high-value product that earned the respondents PhP 277,000/ha when they sold at the PhP 800/kg farmgate price. Middlemen and traders were the major buyers of grouper; they, in turn, sold the grouper to exporters for shipment to Japan and Taiwan. The average yield is 3.25 mt/ha.

Table 10.1 indicates that the net income obtained by the respondents is above the poverty threshold of PhP 12,265 (National Statistics Office 2005). This further shows that more than half of the borrowers are not really impoverished; hence, the Quedancor borrowers are better-off than most of the fishers in the country, although this could not be solely attributed to the availability of Quedancor loans. Borrowers engaged in nonfarm activities (e.g., employment, retailing, vending) are the most well off, with virtually all of them above the poverty line.

10.3.2 Problems in Production

Most (83%) of the respondents claimed that they encountered production problems. Most cited is the occurrence of pests and diseases (64%) followed by the occurrence

Table 10.1 Productivity, net income, and selling price by commodity

Region	Province	Commodity	Productivity (average yield)	Net income (pesos/ha)	Selling price (pesos)
I	Pangasinan	Bangus	725 kg/ha	15,900	37/kg
IV	Batangas	Tilapia	3.5 t/ha	91,290	35/kg
IX	Zamboanga del Norte	Seaweeds	4,900 kg/ha	91,600	27/kg
Caraga	Surigao del Norte	Grouper	3.25 t/ha	277,000	800/kg

Source: Risk Assessment Survey (2005)

of natural calamities (38%). Other reasons that affect production are a lack of capital (11%) and the relatively high prices of inputs (10%).

10.3.3 Average Loss Due to Natural Risks

The average loss of Quedancor borrowers due to natural risks are estimated in this section. This figure is obtained by multiplying expected revenues obtained in the survey by commodity and by location with the percentage loss arising from natural risks. All commodities are affected by natural risks although at varying degrees. The degree also depends on the location of the farm. High-value commodities such as grouper are also subject to risks ranging from pests and diseases, El Niño Southern Oscillation (ENSO), and typhoons. Seaweeds grown in Zamboanga del Norte have incurred losses to the Quedancor borrower of up to about 75%. Although an attractive business commanding a net income of PhP 91,600/ha, Table 10.2 shows that it is a risky venture. If left unabated, all these factors will result in a loss in income on the part of Quedancor borrowers, which in turn deter them from paying their loans to Quedancor.

10.3.4 Coping and Adaptive Practices

Coping strategies, as defined by Davis (1993), are individual or community responses to changes in environmental conditions or responses to its consequences, such as declining food availability. It is a short-term response for securing a livelihood system against periodic stress. Mitigating adaptive strategies, on the other hand, refers to the way in which individuals, households, and communities have changed their mix of productive activities and modified their community rules and institutions over the long term in response to economic or environmental stresses or shocks to meet livelihood needs.

Table 10.3 presents the mechanisms adopted in aquaculture production to mitigate and cope with the effects of natural calamities.

Table 10.2 Average loss (in pesos) due to natural risks, by commodity

Region	Province	Commodity	Natural risk	Loss (%)	Average loss (PhP/ha)
I	Pangasinan	Milkfish	Typhoon	87.80	13,960.20
IV	Batangas	Tilapia	Typhoon	84.39	77,039.63
IX	Zamboanga del Norte	Seaweeds	Pests and diseases	75.00	68,700.00
Caraga	Surigao del Norte	Grouper	Pests and diseases	64.95	179,911.50
			Typhoon	72.68	201,323.60
			ENSO	6.96	19,279.20

Table 10.3 Practices adopted by Quedancor borrowers to safeguard and minimize the impact before and after natural calamity occurrence

Type of aquaculture production	Mitigating measures
Seaweed (*Kappaphycus* and *Eucheuma*) farming	• Manual removal of algae ("lumot") and epiphytes ("lapu-lapu"), and mud • Financially better-off growers transfer their farmed seaweed in a less crowded area where current flows freely • Lower the plant farther from the water surface to prevent too much exposure to sunlight, especially during low tide • For enlarged thallus tips, loosen or untangle string of filamentous plants • Harvest plants as soon as disease occurs
Grouper cage culture	• Locate cage to make it accessible, especially in times of natural calamity, but secure from vandals and poachers • Transfer cages to deeper water during period of continuous rain preventing abrupt changes in temperature and salinity; use strong, weather- and pest-resistant, noncorrosive, and nonabrasive surface
Tilapia cage culture	• Select sites where the terrain of the surrounding shore areas weakens or deflects strong winds and waves harvest stock before an announced strong typhoon arrives
Brackishwater milkfish pond culture	• Secure fish stock by putting a net-fence on top of perimeter dike • Harvest stock before an announced strong typhoon arrives

Table 10.4 *Proactive safeguards* to mitigate impacts of natural calamities by Quedancor borrowers

Commodity	Province	Proactive safeguards of borrower
Milkfish	Pangasinan	Make drainage or canal/use of nets
Tilapia	Batangas	Be alert/prepare farm for calamity
Grouper	Surigao del Norte	Be alert/prepare farm for calamity
Seaweeds	Zamboanga del Norte	Fix/replace/repair/clean if possible

In terms of the proactive practices, the most common responses of borrowers are being alert and preparing the farms for calamities (Table 10.4). Preparing the farms means that farm structures are repaired or fixed (e.g., seaweed growers in Zamboanga del Norte).

The Quedancor borrowers were asked about the most important assistance they need immediately after a major natural calamity. The most common responses were food assistance and financial help to meet other basic needs such as clothing and shelter (Table 10.5).

The assistance requested after the occurrence of calamities has almost always been provided. Responses from the sample surveyed indicated that Quedancor delayed loan interest payment to help its borrowers recover financially. Additionally, awareness/orientation programs were conducted to impart to their borrowers proper measures and practices to reduce their vulnerability to any future occurrence of a calamity. Technical training and seminars were given on a regular basis to enhance

Table 10.5 Most urgent assistance needed after a calamity by Quedancor borrowers

Commodity	Province	Most urgent assistance needed by borrowers
Milkfish	Pangasinan	Financial
Tilapia	Batangas	Food and financial
Grouper	Surigao del Norte	Financial
Seaweeds	Zamboanga del Norte	Financial

proper production management. The local government units (LGUs), particularly the Barangay Council, have been primarily responsible with the provision and distribution of food and farm inputs, particularly seeds. The national government agencies, on the other hand, provide other inputs, such as fertilizer. The milkfish growers in Pangasinan were given fingerlings from the suppliers. The need to enroll in crop insurance continues to be emphasized.

10.3.5 Assistance Provided by Institutions

Physical and social infrastructures have been developed by the government to cater to the needs of the impoverished sector of society. Access to these facilities by the rural poor (farming and fishing households) and the relative distance from their residence is an indication of efforts of the government to reach out to the poor. The respondents mentioned their need for physical facilities and social infrastructure such as farm-to-market roads, bridges, irrigation/canal systems, health centers, and school buildings. The nearest farm-to-market road ranged from about a meter to 5 km from the house of the respondents. The farthest bridge was 10 km away, and the nearest one was less than a meter from their residence. Irrigation/canal systems were also accessible, the farthest being 7 km from their house. Health centers ranged from 2 to 7 km away, and the farthest school was 3 km away. All infrastructure/support services are readily accessible to the respondents, just walking distance away from their residence.

However, in terms of support services, awareness was high only for services that were offered by Quedancor, LGUs, DA, and NGOs present in their communities. Support services needed were in the form of trainings/seminars, technology transfer, livelihood projects, animal and seed dispersal, and marketing assistance. Trainings were offered by the government – Quedancor, LGU, DA, Department of Science and Technology (DOST), Department of Trade and Industry (DTI), Department of Health (DOH) – and NGOs whose offices were less than a kilometer to as far as 38 km away from their houses. Technology transfer came from Quedancor, LGUs, and the Bureau of Fisheries and Aquatic Resources (BFAR), which were within 1–28 km of their homes/businesses. The same thing holds true for livelihood projects and animal and seed dispersal programs. The respondents acknowledged marketing assistance from Quedancor, LGUs, BFAR, and the private sector, where they usually have credit tie-up, whose offices were 3–67 km away from their residence. This means that the borrowers had access to basic social services.

It is worth noting that some respondents identified their need for an insurance company for their commodity. They mentioned that the Philippine Crop Insurance Corporation (PCIC) was just too far and inaccessible to them (about 128 km away from their residence, on average). This need is primarily due to the heavy losses that they incurred because of natural risks. They were banking on the idea that Quedancor would help them along this area as Quedancor had already assisted them as their source of credit, provision of inputs, technology transfer, and marketing their produce.

10.3.6 Quedancor Calamity Bridge Funds

For Quedancor's loan operations, a bridge fund can serve as a potential buffer to regain loans of defaulting fisher borrowers who suffer crop losses due to the effect of natural calamities. A bridge fund scheme in support to a credit program needs to be carefully studied and crafted. The total amount of bridge fund will be based on the frequency of occurrence of natural calamities in a given area and their potential impact as expressed in terms of the value of crop losses. There are critical issues and concerns that have to be clearly understood and addressed for such a task to succeed. One issue would be the proper identification of borrowers who could and will avail themselves of such support services. Other issues include the circumstances under which the extension of credit can be granted and its appropriate size to enable the continuation of production and other livelihood activities. The final issue pertains to determination of the reasonable grace period that would be given to the affected borrowers that allows easy repayment of total loans availed (regular loan plus the extension loan availed through bridge financing). Different types of fisher borrowers require different types of credit and risk alleviation assistance in order to recover. Identifying the specific form and magnitude of assistance requires critical information that must be gathered and analyzed so the operation of lending institutions is not placed at risk.

10.4 Conclusions

When a natural disaster strikes, the Quedancor borrower would cope by reducing his vulnerability, such as by reducing his consumption and social obligations; selling his livestock; in some cases migrating with his household members so they can seek employment elsewhere to augment the family income; withdrawing from his inventory of grains for his household consumption and for sale but at a price lower than the regular price; and in some cases coming up with collective action together with his community. Households with greater assets and other sources of income from nonfarm activities are less vulnerable to natural risks and have better ability to obtain credit from other sources.

The worst affected and vulnerable during calamities are the respondents who are poor and marginalized. Not only are they the worst hit, but their capacity to recover from a disaster is low. Any extreme situation traps the poor in a situation to sell off productive assets that become difficult to retrieve and thereby reinforce poverty almost permanently. Most typhoon-affected respondents have sustained damage to personal dwellings, loss of personal effects, and their source of livelihood – their farms. Those with off-farm income were able to retrieve some of those lost assets. However, those relying only on agriculture and fisheries as their source of livelihood were never able to buy back their assets even during normal years.

To repay their loans, the borrowers looked for other sources of credit (e.g., close relatives or friends, or informal lenders who offered higher interest rates) so they would have capital to start anew. In the process, they still could not pay their loans with Quedancor and were tied to more creditors. This vicious cycle permeates as long as these fisher borrowers are not given a credit scheme that has contingency measures that they can use of during times of calamity.

On the other hand, institutions on disaster management at the LGU level are in place. They offer temporary assistance to the Quedancor fishers in the form of relief goods, disaster shelter, and medical assistance, among others. However, there is no institutionalized credit repayment or restructuring mechanism that assists them with their socioeconomic condition, particularly in regard to helping them recover from the losses they incurred in their livelihood and their personal effects.

10.5 Recommendations

This study takes on the challenge of developing such a credit support mechanism. It would include access to timely and reliable information and forecasts on the possible occurrence of natural calamities and prediction of impending or potential risks and hazards that they may cause to agriculture and the rural community. Such forecasts are anchored on recent scientific and technological advances. In addition, it also formulates location-specific coping and mitigating strategies to minimize the risk in agricultural production associated with natural calamities. These strategies represent protective measures that are appropriate and effective in reducing or preventing dangers of approaching calamities, particularly for agricultural production. It should be stressed that successful development of mitigating strategies needs to be complemented by significant efforts of concerned agencies to generate and make available the statistics required for predicting the possible occurrence of typhoons and other weather disturbances, the incidence of pests and diseases, and estimation of damages that these factors may inflict on fishers' production activities.

The following are recommended coping measures.

- Seaweed. The erstwhile ideal seaweed farm has now been transformed into a poor and unsuitable setting by adding too many farms in the total environment. To cope with the decreased production due to the occurrence of pests and diseases and blooms of other plant species, growers should sacrifice for the good of the majority by relocating some farms. This action is necessary for a sustainable seaweed farming industry in the area.

- Grouper cage culture. To cope with the damages brought about by strong typhoons, the principles and practices of high-density fish culture in low-volume cages can be followed. Among other advantages, low-volume, high-density (LVHD) fish cages give operators ease in moving to a safer area in times of natural calamities (i.e., typhoon, ENSO, or pests and diseases).
- Tilapia cage culture. As for the grouper cage culture, the principles and practices of LVHD cage fish culture should be promoted to cope with the damage of natural calamities. Another advantage that cannot be overlooked is that when a small cage is damaged, fish loss is minimized.
- The promotion of the submerged fish cage, also called a "typhoon-proof fish cage," must be pursued. This is the only type of net-cage culture structure in Laguna de Bay that withstood Typhoon Rosing in 1995 without damage (Edra 2002). It should be noted that more than 65,000 ha were occupied by fish pens before the foregoing typhoon, and about 30,000 ha withstood the calamity. Two methods of submerged net-cage culture were in operation: the completely submerged net-cage and the adjustable submerged net-cage. The former is completely submerged at about a meter from the bottom, and each cage is attached to a buoy that serves as marker on the water surface. On the other hand, the latter is adjustable to a desired level similar to the former or floating like a traditional net-cage. Each cage is tied to a main line raised above the water by bamboo poles that are evenly distributed and enough to support one module.
- Brackish water milkfish pond culture. The foregoing methods of submerged net-cage culture could be modified and adopted for operation in ponds to mitigate the damage done by typhoons and floods.

10.5.1 Structural Measures

- Raisers of grouper in Surigao del Norte usually transfer the cages to deeper water during periods of continuous rain to prevent abrupt changes in water temperature and salinity.
- Tilapia growers in Batangas select sites where the terrain of the surrounding shore areas weaken or deflect strong winds and waves.

10.5.2 Institutional Measures

- Quarantine must be implemented as a policy recommendation. The net effect would be to prevent the entry and invasion of an area by pests and diseases. This is particularly important as invading or "invasive" organisms are known to be more destructive in new habitats. This information is crucial when determining the extent and magnitude of Quedancor's lending portfolio for the area. Seeds of new varieties entering the region must be tested as possible carriers of disease-causing organisms. When these new varieties are indeed carriers, a disease scenario can be forecasted, which Quedancor can use as a basis for planning subsequent lending operations. Furthermore, the movement of these susceptible varieties must be regulated to prevent disease spread that would further increase risk and diminish a borrower's ability to repay loans. This can only be done through collaboration among concerned government agencies.

- Improved seasonal climate forecasting of the occurrence of natural calamities as well as effective dissemination of forecasts for preparedness. Advances in science and technology have led to the development of process-based models that provide an opportunity to integrate institutional capability and interdisciplinary information and knowledge for more systematic and reliable agricultural planning and development.
- Improving the early warning system by concerned government agencies. Early warning or forecasting systems can be the primary means of determining risks and reducing losses due to pests and diseases. The existence of a National Pest and Disease Surveillance and Early Warning System concerned for all major pests and diseases of all economic fisheries in the country has been organized through collaboration among government agencies and several state universities and colleges (SUCs). A link to this network should bolster Quedancor's lending operations in reducing risks due to pests and diseases and provide borrowers enhanced capacity for loan repayment.
- The Information Education Communication (IEC) strategy and/or the Self Reliant Team (SRT) training of Quedancor should recognize different geographical peculiarities as in regional dialects and production management practices. The educational attainment of stakeholders must also be considered when developing appropriate training modules. The strategy, which Quedancor must develop with its partners in agricultural development (e.g., the DA and agricultural extension workers of LGUs), should effectively utilize local communication networks, such as radio and television.

Quedancor through its regional and provincial offices should provide the technical advice in terms of advisories and recommendations concerning impending natural calamities. These could be disseminated through formal and informal networks in the area.

It must be reiterated that these challenges require effective, efficient networking and partnerships among Quedancor, rural development agencies in the area, LGUs, and even NGOs.

- Provision of a standby Calamity Support Bridge Fund to assist fishers in cases of natural calamities.

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Part III
Communication with Society About Climate Change

Chapter 11
Economy and Environment: How to Get What We Want

Carl B. Becker

11.1 Introduction

Our entire lives are influenced by evaluations, by receiving attention and by being ignored. Children learn to act so as to get attention, and to cease behaviors which get no attention. The same is true of our economies; we learn to emphasize things that gain the attention of government and media, and disvalue things that do not. From this perspective, the problems of economy, environment, education, and media, are problems of getting and keeping attention. We can influence progress in the direction we desire, only when we learn properly to measure that progress.

Now our leading economic indicators, invented generations ago, are the Gross National Product (GNP) and Gross Domestic Product (GDP). Like the market system they represent, these indicators are fatally flawed. They value destruction and disasters, and fail to value nature and the most valuable activities of our daily lives. This chapter introduces the importance of measuring what we value, and of finding ways of encouraging and discouraging activities through attention, taxation, and market choice.

11.2 Problems Inherent in the GDP

Imagine that your local policeman gave a report that said, "Activity on our city streets has increased by 50%." What would you think? Surely you would want to ask: *what kind* of activity has increased? Traffic jams and traffic accidents? Stolen cars? Robberies, murders, rapes? Homeless people sleeping on sidewalks? People throwing rocks? Or people picking up garbage? Volunteers planting trees and flowers?

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Children walking and talking with old people? Or people selling balloons and ice cream? The fact that *activity* alone rises by 50% is *meaningless* until we know *what* that activity entails.

Now imagine that government decided to rank cities by the amount of activity in their streets. Every time someone did something in a street, it would be counted. Every time an accident occurred, every time a stone was thrown, every time someone littered – if there were any activity in the streets, it would be counted, the more the better. Surely you would respond, "this is a bizarre if not insane way to evaluate streets. It only adds numbers but fails to evaluate contents." Of course you would be right; amount of activity alone proves nothing.

But this is exactly what happens with that bizarre if not insane measure called the GDP. The GDP is simply one way of adding up all economic activity. It adds up the total monetary value of all goods, services, and economic activity. It does not distinguish between gains and losses, costs and benefits, production and destruction, sustainable and unsustainable activities. It adds everything and subtracts nothing. The more activity a country has, the higher its GDP. Even Simon Kuznets, the American economist who invented the GNP and GDP, repeatedly warned that the GDP was *not* a good measure of quality of life. Yet today, many people imagine that a higher GDP is better, without asking *what* it measures. There are at least five fatal flaws in the GDP; let us examine them briefly below.

11.2.1 The GDP Confuses Production with Consumption

If people plant a forest, that is production. If people cut down a forest, that is consumption. If it costs more money to cut down the forest than to plant the forest, then according to the measure of the GDP, cutting forests is "better" than planting forests. If people plant the forest as a volunteer effort, then the GDP gives it a value of zero – no value at all – even though there are countless ecological reasons that planting a forest is better than destroying one. So confusing consumption with production is one problem.

11.2.2 The GDP Mistakes Capital Depletion for Income

Imagine two families each own some land and small stocks of jewelry. The first family uses its land to grow its own food and its own biomass for fuel. It lives self-sufficiently for many generations, growing its own food and fuel. The second family sells its land, little by little, to buy food and fuel at others' stores. When it has no land left, it continues to sell its jewelry little by little. In a few years, the second family has no jewelry left, and no land where it can grow its own food or fuel. Ultimately, it goes into debt, and must be cared for in a poorhouse or prison at public expense. Surely the former family should be considered the wiser, not to mention the more ecologically and socially moral, family. Yet the GDP says that the self-sufficient family is of no value, because it buys and sells nothing, while the family that sells all its resources is "good," because it creates lots of "economic activity."

11.2.3 The GDP Forgets Quality in Pursuit of Quantity Alone

Imagine that a craftsman makes a table. He chooses local wood, deadfall from his local forest, and using only hand tools and the skill of his hands, he constructs a beautiful table, so well made that it will last for centuries. Now compare this to a second table. It is made in East Asia by huge machines that consume iron ore and coke from Canada, uranium and other toxic minerals from Australia. It is so poorly made that its sharp edges damage people's clothing and cut their skin. It soon rusts, so people soon discard it to replace it with a similar one. Which table would you say is the better, the beautiful local wooden one or the dangerous rusty steel one? The GDP says that the dangerous rusty steel one is better, because it requires more money to transport its raw materials, consumes more energy in its manufacture, and by damaging people's clothing and skin it causes them to buy more clothing and medicine. This is the confusion of quality and quantity!

11.2.4 The GDP Treats the Gains of the Few as if They Benefited the Masses

Recall the work of Albert Schweitzer and Mother Teresa, who devoted their whole lives to improving the health of people in Africa and India. The GDP does not value the health that they brought to Africa and India – it only values the millions of dollars that they received in donations or in Nobel Prize money. Now consider a CEO of a financial institution who makes half a billion dollars a year. He neither creates nor produces anything; he just sits at desks and meetings on weekdays, and on the weekends, he plays golf. He puts his money in hedge funds that gamble on the value of the Thai bhat and the Indonesian rupee. When the hedge funds pull out of Southeast Asia, the rich banker gains another half billion dollars. The economies of Thailand and Indonesia crumble, millions of people are out of work, out of food, and in great suffering. Sadly, this was a real scenario only ten years ago. Now whom should society value more, Mother Teresa or the hedge fund gambler? The GDP says that the gambling of one billionaire is more important than the health of thousands or even millions of common people. It acts as if the gains of rich people help everyone – when in fact they do not.

11.2.5 The GDP Praises the Costs Incurred by Wars, Disasters, and Human Tragedies

According to the measure of the GDP, the best things that can happen are wars, because it costs great sums to make war and far more to pay for the hospitals, diseases, rebuilding, and after effects. If we were to measure GDP on a personal level, the best things for a family's GDP also resemble wars: expensive divorces, where the family is broken, everything is sold, two new houses are bought, the parents are hospitalized with expensive diseases, and the children are sent to prison after expensive police investigations. Like an anthill that has been kicked over, a society in shambles, scrambling to recover from countless disasters, is valued more than a peaceful, smoothly functioning society, by the logic of measuring the GDP. In short, the GDP values past problems which cost society money to repair, remedy, or fix up; present activities which move people from home and family to working part-time or second jobs; and depletion of resources which our children will not be able to use in the future.

11.3 How the Switch from GNP to GDP Veils the Gap Between Exploiter and Exploited

The GNP was the standard measure until 1991, when America shifted to using the GDP, and most countries of the world followed suit. How do they differ? In the old days, the GNP measured profits where a company is owned and where its profits are deposited. Imagine that an American company owns a coffee plantation in Latin America, a gold mine in Africa, and a sweatshop factory making sporting goods in Asia. Imagine that the sales of its coffee, gold, and sporting goods come to billions of dollars a year, but that it pays its workers in each country only ten cents an hour. Of course the primary profits and benefits from this exploitation accrue not to the countries where resources and workers are exploited, but rather to the exploitative country, in this case, America. The old GNP showed this as a profit for America, and it showed that third world countries were receiving pathetically little reimbursement for all their labor and resources. In short, the GNP starkly revealed the growing gap between the rich and the poor.

Now the GDP says, "let's measure the value of coffee, gold, and sporting goods *as if* all the profit from them were being returned and reinvested in the countries that produce the coffee, gold, and sporting goods." Since so much coffee comes from Latin America, precious metals from Africa, and sporting goods from Asia, the GDP *creates the illusion* that their economies are doing very well. It disguises the growing gap between the rich and the poor, by disguising the fact that labor and resources are being taken from the third world with minimal benefit to their people or societies. For rich countries that do not want to acknowledge this ugly and uncomfortable fact, the GDP is a less disturbing number than the GNP. But both numbers conceal the real quality of life.

11.4 Services Unappreciated by the GDP

Most of us would agree that real quality of life depends in large part on Mother Nature. Clean fresh air, delicious pure water, and fertile loamy soil are so basic to our happiness that we often forget to count them. In fact, the services of Mother Nature are what make air clean, water delicious, and soil rich. Sun and rain, forests and greenery take carbon and pollutants out of the air, and return fresh oxygen for us to breathe. If we had to pay for machines to purify our air, it would cost unthinkable trillions of dollars. Yet we often destroy nature and forests without thinking of the costs. Evaporation, streams, rivers, underground water systems, and bacterial action purify polluted water. If we had to pay for machines to purify our water, it would cost unthinkable trillions of dollars. Yet we often destroy rivers and water systems without thinking of the costs. Animals, insects, and innumerable bacteria and microorganisms slowly change poor soil into rich fertile soil. If we had to pay for machines to enrich our soil, it would cost unthinkable trillions of dollars. Yet we often destroy insects and soil systems without thinking of the costs. The GDP counts destruction of nature as a *good*. Yet in the long run, the uncounted services of Nature are far more valuable than short-term gains.

Most of the continents on the earth were once covered with forests – the reason many places are arid today is that men cut down those forests. When a forest is cut down, the cycle of water and CO_2 is affected, and climates become more severe. Even a small grove of trees on the north side of a house can raise temperatures by 5–10° in winter by reducing wind chill, while a few trees on the south side can lower temperatures by 5–10° in summer by providing shade from the sun. On a larger scale, we are coming to see how burning of forests in Indonesia and Brazil has affected the weather patterns of the whole globe in recent years. If we had to place a money value on these services of nature, surely it would cost trillions of dollars to cool, warm, or modify weather patterns – even *if* we really had the ability to do so.

Let us consider some more examples. Pollination and pest control could be done by humans – indeed, in some sad situations, humans have to move the pollen from flower to flower by hand, and pick off the insects by hand as well. If we had to pay for all that labor, we would painfully realize how valuable are the bees and butterflies that pollinate the flowers, and the frogs and ladybugs that eat insect pests.

Only recently, we are beginning to realize and appreciate the difference between resources that are usable only once, like coal and oil, and renewable resources, like sunshine, wind power, water power, wave power, and biomass. As problems of pollution force us to move from burning fossil fuels towards using renewable energy, we shall appreciate even more the value of natural resources like wind, sunshine, and water power.

The more we know of nature, the more we find new medicinal herbs, roots, barks, leaves, and chemicals that have the potential to save us from a wide range of diseases. Numerous studies have found that the best way for us to escape the stresses of modern society and restore our bodies and souls is to go hiking for a day in the forest. After all, our ancestors lived in forests for millions of years.

The value to our health of walking in nature is difficult to measure in numbers, and has absolutely *zero* value to the GDP.

Yet another range of services that the GDP ignores is those that have been a part of traditional family and community life. For example, we would all agree that providing a good home environment and education, that good parenting is one of the most important jobs in the world. The home and parenting that parents provide may determine whether their child becomes a saint or a criminal, a friend to many or a friend to no one. Yet such home environment and education is not considered by the GDP. How about the other services that many wives, mothers, and homemakers perform? All the cleaning, cooking, washing, painting, decorating, maintaining, and improving of homes would be tremendously expensive if everyone were paid to do it, yet we do it by ourselves everyday. Cooking, cleaning, and home maintenance are essential – some of the most valuable parts of our lives – and yet the GDP completely ignores them.

Recently, some countries in Europe have socialized medicine and elder care, so that the taxpayers pay social workers and caretakers to care for old people, while their children work in so-called "money-making" jobs counted by the GDP. Every country that has tried this has found that elder care is far more expensive, and its quality is poorer, when children work and pay helpers to care for their parents, than when children care for their elder parents without pay. The GDP values people caring for others *only* when they are paid to do so. In fact, the work that most people do in caring for others, helping them, listening to their problems, is unpaid but of very great value. And then there is the great value of communicating information itself. If we had to learn everything on our own that we can learn from talking to other people, it would take tremendous time and money to get all the information and knowledge that we need. This list could go on and on, but the point is clear. Many of the most important things in life are not – and probably should never be – bought and sold. That means that the GDP counts them as *zero*, of no importance. This too is a damning criticism of using the GDP as a measure of value or progress.

11.5 Morally and Psychologically Preferable Alternatives to the GDP

By now it should be clear that the GDP is a bad measure, not to say a measure of badness. Yet there are many alternatives. Let us compare just four that have become well known in the last decade: the *Index of Sustainable Economic Welfare* (ISEW), the *New OECD Index* (OECDI), the *Sustainable Net Benefit Index* (SNBI), and the *Genuine Progress Indicator* (GPI). Each of these scales considers the values of uncounted home and volunteer labor. More importantly, they consider the effects of income inequality, crime, accidents, pollution, and environmental damage as minuses – real losses that lower the quality of our lives, even if our GDP is rising. Let's take a minute to simply look over some of these alternatives. For the sake of clarity, let us present each in abbreviated chart form, rather than text, where pluses indicate things positively valued, and minuses, things subtracted from the total value.

(1) The *Index of Sustainable Economic Welfare*
(ISEW: Daly and Cobb 1989; Jackson 1994) values/devalues:
+ Expenditures
+ Home labor
– Income inequality
– Accidents and crime
– Air and water pollutions
– Loss of farms/wetland
– Environmental (and O_3) damage
– Resource depletion

(2) The *Sustainable Net Benefit Index*
(SNBI: Lawn and Sanders 1999) values/devalues:
+ Expenditures and services
+ Home labor
+ Leisure time
– Income inequality, crimes and accidents
– Long commutes, unemployment
– Family breakdown
– Environmental damage and pollution
– Resource Depletions

(3) The *New OECD Index*
(OECDI: Ekins 1997) values/devalues:
+ Percentage of national area protected
+ Percentage of waste treated and recycled
– Solid waste and water pollution per capita
– COX, SOX, NOX air pollution per capita
– Primary energy use and private car transport
– Imports of tropical wood
– Percentage of species threatened
– Nitrates/km^2 cropland

(4) The *Genuine Progress Indicator*
(GPI: Daly and Cobb 1989; Lawn 2003) values/devalues:
+ Expenditures/services
+ Home, volunteer labor
– Lost leisure time
– Income inequality
– Crime and consequences
– Accidents and illnesses
– Pollution purification
– Resource depletions
– Environmental damage

The scales, ratings, and measurements used to evaluate something determine its future. These scales presented above are only extremely rough outlines of the detailed proposals and practices that are already being emulated in much of the EU. Subsequent revisions of these proposals may show further improvements or fine tuning not apparent in the above rough outlines. The above rough outlines do demonstrate a wide agreement that *non*-GDP factors are more numerous and more important than the GDP. Yet when we continue to evaluate economies by their GDPs, we value consumption and waste and *de*value nature, parenting, and tree planting. So it is important that we understand how our evaluations encourage or discourage the activities or conditions that we want to encourage or discourage.

11.6 The Roles of Taxation and Consumer Choice

Consider an example connected both to the economy and to discouraging and encouraging activities: the collection of taxes. Like the GNP/GDP, tax collection systems are some 50 to 100 years out of date with our times today. All countries need taxes, to support their national health and medical systems, schools, communication, and transportation. Taxes all collect funds for those purposes; but taxes also have the effect of encouraging and discouraging specific activities. Although there is some difference from country to country and state to state, by and large we can see the following trends in the way taxes influence people.

Most countries tax employers, to provide health insurance and social security benefits for their workers. This is not to criticise health insurance and social security benefits – but this same tax encourages employers to hire fewer people, or to hire illegal aliens, for each person legally hired means more tax taken from the employer. Similarly, most countries now tax income. The longer we work, the more we earn, and the more we earn, the more income tax we have to pay. There are cases where many family members work part time, because they fear that if they were to work full time, they would lose more in taxes than they would gain in income. In such ways, taxes can end up discouraging full-time employment.

Many countries also tax earnings from bank deposits, savings accounts, and investment profits. Others tax building and home improvement projects. If the goal of the tax program is to reduce investment and redistribute wealth, or to discourage building improvements in certain areas, then this would make good sense. In fact, most countries *want* to encourage saving money and improving property, so it is counterintuitive that they should discourage it through taxation.

On the other hand, most countries continue to give tax breaks (discounts) for companies that remove natural resources, like chopping forests, mining coal, iron, minerals, and uranium, or drilling for oil. Other tax breaks are given to families with many children; yet others to people who buy trucks, 4WD SUVs, and second homes – encouraging rich people to explore and exploit the virgin countryside. These taxes might have made sense a century ago, when some countries could still claim to be underpopulated. Today, they encourage behaviors that directly harm both the social environment and the natural environment. What could be done instead?

Simply speaking, we could discourage undesirable activities by taxing them – as some countries are already beginning to do so. For example, high taxes on tobacco, alcohol, gasoline, and even meat, have had beneficial effects on the health of many European populations. The EU and UK have already introduced versions of carbon emissions taxes; henceforth taxes on sulfur and nitrate emissions may also become desirable. Taxes on many of the activities viewed as "minuses" in the environmentally-friendly evaluative scales displayed above would also motivate citizens to healthier and more sustainable directions. For example, taxes on unrecycled waste dumping and landfills, or on Dioxin and PCBs that they produce; taxes on pesticides and other poisons, possibly including batteries and heavy metals; taxes on virgin resources; even taxes on food mileage may be desirable in order to stimulate more sustainable thinking and lifestyles.

First we must *identify* what we value and disvalue, and then find ways of discouraging or encouraging those behaviors. The critical issues become *what* we choose to encourage or discourage, and *how* we value or devalue it. So far, we have already seen two ways of encouraging and discouraging. The first is by paying attention (positive ratings) to what we want to encourage, and no attention (negative ratings) to what we want to discourage. The second is by taxation and tax benefits. The third item which must not be forgotten is the power of shopping choices.

Every time we buy something, we send powerful messages to the manufacturer and society: "please make more of this, the way you made this one." When we buy paper and pens, for example, if we buy virgin bleached paper and virgin plastic pens, we invest our labor into paying the people who make them. We encourage them, "Please cut more forests, please pollute the water with more bleach, please consume more petroleum." On the other hand, if we choose to buy unbleached recycled paper and recycled pens, we send a different message: "Please recycle paper and plastic, please do not cut forests or consume oil." The choice is ours.

Manufacturers are acutely sensitive to the messages that consumers send. If consumers send the message that they want more of the things that are now damaging the environment, manufacturers will continue to try to meet those demands. But if consumers demand more environmentally responsible goods and services, manufacturers will quickly change to meet those new consumer demands. Some people say that environmentally friendly products are more expensive, but this is true of any goods in the beginning. When production of organic vegetables and recycled products becomes widespread, prices will fall to low and sustainable levels. The bottom line is that we can choose our future by the products that we purchase. Manufacturers and governments will produce what we demand. But first we must know *what* we value, and why.

11.7 Conclusions

There is growing concern about environmental issues among the citizenry of the EU and Japan. However, the scales that their governments and media continue to publicize perpetuate misperceptions detrimental to environmental sustainability, and downright reprehensible for their concealment of human suffering and injustice. Far more reasonable and moral scales already exist in abundance, and they are being steadily improved. Concerned citizens must insist on our governments and media using scales that *reflect* what we value. The revision of our economic scales is in fact a prerequisite to a much-needed revision of our perception of desirable reality. Coupled with tax systems to modify behavior patterns, and shopping patterns based on educated choice, the choice of measures of *prosperity without growth* (Jackson 2009) is the only way to effectively influence economic activity on the road to environmental sustainability.

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Chapter 12
A Mapping of Global Warming Research Based on IPCC AR4

Ai Hiramatsu, Nobuo Mimura, and Akimasa Sumi

12.1 Introduction

Research activities on climate change and global warming have experienced a remarkable worldwide increase in recent years. Since the release of *The Stern Review* (Stern 2007) and the *Intergovernmental Panel on Climate Change Fourth Assessment Report* (IPCC AR4) (IPCC 2007a, b, c) in 2007, climate change issues have been prioritized in both national and international arenas. Given that post-Kyoto arguments remain active, and the Bali Roadmap was defined at the Conference of the Parties, 13th Session (COP13), there is an urgent need to develop an international initiative to increase efforts to reduce greenhouse gas (GHG) emissions at the local and global levels. However, conventional research has addressed these problems from the specific viewpoints of particular fields and, up to this point, it has been very difficult to present a comprehensive view of the future. Designing sustainable countermeasures for addressing global warming requires an approach that unifies the various aspects of climate change, including impact assessment, prediction, mitigation and adaptation measures, policy issues, and social issues. It is essential to attack the problems from a wide range of viewpoints from different academic fields, including natural science, engineering, agriculture, economics, and political science.

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Recognizing the need for a new academic discipline of sustainability science, which must adopt a comprehensive and holistic approach to identification of problems and perspectives involving the sustainability of global, social, and human systems, the University of Tokyo inaugurated the Integrated Research System for Sustainability Science (IR3S) and invited universities and research institutes to set up a nationwide research network in Japan (Komiyama and Takeuchi 2006). IR3S has conducted flagship projects with five participating universities (the University of Tokyo, Kyoto University, Osaka University, Hokkaido University, and Ibaraki University) and six cooperating organizations (Toyo University, the National Institute for Environmental Studies, Tohoku University, Chiba University, Waseda University, and Ritsumeikan University). Through the cooperation and participation of these universities and organizations, the flagship projects represent models of the type of transdisciplinary research needed to achieve sustainable society. This study is part of the flagship project, "sustainable countermeasures to mitigate and adapt to global warming" (hereafter, FP-GW). The IR3S participating universities and cooperating organizations already have knowledge and experience, and have contributed to research on global warming. Active communication, linkage of knowledge and experience, and mediation between experts in different fields and decision-makers is effective in mobilizing knowledge into action, and these boundary management functions can be performed effectively through various organizational arrangements and procedures (Cash et al. 2003). The integration of our activities will lead to a new vision for sustainable society, and takes the following items into consideration:

- Clarification of certainties, uncertainties, inadequacies, and challenges in addressing global warming by organizing current scientific knowledge and restructuring the statement and/or solution of the problem.
- Utilization of the best research capacities of the participating universities and coordinating to conduct research that focuses on the mutual relationships among the various fields. Encourage feedback on the results of each study and exchange of information and opinions by researchers.
- Propose multiple designs for society in the twenty-first century, accounting for uncertainties in predictions of global warming, possibility of maladaptation of socioeconomic systems, and uncertainties in technical development and available resources.

Global warming research is wide-ranging. Such research is a core part of sustainability science, which is considered to be use-inspired basic research, motivated both by the quest for fundamental understanding and by problem-solving considerations (Clark 2007; Stokes 1997). As is often the case, just listing and strewing keywords or showing causal connections or relationships among elements is cumbersome and can result in problems that are difficult to understand comprehensively. Mapping approaches are sometimes used to systematically understand complex problems involving many diverse elements. To present a conceptual framework to guide the understanding of the overall issues, examine their constituent elements, and organize existing knowledge on sustainable development, Choucri et al. (2007)

proposed a three-dimensional (3D) pillar map with an integrated frame system comprising slice (domain of core concept), ring (dimension of problem and solution), and cell (granular manifestation). Another interesting approach is to draw a research overview map of sustainability science by analyzing the citation network of papers published in academic journals and detecting research domains (Kajikawa et al. 2007). Bozeman (2003) sought to develop conceptual tools and measures that would enable a better understanding of the impacts of scientific research on desired social outcomes with his *Public Value Mapping of Science Outcomes*. Global warming issues can be well structured and visualized by mapping, so that we can comprehensively recognize problems and create and implement compatibly designed and appropriate countermeasures.

In this study, we propose a map of global warming issues to restructure our knowledge. We introduced a framework of seven phases of the global warming process into the mapping. The classification of phases is based on the interaction among human society and nature. This is arbitrarily defined by experts and should be evaluated further in the future. The objective of this study is to reorganize current research results and clarify problems and solutions. We also aim to clarify certainties and uncertainties of scientific knowledge and to identify higher and lower priority areas for future research.

12.1.1 Overview of the Research

This study followed the methodology below with the cooperation of scientists of climate change including coordinating lead authors (CLAs) or lead authors (LAs) of IPCC.

12.1.1.1 Development of the Mapping Framework

Global warming issues were classified into seven phases from the points of view of the process of global warming and the response of human society to it. Keywords and key questions were distributed into each phase from the academic view to analyze current scientific knowledge.

12.1.1.2 Application of IPCC AR4 Findings to the Mapping

As a source of comprehensive information of current research results, IPCC AR4 was applied to the mapping framework. The scientific results are summarized and classified into the phases based on bullets of summary for policy makers (SPM) of working groups I–III so as to compare the numbers of the results (quantitative analysis).

Next, the certainty of scientific knowledge in IPCC AR4 was analyzed (qualitative analysis). The findings of IPCC AR4 were reorganized and classified into three ranks of certainty to examine the extent to which scientific knowledge provided answers to the major concerns. The classification was conducted by experts, and is based on the level of reliability indicated in the IPCC report. The ranked IPCC findings were also classified into seven phases for further analysis.

12.1.1.3 Discussion: Answers to Key Questions of the Map

We compared the current scientific results in each phase quantitatively and qualitatively so that we could understand the whole picture of current global warming research. We discussed gaps in scientific knowledge, as well as the research progress and research shortfalls that could affect the decision-making of future directions for research.

12.2 Development of the Mapping Framework: Structuring Knowledge of Global Warming Issues

12.2.1 Phase Classification for Mapping

Global warming is caused by the disruption of the balance between nature and human society. To make it easier to understand the complex and wide-ranging elements related to global warming, we need an organizational framework. Therefore, we classified global warming issues into seven phases from the points of view of interactions between global natural systems, socio-economic systems and human systems (Komiyama and Takeuchi 2006). This sequence of phases naturally follows the process and is easy to understand. Similar framing of these processes is used implicitly in the IPCC assessment reports, and is more clearly shown in the reports of the Council for Science and Technology Promotion (Ichikawa 2004; Koike 2006).

1. GHGs and aerosols are emitted and natural environments are changed by the economic activities of human society ("socioeconomic activity and GHG emissions" in Fig. 12.1).
2. In the natural system, carbon circulates in the atmosphere, in the ocean, and on land through photosynthesis, respiration, decomposition, and other processes. Emitted GHGs enter these circulation processes and finally determine the GHG concentration in the atmosphere ("carbon cycle and carbon concentration").
3. GHGs in the atmosphere cause climate change, such as increases in air temperature and sea level ("climate change and global warming").
4. Climate change induces various effects on ecosystems and human society, such as submerging of low-lying areas, extinction of species, and changing food production and water resources ("impacts on ecosystems and human society").

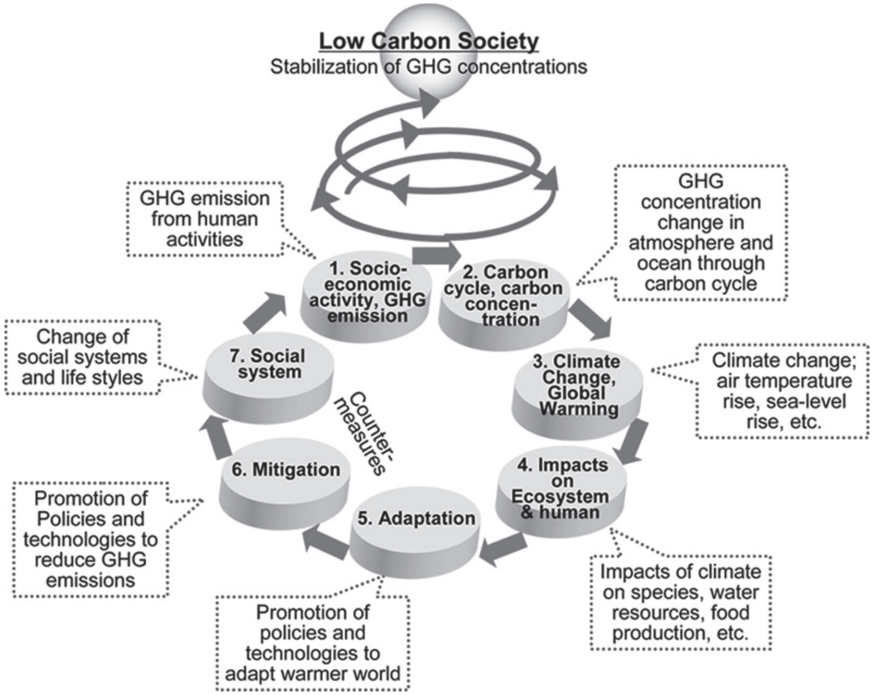

Fig. 12.1 Framework for understanding global warming

5. To address the impacts of climate change, human society must promote policies and technologies to adapt to a warmer world ("adaptation").
6. In addition to adapting to a warmer world, human society must also reduce GHG emissions to decrease GHG concentrations in the atmosphere, and must therefore introduce various mitigating policies and technologies ("mitigation").
7. New social systems should be developed. Changes in social values, lifestyles, and education, and voluntary actions taken by society must occur ("social systems").

The change of social structure in phase 7 has the possibility of producing new problems, meaning that we will have to look again at the problem with the whole cycle. Interactions between human society and nature will continue, and the issues raised by the process of global warming will be endlessly repeated. This cycle is not at equilibrium but is continually changing based on the dynamic interaction between nature and human society. Therefore, we have to consider problems with the whole cycle continuously. The sequence of the phases will repeat in spirals towards a low carbon society. Based on this dynamic structure, we created the seven-phase framework of global warming issues shown in Fig. 12.1. This mapping framework is conceptually clear and easy to understand, yet it is also comprehensive and encompasses a broad range of global warming elements.

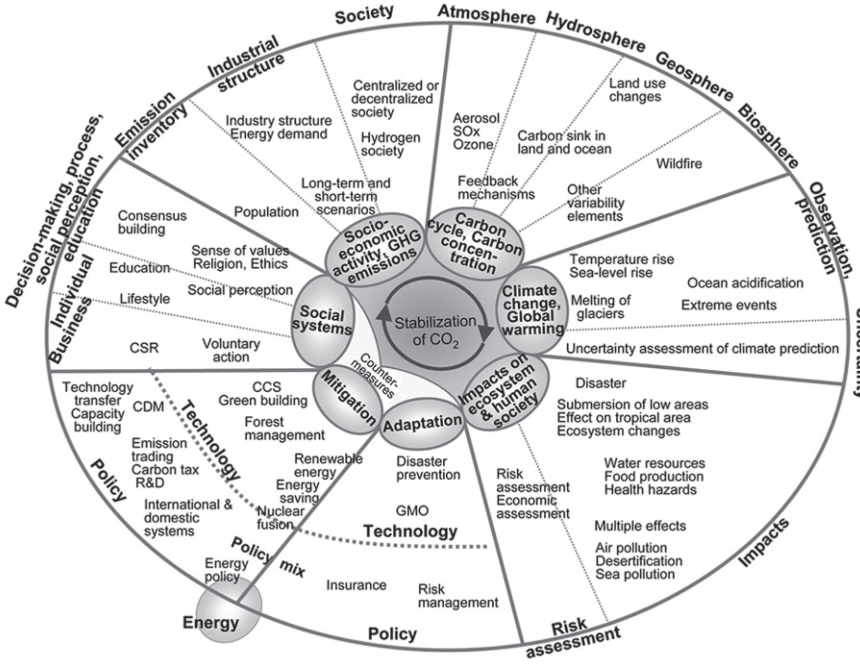

Fig. 12.2 Map of the seven phases with keywords from global warming research

12.2.2 Mapping Framework and Identification of Key questions

We created a map of global warming with the seven phases, as shown in Fig. 12.2. To better represent the issues, we divided each phase into several categories and input major keywords of current research programs in the world into those categories. Generally, items located closer to the center represent more fundamental issues and items located further from the center are more applied. The items closest to the center of the map represent the most fundamental issues in phases 1, 2 and 7; the more serious phenomena and effects in phases 3 and 4; and the highest priority options in phases 5 and 6. The items listed further from the center are the more practical challenges on which society needs to work, especially in phases 1 and 7.

Phase 1 incorporates the industrial structure and basic social structure that determine GHG emissions and relate to the emission inventory, including population and society's energy demands. In phase 2, the carbon cycle was divided into the atmosphere, hydrosphere, geosphere, and biosphere. The behaviors of GHGs and aerosols, mechanisms of the carbon cycle (e.g., carbon sink), and other environmental elements affecting the carbon cycle are included. Phase 3 was divided into observation and prediction of climate change, as well as the related uncertainties. Observed global warming items and models predicting the future climate are included here. Phase 4 contains the categories of impacts and risk assessment. Impacts include the direct effects of global warming as well as the indirect or multiple effects associated with other causes. Categories for technology and policy are included in phases 5 and 6. Examples of adaptation technologies are revetments against high storm surges or flooding, and improvement or introduction of genetically modified organisms (GMO) to ensure crop yields in a warmer climate. Adaptation policies include insurance schemes and other types of risk management. Examples of mitigation technologies include energy saving, renewable energy, and carbon capture and storage technologies as well as forest management techniques used to increase the carbon sink. Mitigation policies include creation of an international/national regime to reduce GHG emissions and economic measures, such as emissions trading and clean development mechanism (CDM). The energy sector has strong ties to climate change and plays a very important role in mitigation. However, this sector sometimes has other objectives (e.g., energy security) and there is an enormous amount of research in this area. Therefore, we treated the energy sector separately and minimized the types of energy represented, mainly including those that deal with climate change, energy saving, renewable energy, and other related issues. There are some policies and technologies that relate to both phases 5 and 6 (e.g., the policy mix or technology portfolio). Phase 7 includes philosophical aspects and the governance of society (e.g., the behavior of businesses and individuals, education, social norms and values, religion, and the decision-making process).

By using this mapping framework and considering the issues in each phase holistically, well-balanced countermeasures against global warming can be developed. The map can be changed in response to feedback from scientists and policy makers or new research results.

To understand the structure and core problem in each phase, we identified key questions that are both representative of each phase and highest on the list of concerns regarding climate change for that phase (Table 12.1). Of course, there are many underlying issues and more detailed questions in each phase. We used these key questions and our mapping classifications to measure the quantity and reliability of answers that research has thus far provided to society.

12.3 Application of IPCC AR4 Findings to the Mapping

The IPCC is an intergovernmental scientific body established to provide decision-makers and others interested in climate change with an objective source of information about climate change (IPCC 2008). While the knowledge on global warming is vast, IPCC reports are a good source of comprehensive information to help understand current research results regarding global warming. The IPCC provides these reports at regular intervals and released AR4 in 2007, 6 years after the Third Assessment Report (TAR) in 2001 (IPCC 2001a, b, c). The IPCC has three working groups. Working group I (WGI) assesses the physical scientific aspects of the climate system and climate change. Its latest report is *Climate change 2007: the physical science basis* (IPCC 2007a). Working group II (WGII) assesses the vulnerability of socioeconomic and natural systems to climate change, the negative and positive consequences of climate change, and options for adapting to it. Its latest report is

Table 12.1 Key questions for each phase

Phase	Key questions
1. Socioeconomic activity and GHG emissions	How will the amount of anthropogenic GHG emissions and their emission sources change?
2. Carbon cycle and carbon concentration	How do GHG concentrations change? What is the mechanism of the carbon cycle and what are the environmental variation factors relating to climate change?
3. Climate change and global warming	Does global warming occur? How will the climate change in the future?
4. Impacts on ecosystems and human society	What are the impacts of climate change? What level of climate change will put humans and ecosystems at risk?
5. Adaptation	What kinds of adaptation policies and technologies are required? By how much will adaptation measures reduce the risk?
6. Mitigation	What kinds of mitigation policies and technologies are required for reductions in GHG emissions? How much GHG emission reduction will be possible?
7. Social systems	How can human society change social systems to create a low carbon society Do the changes contribute to a sustainable society?

GHG greenhouse gas

Climate change 2007: impacts, adaptation and vulnerability (IPCC 2007b). Working group III (WGIII) assesses options for mitigating climate change through limiting or preventing GHG emissions and enhancing activities that remove them from the atmosphere. Its latest report is *Climate change 2007: mitigation of climate change* (IPCC 2007c). IPCC AR4 consists of these three reports, and our study used the results presented in the SPM of each report for analysis.

12.3.1 Quantitative Analysis: Research Results of IPCC AR4

We tried organizing and restructuring the knowledge on global warming. We assumed that the results summarized by the bullets in the three SPMs represent the essence of the current state of scientific knowledge and applied them to the mapping. We summarized and classified the results into each phase (Fig. 12.3). This visual map makes it easier to grasp the distribution of research in each phase and the types of results that have been obtained. The number of scientific results obtained by each WG in each phase are shown in Fig. 12.4. It is clear that WGI deals primarily with phases 2 and 3, WGII with phases 4 and 5, and WGIII deals with phases 1, 6, and 7.

There are a larger number of results in phases 4 (number 75) and 6 (number 82). Many of the results obtained in phase 4 deal with the observed impacts of global

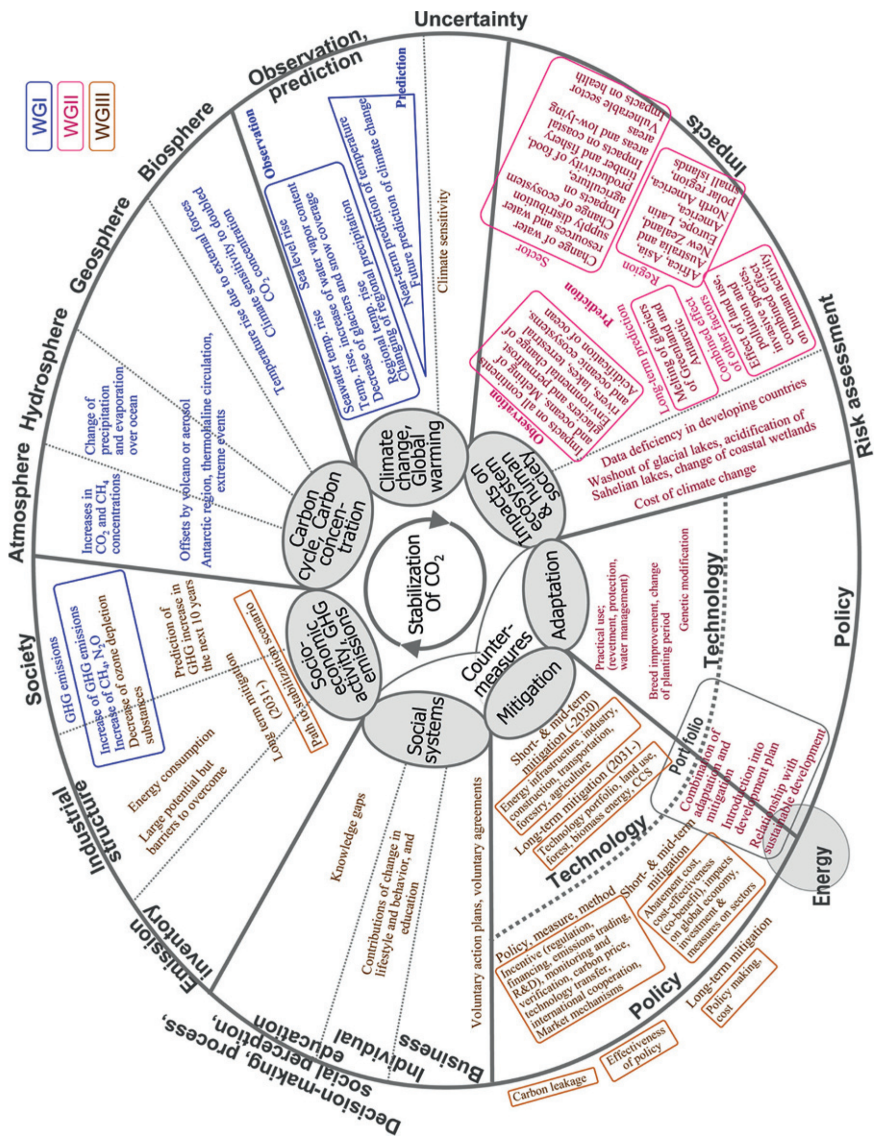

Fig. 12.3 The mapping of scientific results listed in the *Intergovernmental Panel on Climate Change Fourth Assessment Report* (IPCC AR4). *Blue* Results from working group I (WGI), *pink* WGII, and *brown* WGIII (see Color Plates, Fig. 12.3)

warming and predictions of future impacts in regions and sectors, and a smaller number cover risk assessment. More of the results obtained in phase 6 deal with various short- and medium-term mitigating technologies, policies, measures, and methods and their economic costs, whereas fewer focus on long-term mitigation. In phase 3, there are 52 research results on observations of global and regional climate

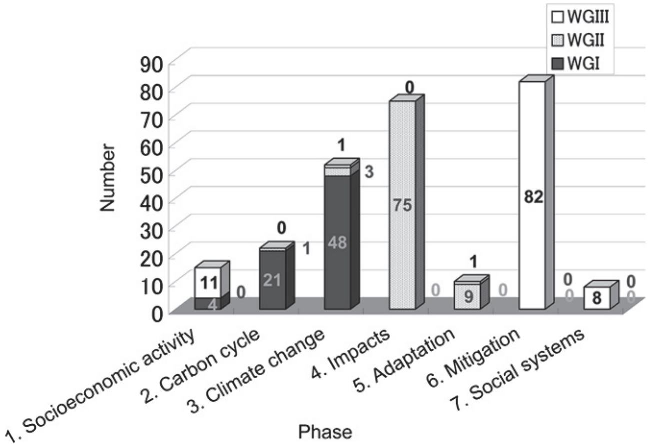

Fig. 12.4 Number of scientific results listed in IPCC AR4 for each phase

change in the atmosphere, ocean, and snow-covered areas, as well as future projections by climate models, primarily on the global level. The amount of scientific knowledge in these three phases is relatively large as compared with the other phases. In phase 2, 21 research results have been obtained. Most of these deal with radiative forcing of GHGs and aerosols and investigations of the causes of climate change, including mechanisms. In phase 1, there are 15 results dealing with emission sources and emission pathways for stabilization of GHG concentrations. Even fewer research results have been obtained in phases 5 and 7: 10 in adaptation (phase 5) and 8 in the social system (phase 7). In phase 5, the necessity of adaptation has been recognized and practical uses of adaptation have been introduced, but there are almost no practical results on adaptation policy. In phase 7, research has focused on individual behavior, voluntary action, and industry management.

The content of IPCC reports was assumed to be policy relevant. The research results of SPMs were selected from the point of view of scientific and policy needs, and the difference in the numbers of results represents these characteristics. From the SPM analysis, it is found that a focus was placed on research such as acquiring scientific evidence of global warming and its causes, identifying the effects of climate change, and backing up mitigation options argued by various nations. Therefore, the numbers of scientific results for phases 2, 3, 4 and 6 are much higher than those of other phases.

12.3.2 Qualitative Analysis: Certainty of Research Results

In this section, we discuss the certainty of the scientific results. We defined the major concerns of the IPCC WGs and set the list of questions shown in Table 12.2. To examine the extent to which scientific knowledge has provided answers to the major concerns, and to clarify the level of certainty of those answers, we then reorganized

Table 12.2 Questions related to the major concerns of the Intergovernmental Panel on Climate Change (IPCC) working groups (WGs)

WGI

Q1. Does the anthropogenic effect in the climate system cause global warming?
(1) How do GHG emissions change?
(2) In what way is radiative forcing due to anthropogenic effects?
(3) Is climate change (global warming) observed?
(4) How much is the mechanism of climate change understood?
(5) Are there anthropogenic effects in the climate system?

Q2. What will the climate be like in the future? How reliable are the predictions of future climate?
(1) Are the climate models validated? Are their results reliable?
(2) How accurate are projections of future global and regional climate changes?

WGII

Q1. What are the observed impacts of climate change (global warming)?
(1) What are the observed impacts in natural systems?
(2) What is the observed influence on human systems?
(3) How about the rate of appearance of impacts? (Has it accelerated?)
(4) Where are the most seriously affected regions?
(5) Are there multiple effects of climate change and other drivers?

Q2. What impacts will climate change have in the future?
(1) What impacts will climate change have on sectors?
(2) What impacts will climate change have on the regions and nations of the world?
(3) What kind of sectors and what areas will suffer the most serious impacts?
(4) When will impacts appear? How severe will they be? (Projection of the path of effect with time)

Q3. What is the dangerous level of the impacts of climate change and when will such impacts occur?
(1) What is the level at which natural and biological systems will be irreparably affected?
(2) What is the level at which food production will be irreparably affected?
(3) What is the level at which the world economy will be irreparably damaged?
(4) What is the level at which the irreparable influence will occur? (e.g., serious disasters)
(5) What is the level at which long-term extreme events (e.g., melting of Greenland and West Antarctic ice sheets, shutdown of thermohaline circulation) will occur?

Q4. How effective are adaptations to climate change?
(1) Have adaptations to climate change started?
(2) To what extent can adaptations prevent adverse effects?
(3) What kind of options are there for adaptation?
(4) What are the elements that determine the effectiveness of adaptations?
(5) How high are the costs of implementation compared with the costs of effects?

Q5. Which climate policies will contribute to sustainable development?
(1) Will adaptation contribute to sustainable development?
(2) What are the relationships between mitigation and adaptation? How can they be appropriately combined?

WGIII

Q1. How effective is mitigation in the short and medium term (until 2030)?
(1) How great is the potential for GHG reduction?
(2) How much is the reduction cost?
(3) How is cost-effectiveness?
(4) What are the global impacts of mitigation?
(5) How much is reduction potential by sector?

(continued)

Table 12.2 (continued)

(6) How much is reduction potential by changing lifestyle and behavior?
(7) How is carbon leakage?
Q2. What are the long-term mitigation options (after 2030)?
(1) What are the emission pathways toward stabilization?
(2) What are the stabilization scenarios?
(3) How much is the cost of stabilization?
(4) What decision-making for stabilization is required?
Q3. What kind of policies, measures, and instruments exist to mitigate climate change?
(1) How is policy assessment?
(2) How effective are mitigation policies?
(3) How much is carbon price?
(4) How effective is international cooperation?
Q4. Are there any gaps in knowledge among nations and societies?

the findings of IPCC AR4 in the form of answers to these questions. As well as considering the level of reliability placed by IPCC on the results, with the cooperation of two to three CLAs or LAs from each WG, we answered the questions and ranked the answers in terms of certainty on the basis of expert judgment as follows:

- A: Answered with high certainty.
- B: Partly answered (incomplete).
- C: No answer or still uncertain.

Results described as “virtually certain”, “very likely”, and “high confidence” in the SPMs were almost always ranked A. If there was difficulty in deciding between A/B and B/C or the judgment of CLAs or LAs was divided, we chose the lower rank. Figure 12.5 summarizes the certainties and uncertainties of the answers to the questions presented in Table 12.2. Detailed answers, with phase classifications and rankings, are given in the electronic supplementary material. When the certainty of answers is compared among the WGs, the proportions of answers ranked A–C is more meaningful than the actual number of questions ranked.

Two-thirds of answers were ranked A in WGI, which covers the anthropogenic effect on the climate system. Answers ranked A contain observations of increases in the average global air temperature (100-year linear trend of 0.74°C), average global temperature of the oceans, and average sea level (an average increase of 1.8 mm per year from 1961 to 2003), and a decrease in the amount of glaciers and snow cover in both hemispheres. Answers ranked A also contain new results of radiative forcing of GHGs. Climate models using both natural and anthropogenic forcings showed temperature change consistent with the observed temperature, whereas models using only natural forcings did not. From these results, it can be concluded that global warming exists, and that there is a high probability that global warming was derived from anthropogenic activity. On the other hand, answers on the effects of aerosols and the mechanisms of climate change remain uncertain. On the question of the future climate, half of the answers were ranked A. This is the result of the improvement in performance of climate models. There is almost no difference among

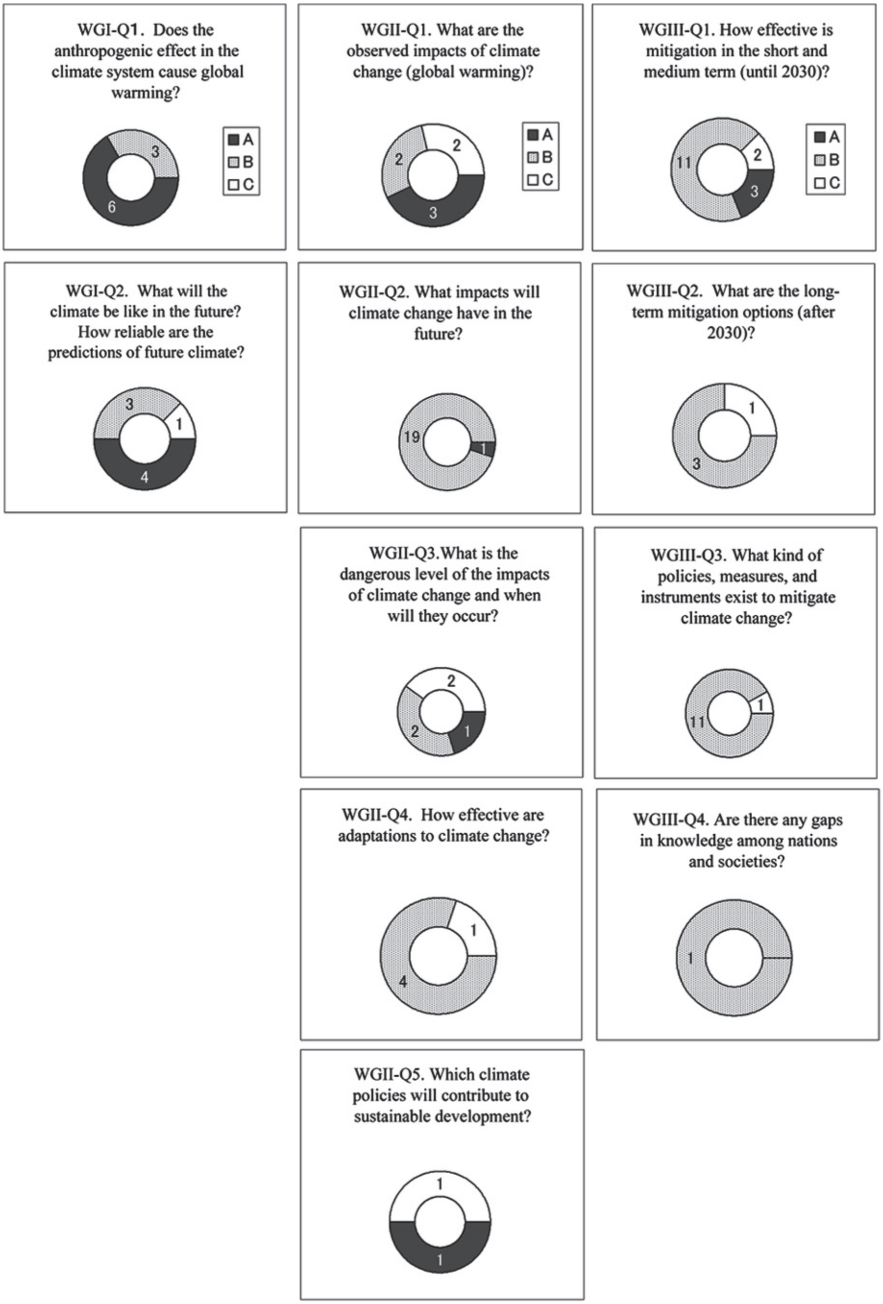

Fig. 12.5 Certainty rankings for the scientific results generated by each WG. The number of IPCC AR4 results in each ranking category is shown for each question listed in Table 12.2

scenarios in the predicted decadal average warming by 2030. Climate models predict, with high levels of certainty, a warming of about 0.2°C per decade for the next two decades, an increase in the sea surface and ocean temperatures, a rise in global average sea level, a continued decline in continental glaciers and the amount of snow cover, and more frequent heat waves. However, projections of regional changes have higher levels of uncertainty. Climate–carbon cycle coupling is expected to add carbon dioxide to the atmosphere as the climate system warms, but the magnitude of this feedback is also uncertain. As a whole, the certainty of scientific answers of WGI is high as compared to those presented in the TAR.

Various impacts of climate change and global warming have been observed in some regions (WGII-Q1), and more than one-third of answers on observed impacts were ranked A. Specifically, significant changes in snow-covered areas, polar regions, and highlands, and a strong influence on terrestrial biological systems have been observed. However, as their lower rankings indicate, the effects on human systems are more difficult to discern, as are multiple effects. Only 1 answer out of 20 was ranked A for future impacts (WGII-Q2), and it identifies the regions that will suffer the most serious impacts. Almost all other answers were ranked B, primarily for predictions in sectors (water resources, ecosystems, food and forest products, coastal systems and low-lying areas, industry, settlement and society, and health) and regions (Africa, Asia, Australia and New Zealand, Europe, Latin America, North America, polar regions, and small islands). There was one A-ranked answer to the third question, on the danger level of the impact. There is a high level of certainty for a decrease in cereal productivity at temperatures greater than 3°C above 1990 levels. However, the level at which an irreparable influence will occur is uncertain. Answers on adaptation (WGII-Q4) were almost all ranked B. Although the assessment of the effectiveness of adaptation is incomplete, the importance of adaptation has been recognized. There was one A-ranked answer to the question of whether adaptation will contribute to sustainable development (WGII-Q5), but methods of enhancing adaptation still need to be developed. A portfolio of adaptation and mitigation measures or sustainable development measures is recommended. As a whole, WGII has many partial answers. The certainty of answers to questions on regional and sectoral impacts needs to increase, and there is a need for more studies of adaptation policies.

For WGIII-Q1, concerning the effectiveness of short- and mid-term mitigation, 3 out of 16 answers were ranked A. These results indicate that there are co-benefits with health and energy security that will enhance cost savings, and that there is substantial potential for reduction of GHG emissions in the energy sector and through forest management. However, effectiveness varies by region and sector, and there are barriers to be overcome in many cases. For long-term mitigation (WGIII-Q2), there are only a few, somewhat uncertain results. There are several emission pathways, and decision-making about the appropriate level of global mitigation over time involves an iterative risk management process. Estimates of average cost for stabilization range from a 1% gain to a 5.5% decrease in global GDP in 2050, but costs for specific countries and sectors differ considerably from the global average. Almost all answers concerning mitigation policies and methods (WGIII-Q3) were ranked B. Research in this category includes studies on regulations and standards, taxes and charges, tradable permits, financial incentives, voluntary agreements, information instruments, research and development, governmental support for technology development and transfer, and CDM. There are uncertainties in carbon price, although it may create incentives for producers and consumers to significantly invest in low-GHG products, technologies, and processes. The effectiveness of international cooperation is also uncertain. There are gaps in knowledge among nations and societies (WGIII-Q4), but there was only one relatively uncertain result for this question. Throughout WGIII, many and varied mitigating options have been proposed, but there appears to be no single perfect solution. An optimum policy mix will be required to establish consensus and make those options effective.

12.3.3 Discussion: Answers to Key Questions in the Seven phases of Mapping

We classified the answers from the previous section into our seven phases in the mapping and analyzed the certainty with which the scientific knowledge presented in IPPC AR4 answers the key questions of each phase (Table 12.1). The results of this analysis are presented in Fig. 12.6.

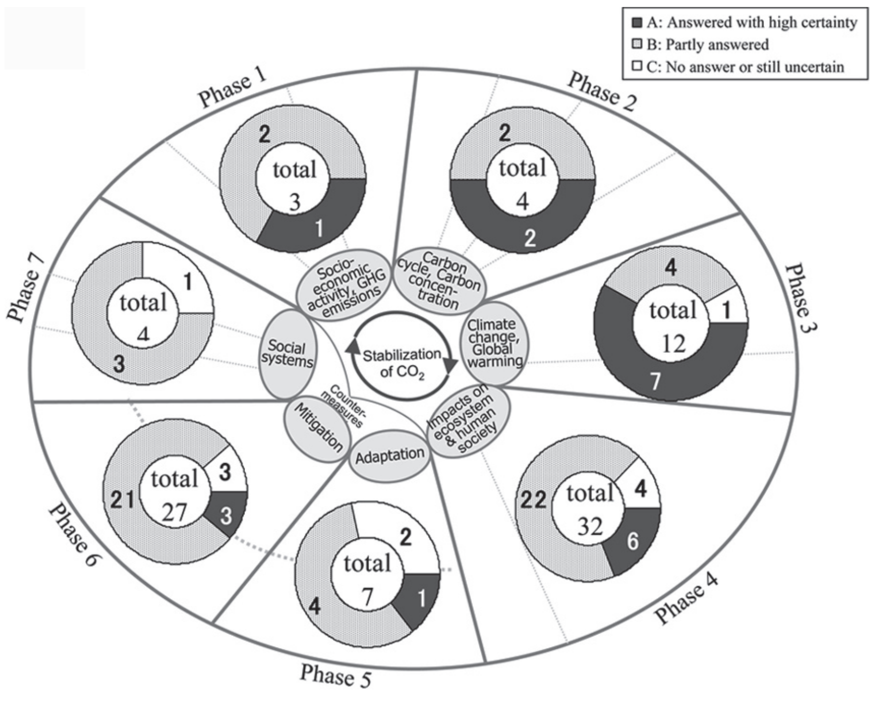

Fig. 12.6 Certainty rankings for answers to the key questions in each phase (Table 12.1). The number of IPCC AR4 results in each ranking category is shown for each phase

In response to the question posed in phase 1, it is clear that CO_2 emissions derived from fossil fuels have increased, from an average of 23.5 $GtCO_2$ per year in the 1990s to 26.4 $GtCO_2$ per year in 2000–2005. Although there are some uncertainties, it appears that a smaller proportion of CO_2 emissions is due to land use change, CH_4 emissions result predominantly from agriculture and fossil fuel use, and N_2O emissions are also from agriculture. CO_2 emission scenarios for six alternative categories of stabilization levels (from 445–490 to 855–1,130 ppm CO_2 eq.) have been proposed as future emission pathways, and results have indicated that the lower the stabilization level, the sooner this peak and decline would need to occur. However, it is still uncertain which pathway to take because outcomes depend on action taken by the world as a whole and by individual nations. The cost for each scenario is estimated as GDP share, but more accuracy is required for decision-making in regards to climate policy. There is a need for more concrete future scenarios for energy structure, industrial changes, and other emission sources.

In phases 2 and 3, the proportion of answers with a high degree of certainty is high (more than 50%). Answers to questions about the mechanism of climate change have become much clearer. New observational data, research on radiative forcing, and model calculations have clarified the view that recent global warming can be explained only by combining natural changes with the increase in anthropogenic GHGs, leading to the conclusion that recent human activities have caused global warming. Answers to questions concerning changes in thermohaline circulation, other drivers, and feedback systems have higher levels of uncertainty. In phase 3, the question about whether global warming has occurred has also been clearly answered. The climate has been getting warmer—the global average temperature has increased by 0.74°C in the past 100 years (1904–2005). Looking at the future climate, the estimated temperature increase ranges from 2.0 to 6.1°C, and an increased number of extreme events and other climatic change have also been predicted. Predictions provide clear answers for the near future climate, but predictions are less clear for the long-term future climate.

In phase 4, the impacts of climate change on ecosystems and human society have already become apparent, most obviously changes in snow- and ice-covered areas and biological systems, as mentioned above. Polar regions, high latitude areas, and coastal areas have been identified as areas that will be vulnerable to climate change in the future, perhaps with severe impacts. Although the amount of research in this area has increased, impacts vary by sector and region, and there is still uncertainty in the answers. More studies for the detection of dangerous levels of impacts of climate change and of the multiple effects of other drivers are required. Risk management of global warming requires study, and adaptation will also be required. However, in phase 5, there are few research results and few certain answers. Adaptation has begun with existing technology, such as coastal revetment and agricultural adaptation. Options for adaptation are being studied, but the practical effectiveness and costs are not yet clear. Although there are needs for more integrated study of adaptation to address the unavoidable impacts resulting from warming due to past emissions, adaptation alone is not expected to handle all the projected effects of climate change. A portfolio of adaptation and mitigation measures is therefore required to diminish the risks associated with climate change. The design of such a portfolio remains as a future challenge.

Various studies, answers, and discussions have addressed, and continue to address, the mitigation questions posed in phase 6. There is a good deal of potential for a reduction in emissions in each sector through the use of available technologies for mitigation in the near future, especially in the energy infrastructure and forest management sectors with high reliability. Technology transfer is also effective. However, there is still a good deal of uncertainty about cost-effectiveness, carbon pricing, emissions reduction by sector, and policies for long-term mitigation. As a whole, in the absence of a clear global direction, the answers in this phase remain ambiguous despite the many suggestions. More cooperation and consensus building among nations are required to reach agreements, and appropriate measures are necessary to penetrate down to the local level to guarantee effective policy implementation. Moreover, to reduce GHG emissions drastically, a change in the structure of society itself is required, but the current answers on social systems (phase 7) provide few answers and low levels of certainty. Even though there is solid research potential and a demand for such research, results are quite limited in this phase. To date, research has been conducted on contributions from businesses (e.g., voluntary actions resulting from voluntary agreements) and behavioral change, but there have been no systematic studies and few certain scientific results in relation to the social system have been reported throughout the WGs.

The research results presented in IPCC AR4 represent a marked improvement over those presented in TAR, especially the physical research on climate change. There remains, however, a need to improve the more practical studies and social science research if successful action is to be taken to address global warming. Examples include the appropriate implementation of a portfolio of adaptation and mitigation strategies, and more concrete societal assumptions for stabilization. It is important to fill in gaps in knowledge through education and capacity building. Studies on improving the participatory process of citizens; the effects of culture, ethics, and religion; and the cooperation of various actors are also required. Research in the field of social systems has been weak. The IPCC (1995) report on the economic and social dimensions of climate change focuses primarily on economic aspects and equity considerations between developing and developed countries. Of the global warming research programs, the Japanese government budgeted the least amount for social systems (TIGS 2008). Most of the United States government's global-change budget has focused on upstream uncertainties in the natural sciences, and little has been budgeted for social and behavioral sciences (Pielke 1995; Nordhaus and Popp 1997). The supply of and demand for science in decision-making has not been in alignment (Sarewitz and Pielke 2007). It is important that scientific knowledge is communicated effectively within society, so that science can be utilized effectively and new technologies and policies that address climate change are accepted. Moreover, as well as taking effective measures against global warming, it is important to assess whether these measures are compatible with other problems and contribute to the larger goal of achieving a sustainable society.

12.4 Summary and Conclusions

To get a complete picture of the current state of scientific knowledge regarding global warming, we developed a mapping framework for global warming issues. The framework consists of seven phases based on the interaction of nature and human society. We then applied the research results presented in the SPMs of IPCC AR4 to the mapping and analyzed the results in each phase quantitatively and qualitatively. Our conclusions can be summarized as follows.

- The results presented in IPCC AR4 have a high proportion of high certainty answers to questions on the carbon cycle and carbon concentration (phase 2), and climate change and global warming (phase 3). These answers identify the cause of recent global warming and predict future climate change.
- There is a large amount of information on impacts on the ecosystem and human society (phase 4) and mitigation (phase 6), although the results presented do not always have a high level of certainty. The impacts and effective mitigation options will vary by regions and sectors.
- While there are only a few answers to the questions posed regarding adaptation (phase 5), practical applications have begun to be implemented. More options are required.
- Throughout all the WGs, there are still only limited answers to the key questions about a low carbon society posed in the phases on socioeconomic activity and GHG emissions (phase 1) and social systems (phase 7).

Mapping global warming research results in such a way has made it possible for us to better understand the overall state of current scientific knowledge regarding global warming. With the application of this type of mapping framework, we were able to identify which areas of research have progressed and which are lagging behind with regard to global warming. This is important when society decides future directions of research. On the other hand, this paper did not validate sufficiently to what extent the answers from science match the needs of society. How science should answer the needs of society, which change widely and often include individual values or political will, is a future challenge to be discussed in the study of sustainability science. Nevertheless, this mapping approach provides a framework that will also be useful in organizing the various needs of society.

Since the publication of IPCC AR4, there have been discussions about the next IPCC report (AR5). Some scientists have argued that the *Special Report on Emissions Scenarios* (SRES) (IPCC 2000) is outdated and have demanded more realistic assumptions for emissions pathways (Pielke et al. 2008; Schiermeier 2008). Other scientists have discussed seeking a new IPCC step, one that puts more focus on solutions (Raes and Swart 2007; Tollefson 2007). We hope the findings of the present study will support setting the future directions of research and of the IPCC framework toward establishing a low-carbon and sustainable society.

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Chapter 13
Science and Climate Change Policy Making: A Comparative Network Perspective

Jeffrey Broadbent

13.1 Introduction

When the author was conducting field work on environmental politics in Japan (1978–1981), he and his family (wife, son 1, daughter 3) lived in a small mountain farming village in Oita Prefecture, Kyushu, Japan. In this area, terraces of rice paddies held up by hand-built stone walls stepped down the mountainsides. Hundreds of years ago, the residents had hand-chipped a tunnel through a kilometer of mountain rock to bring water from the river on the other side over to water their mountain rice paddies. The water still flows through this tunnel, and then down through channels (*mizo*) along the sides of rice paddies with little gates to let it in when permitted. The residents carefully shared this precious resource, with a village committee deciding when each farmer could periodically get enough water to plant the rice seedlings in the spring, and to keep them growing in the summer. In this way, the village had survived for hundreds of years (Broadbent 1998).

Over these centuries, this careful management had become a deeply habituated norm of collective responsibility. Most people did not question it. In the spring, for instance, we worked as a group to clean out the water channels and afterwards celebrated with tea and cookies together. Of course, not everyone always followed their duty. But those who failed were punished by social ostracism – in the past a harsh punishment indeed in this small and interdependent world. The acknowledged mutual dependence, collective enjoyment, and occasional punishment kept the system going.

In the same way, building a sustainable society and world, including stabilizing and reducing the threat of global climate change (CC), will depend upon a careful and fair disbursement of resources so that no one starves, no one takes too much, and each one can have a decent life if they work hard. But world society, for all that we refer to it as a community, is in fact very far from this normative vision of cooperation.

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We still live in an age of barely-moderated harsh global competition for resources, prosperity and dominance. To govern earth systems and reduce world output of greenhouse gases, we need the same kind of cooperative norms as found in the village, based on the duty of sharing of both benefits and burdens. We all depend upon the same limited resource – a temperate planet derived from caring for our collective atmosphere. But how can we, as global humanity, build such cooperative and responsible norms on a global scale? We distrust each other, sometimes with good reason. Here indeed we are as babies, just learning to take our first steps.

Former U.S. President Bill Clinton has called global climate change "the greatest challenge of our era" (Giddens 2009). If we think about the next 50–100 years, on a business-as-usual trajectory, the planetary ecosystem will continue to warm and disasters will continue to intensify. If nothing is done to control the root cause – increasing concentrations of greenhouse gases (GHG) in the global atmosphere – efforts to adapt, to fend off disaster by building dikes or planting new crop varieties, or to help those most hurt by early disaster, will eventually be overwhelmed by the increasing scale of the disasters (IPCC 2007). This threat cannot be met piecemeal by a few countries. To respond effectively humanity must develop new, effective ways to collectively manage the earth's ecological systems as carefully as the Japanese farmers do their water supply. Unfortunately, this kind of global governance, while long the dream of a few visionaries, has so far eluded substantial realization. The image of the Earth from space, a blue–white pearl floating in infinite darkness, gave new impetus to the idea. Just as Europe has gone from warring kingdoms, to larger nations, and now to the European Union, there is also hope for planetary cooperation. But never before has all of humanity had such a sword hanging over its collective neck to punish its failure in this daunting task.

Mitigating global climate change (by stabilizing and then reducing average atmospheric concentrations of GHG over the next century) will require enormous local, national, regional and global cooperation. Successful mitigation of CC will require both technological innovation, willingness to change habits, and finding better ways to inspire and ensure national mitigation efforts and willing cooperation to meet the goals of an international treaty. However, it has proven very difficult to find workable arrangements that can overcome the mutual distrust of persons and states and bring about such cooperation for the long-term global good. Yet, if based on a sufficient understanding of how society and politics works in these situations, we may be able to discover ways to overcome these barriers and craft effective agreements. The Compon project – Comparing Climate Change Policy Networks – is dedicated to finding such principles through the use of social scientific research as explained in this chapter. In particular the Compon project focuses on finding the basic social principles that explain why political societies (populations bounded by a state political jurisdiction) have differed so greatly in their responses to CC up to the present and into the near future. Through this research we hope to contribute to knowledge about the conditions and arrangements that facilitate positive and effective action to mitigate CC.

Until recently, social scientists concerned with global environmental problems including CC have paid their main attention to the design of international agreements (or regimes) (Schneider et al. 2002; Helm 2005; Speth and Haas 2006; Young 2002). But the relative weakness of many of these, especially the failure of many nations that ratified the Kyoto Protocol to attain their targets during the current commitment period (2008–2012), has turned attention toward the factors within countries that affect their responses (Evans et al. 1993; Jacobson and Weiss 1998; Schreurs 2002, p. 261; Weidner and Janicke 2002, pp. 430–431). Building on their accomplishments, the Compon research project is designed to take the next step in this direction. The Compon project will test hypotheses about basic social and cultural factors that help or hinder national responses to mitigating climate change, including the stimuli coming from the relevant international agreements and regimes. The Compon project is collecting empirical data to test these hypotheses through rigorous cross-national comparative analysis. The findings are intended both to develop sociological and political theories and case studies of such reaction processes, and also to contribute to the design of better national and international regimes for climate change mitigation. The project focuses on the issue of mitigation, rather than adaptation, because without mitigation, over the coming decades the resulting disasters will only increase in intensity and eventually overcome adaptive efforts (IPCC 2007).

The Compon project is a collaborative effort among teams of scholars in 16 societies[1] and at the international level so that it directly brings in many of the voices comprising the debate and the world carbon system. The currently participating societies include China, South Korea, Japan, Taiwan, New Zealand, Canada, the United States, Brazil, the United Kingdom, Germany, Sweden, Austria, Greece, Russia, Lithuania and India, plus the international level of negotiations about the post-Kyoto climate change regime. These national societies represent a variety of conditions (developing/developed; democratic/authoritarian; large/small) that affect their responses to the task of mitigating climate change. This collaborative and comparative project will contribute to understanding the social principles crucial to the successful mitigation of climate change at national and international levels. The enormous task of constructing a new, inclusive and successful international climate change mitigation regime has only just begun; it must be based on solid knowledge of such motivating principles.

As a formal method, the Compon project uses cutting edge but well-tested methods appropriate to the complexity of the social and political processes under investigation. The discourse and policy network methods allow the researcher to gather fine-grained but systematic information on the interactions among the ideas and organizations that make up processes of social and political change. This method allows researchers to peer into the inner workings of social and political processes at the middle level, and trace out how they operate as a society-wide system of relations among organizations engaged in influencing society and shaping national policy. For instance, the method provides empirical data on the different types of exchanges of information, political

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[1] This term for the unit of analysis or case avoids thorny debates about the case of Taiwan. However, as the term *cross-national comparison* is very well know, the project will sometimes use the term nation for summary reference.

support, trust and reciprocity and other influences among the engaged organizations (and also significant individuals). This new level of detailed information permits the precise formulation and testing of a new class of hypotheses about complex political and social processes.

13.2 Explaining National Responses to Climate Change

Since 1988 the Intergovernmental Panel on Climate Change (IPCC), established by the United Nations, has provided the world with increasingly certain *scientific information* concluding that climate change is real, caused by humans and disastrous in its consequences. The 1992 United Nations Framework Convention on Climate Change (UNFCCC), signed by virtually every country, established a new global *norm* – that all nations and areas should contribute to reducing atmospheric levels of GHG. The 1997 Kyoto Protocol, currently in its goal-attainment phase (2008–2012) represents humanity's first attempt at *regulation*, to secure binding commitments to reduce GHG emissions from industrialized countries. International agreements impinge on nations and other actors with these three stimuli: information, norms and regulations. However, nations differ widely in their responses.

Up to now, national responses to climate change have been haphazard. The Kyoto Protocol obligates the signing countries to an average reduction in their GHG emissions of 5% below their total 1990 levels. This 5% burden is distributed very unevenly, with some of the poorer countries given the right to increase their emissions by a great deal, with others have to reduce by much more than 5%. Of course, the Kyoto Protocol mainly included the more prosperous and highly industrialized countries. It explicitly excluded developing countries such as China and India that still needed to burn fossil fuels in order to grow and meet basic needs. Therefore, though the Kyoto Protocol takes path-breaking steps towards global governance of climate change, it is in fact a multilateral treaty among the limited set of ratifying nations. The fragility of this bold experiment was shown by the withdrawal of the United States from the treaty, on the grounds that it might hurt the US economy. All of the signing countries had such worries, and among them some had little intention to achieve the goals of the treaty. Since the initiation of the Protocol, some nations have made visible progress in reducing their greenhouse gas emissions levels, but others have not (see Fig. 13.1) (United Nations Framework Convention on Climate Change 2007). Figure 13.1 adds other large emitters to indicate the diversity of response to the problem itself. The new post-Kyoto regime currently under negotiation will have to include all large emitters and sinks, making compliance even more difficult.

The kind of variation in performance shown in Fig. 13.1 is likely to continue as the world tries to shape a post-Kyoto climate change agreement including all the significant GHG polluters and sinks. Unless a new, more inclusive treaty can elicit greater national compliance, it will fail to stabilize or reduce atmospheric GHG levels.

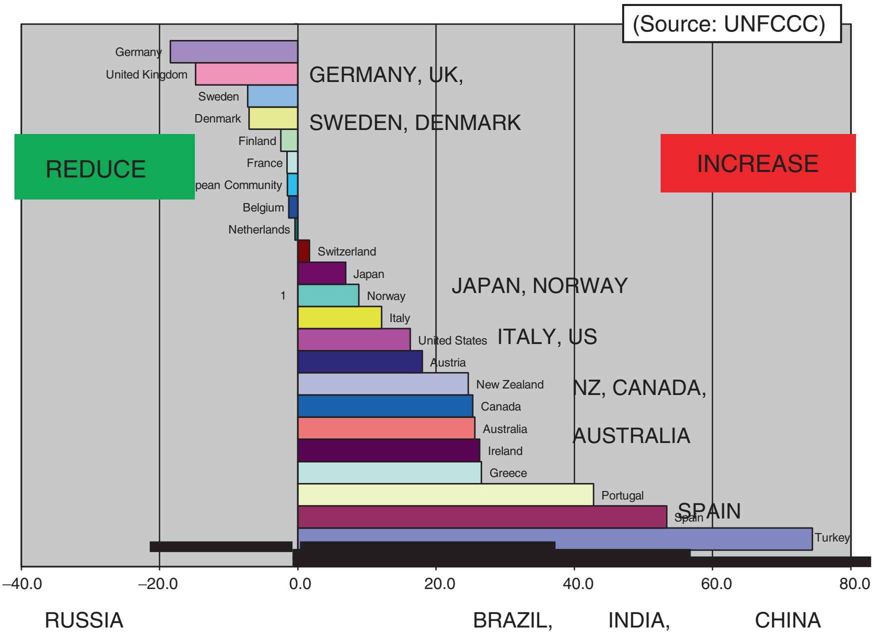

Fig. 13.1 Percentage GHG change (1990–2004)

Therefore, explaining variation in national response holds the key to successful global governance of this looming global problem.

National response to global climate change is a very complex process involving many interacting factors. The relevant factors can be broadly modeled as two dynamic fields – *discourse* and *action* – operating on a more stable background of *context*: basic social conditions (variously referred to by different schools of social science as institutions, structures or systems) that constrain, facilitate and channel the possibilities for discourse and action. The field of discourse represents the distribution of perceptions (beliefs, "knowledge") and interpretations (evaluations, frames, meanings) about climate change prevalent in a society.[2] The field of action represents the behavior of actors – individuals, organizations, states – as they interact to promote or oppose change. Both fields are social phenomena; that is, they are more than the sum of individual discourses and actions. They both have their own systemic dynamics and properties. Depending on the nation in question, contextual factors can make the dynamics of either field more or less solid and enduring or fluid and volatile. The more fluid the system, the more that actions interact with

[2] The concept of frame refers to how a person or organization places moral and normative meaning upon a given phenomenon, be it economic downturn, racial segregation, or change in the climate (Snow et al. 1986).

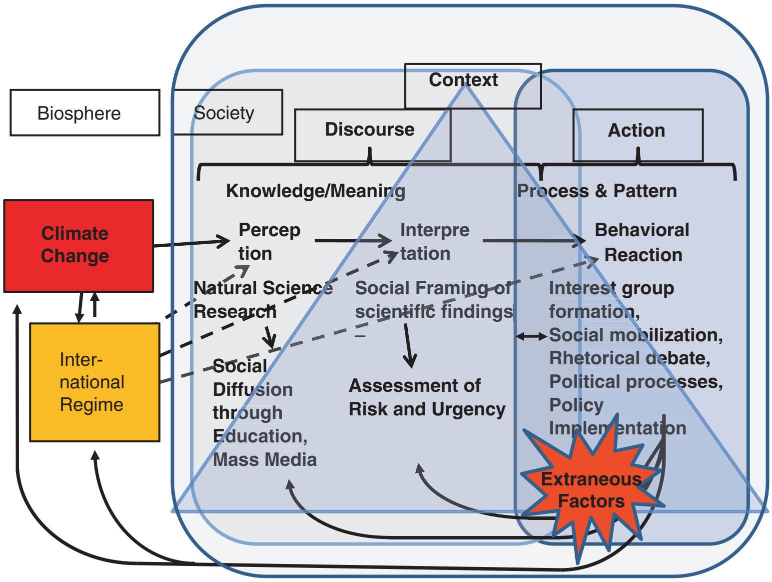

Fig. 13.2 Climate change reaction process

discourses to produce new forms of power and in the current concern, change societal practices and political policies affecting climate change mitigation. Figure 13.2 presents a hypothetical model of that process within the national arena and between national and international levels.

In the Fig. 13.2 schematic, the geochemical phenomenon of climate change is first understood by scientific research, and then diffused into fields of discourse (among leadership and public) through various media. Social actors initially accept or reject this scientific "claim" and frame it with varying levels of risk and urgency. Eventually, the issue stimulates social action; concerned groups mobilize for or against the new ideas. Discourse and action occurs with a context that supports some types and sanctions others. Extraneous factors such as economic recessions or unexpected climate disasters also influence reactions and outcomes. Early-reacting nations (such as Sweden) affect the initial formation of the international regime on the problem, which then feeds back into nations/areas to further affect their reactions. This cycle produces effects on the original geophysical phenomenon of climate change.

As the United States exemplifies, even the existence of climate change, not to speak of what to do about it, can be much contested (McCright and Dunlap 2003). In some nations, coalitions of climate change deniers attain great political power. The link between power and knowledge has long been stressed by social theorists (Foucault 1972). For change to occur, influential sectors of the population, especially its leading organizations, must learn new ways of knowing and framing an issue.

For instance, important authorities must change from denying the existence of climate change to accepting it as demonstrable fact. Moreover, they must decide that climate change poses great risks to the public good and national and global welfare, and treat it as a top priority. The physical qualities of a phenomenon (such as higher levels of atmospheric GHG or more hurricanes) do not directly determine its social interpretation. Rather, actors define a thing by attaching meanings and importance to it, building on their cultural predispositions, education, habits, news coverage, propaganda, social pressure, expectations and other factors. Sociologists call this process the social construction of an issue (Perrow 1984; Hannigan 1995; Eder 1996). At any given time, the field of discourse in a society around an issue – its current social construction – reveals the understandings and interpretations that help steer the social response. Change in the dominant discourses occurs through the mobilization of change-oriented actors, as enabled by the possibilities inherent in their contexts. Existing cultural and social conditions constrain the emergence of new discourses and the possibilities of their application to create change. The Compon project hypotheses express these defining conditions that cause variation in national climate change responses.

Since it occurs as a long-term geophysical transformation, climate change can only be known about through advanced, highly specialized scientific research on atmospheric chemistry and climatological processes. This knowledge is not accessible to the ordinary senses. Therefore, as different from many social problems, for non-specialists to perceive and understand this phenomenon requires them to place a great deal of trust and faith in climate science and scientists. That such faith is contestable is obvious from the presence and popularity of climate change deniers, who question the dominant scientific claims on many bases from the scientific to the religious. Even if the majority or most powerful actors of a society have accepted climate change and the risks it poses as fact, making the issue a top priority and acting on it to produce real social change and reduction of national GHG share is still very difficult to achieve. Since climate change is a global issue of unprecedented proportions, its vastness can induce individual actors, whether nations, organizations or persons, to dismiss their own responsibilities and efforts as insignificant or futile. For international climate change treaties to elicit the needed global cooperation, along with regulation and sanction, actors at all levels will have to think of their own contributions as significant, important and fair. This acceptance will spring directly from the risks posed by climate change threat itself or from global agreements, but will have to be cultivated and built through appropriate domestic social and cultural arrangements tailored to each country.

To successfully mitigate climate change, at some point domestic actors must move beyond discourse and engage in action that changes the existing patterns of energy sourcing and usage that cause the problem. Thorough change will proceed through a combination of persuasion and, once new regulations are in place, sanction. Individuals by themselves, no matter how powerful, cannot bring about such vast changes. Such change requires the mobilization of collective action, either by a few powerful actors or by many less-powerful actors. Would-be change agents have to form groups, mobilize movements and join coalitions to persuade and pressure.

However, collective action faces a fundamental social obstacle. Controlling and reducing climate change is a huge public good– it will benefit all of humanity and most other species as well. However, the early actors that push to solve the problem are often not highly valued or rewarded for their services. Rather, the stream of personal benefits flows to actors who stay within comfortable or known routines and continue business-as-usual. Due to this imbalance, all sorts of public goods – from pot holes to public health to climate change – tend to get neglected. This neglect is a basic flaw in the economic theory of the market. Instead of an "invisible hand" that benefits all, in terms of its effect upon the environment, the market produces an "invisible foot" (or in economics terms, an externality) that kicks us all (though some more than others) (Daly and Cobb 1989).

This social mechanism is known by many names: the common resources problem, the Prisoners' Dilemma and the Tragedy of the Commons (Dietz et al. 2002). Applied to the difficulty of mobilizing actors to protect their common welfare, it is called the *dilemma of collective action.* Since the benefits of protecting a public good will go to everyone anyhow, why should any individual rational actor bother to help in the protection effort (Olson 1975)? These inertial mechanisms operate at all levels of social organization, from inter-personal to inter-national.

Politics is essentially about solving public goods problems, and though messy, it sometimes ends up protecting the public good. But it depends upon vociferous campaigning, either within a limited circle of elites or more widely throughout society. Such mobilization depends upon many cultural and social conditions. Mobilization can be stimulated by moral and social as well as material incentives, from norms about defending the public good to peer pressure to provision of financial resources. It also depends upon the costs imposed by opponents and political regimes (McAdam et al. 2001; Goodwin and Jasper 2004). Once mobilized, groups often form coalitions to strengthen their common influence. Movements and coalitions appeal to mass publics asking for voluntary change, but also pressure government to pass regulations that enforce changes on everyone (for instance, by placing a tax on fossil fuels to discourage their use). In so doing, they often give rise to counter-movements and opposing coalitions that try to stop such changes. In this way, the field of action can display dynamic swirls of interaction. Depending on the social context and the issue, the dynamics of change can involve mainly tense negotiations among high-level government officials and politicians, or can rise up from ordinary citizens who protest on the streets, or many other combinations of actors.

A descriptive comparison of the reaction of Sweden and the United States to climate change will put some flesh on these theoretical bones. The two cases' GHG outcomes differ greatly. Sweden ratified the Kyoto Protocol while the United States refused to do so. Figure 13.1 shows that Sweden is among the top achievers in attaining its Kyoto Protocol emissions reduction goals, while the United States has greatly increased its GHG emissions. Starting in the 1990s, Sweden passed policies to reduce its GHG emissions levels. But the US did nothing until the Energy Bill finally passed under President Obama in 2009, and the effectiveness of that bill is still in question. Evidently, Sweden found a way to overcome the dilemma of collective action and serve the long-term global public good, while the United States did not. Investigating their climate change response processes, we find that the two cases differ in their qualities of discourse, action and context. The current comparison is tentative based on the authors' initial field interviews in Sweden plus general information on the U.S. and is intended for heuristic purposes to demonstrate the model and generate hypotheses.

In the *discourse field*, on the whole, the Swedish media seem more favorable to the validity of science than the US media. Culturally, the Swedish public also has a more accepting orientation toward the validity of science than the bifurcated US public, which is more heavily influenced by the rejection of scientific logic. Also, in Sweden climate change scientists play a stronger role in the formation of policy through their participation in multi-stakeholder discussion forums. Through their rational discourse, such forums seem to amplify the spread of agreement on the conclusions supported by the most evidence, which would tend toward acceptance of scientific assessments of the risks posed by climate change. In the US, conversely, stakeholder participation in policy formation tends to take place in secret by lobbying groups or else in adversarial public hearings that are not oriented to discussion and mutual learning. Scientists play very different roles in the two societies. The intellectual independence of the domestic climate change science community is high in both countries. However, the legitimacy of the domestic climate change science community is relatively unquestioned in Sweden, whereas in the US it is highly contested. In Sweden climate change scientists seem to play much more central and determining roles in policy formation. In the 1980s, as the climate change issue arose, compared to the US, Sweden probably had a more highly developed set of existing discourse networks and cooperative patterns built up among many stakeholders that could be mobilized to confront the climate change threat. Therefore, the potential for social learning was much higher in Sweden than in the US.

In the *action field*, the political strength of advocacy coalitions for taking action against climate change seems very strong in Sweden and relatively weak in the US. As noted above, in Sweden these coalitions have more chances to participate in and influence the policy-making process than in the US. At the same time, the array of economic interest groups that are highly invested in fossil fuel production, sales and consumption, while important to the industrial systems of both societies, seem to be much stronger and exercise much more political power in the US. US political institutions, wedded to the pluralist contention of interest groups lobbying Congress with the wealthier ones able to buy more influence, tend to give dominance to powerful business groups. In contrast, Swedish political institutions, as forms of social corporatism formed in the aftermath of World War Two, give much more equal representation to all sectors of interest groups: business, labor and farmers. The long dominance of the Social Democratic Party in Sweden has tempered all these groups to think about the larger and longer term social good as well as their own immediate benefits. But in the US, the political system virtually forces all economic groups to pursue their immediate short run benefits or be left out. While both societies display strong and active citizens' groups devoted to various causes of the social good, in Sweden the environmental NGOs seem to have attained stronger incorporation into the corporatistic policy formation process, while in the US, such groups are more left outside that process, especially during eras of Republican political dominance. It would seen that the interaction of these differing factors, probably plus others to be discovered, affected the discourse and action phases of the two societies so as to produce very different reactions to climate change and GHG outcomes. As the Compon research project matures, it will be able to greatly refine and specify the effect of these and other factors through empirical multi-national comparison in the evolving global regime and climate change context.

National reactions interact with and help or hinder the formation of global regimes. In the late 1980s, Sweden reacted first among nations to global climate change – its climate scientist Bert Bolin set up a scientific council to assess the data on the phenomenon (Bolin 2007). In a few years, Bolin's Swedish council became the model for the global IPCC, with Bolin as its first leader. This early-riser behavior indicates that in Sweden the underlying conditions were very favorable to climate change action. The diffusion of scientific knowledge from the IPCC was crucial in setting up the international climate change regime – the UNFCCC, established at the Rio UNCED in 1992. Almost all nations in the world signed the UNFCCC framework, which stipulated a common moral commitment to work to solve the climate change problem. Thus, in addition to scientific knowledge, the UNFCCC added a moral or normative stimulus to the climate change issue around the world. Exactly how these two stimuli affected national behavior is unclear, but they did encourage governments to convene the Kyoto Conference. In turn this created the Kyoto Protocol, the first agreement to set clear reduction targets for the prosperous or industrialized countries (in the UNFCCC, Annex 1 countries) and to speak about sanctions for non-compliance (though not enact them).

This two case descriptive comparison illustrates how cross-national differences in discourse, action and context can help explain the cross-national patterns and principles of reaction to climate change. To develop formal hypotheses about the factors explaining these differences, though, we cannot draw from descriptive case studies alone, but must also bring to bear ideas from existing social scientific research and theory.

13.3 Causal Hypotheses

The COMPON project develops and tests hypotheses about how discourse, action and context interact to produce different degrees of climate change mitigation. The reaction processes occur of course not only at national but also international as well as at sub-national and regional [EU] levels and these will be included in the analysis. In each national unit, though, unique fields of discourse and action interact with national and other contexts to produce very specific processes and outcomes of

Table 13.1 Conditions of discourse and action

- International
  - International regime (information, norms, rules)
  - World political-economic system position
- National
  - Geophysical factors (resources, vulnerability)
  - Demographics: population size, development and prosperity levels, carbon intensity of economy…
  - Cultural orientations toward science, public good…
  - Networks that can facilitate learning and mobilization
  - Mobilization of movements/advocacy coalitions
  - Effects of institutions on discourse and action
  - Relative power of fossil-fuel dependent interest groups
  - Participation in formation of international regimes

mitigation. Finding social principles that explain more than one national case has long been the goal of cross-national comparative social science (Tilly 1984). While each national unit has its unique aspects, there may be more general principles that govern how more than one of them, perhaps a category of them (developed/developing, democratic/authoritarian, etc.) wrestles with the thorny task of mitigating climate change (Table 13.1).

In explaining a national reaction process, its level of development and type of economy will of course be very important. Less-developed countries use their lower levels of prosperity to justify exemption from GHG emissions reductions, arguing that the more prosperous nations bear the major responsibility. In contrast, national dependence upon external sources of fossil fuels may prompt support for the development of alternative types of energy, sometime nuclear rather than sustainable ones. Fears of losing international trade competitiveness is causing many trading nations to hesitate to go first in imposing costly emissions reductions measures on their own industries. Frames representing such concerns will show up in national discourse fields and be carried by advocates into political contention.

As outlined in Fig. 13.2, for individual actors as for whole societies, the path to action about climate change depends first of all upon acceptance of the dominant scientific consensus as valid and factual. The next step is to frame that knowledge as urgent, so that the risks of inaction outweigh the costs of action. This depends on raising the financial or moral costs of inaction (by taxes or conscience) or by lowering the cost of action (by subsidies or building confidence in burden-sharing). The spread of new knowledge and new ways of framing it is strongly facilitated by existing networks: "stakeholder beliefs and behavior are embedded within informal networks" (Sabatier and Weible 2007, p. 196). Accordingly the creation of networks through stakeholder participation may be crucial to spreading belief and action. Existing network patterns and cultural orientations exert independent effects upon variation in national reaction to the international climate change regime (Tompkins and Amundsen 2008).

In order to change behavior at a social level, the initial bearers of claims and norms must expand networks, persuading an increasing circle of adherents until their number and activity reaches a critical mass. In this process, social learning must turn into social mobilization. Gaining new voluntary adherents can proceed as far as possible through persuasion. However, given the high degree of social inertia and disinterest, personal voluntary action will never suffice to change social behavior enough to effectively reduce atmospheric GHG concentrations. To attain that goal, advocacy coalitions will have to attain sufficient political power to enable them to pass and enforce regulations and laws that demand and enforce certain general standards of behavior, such as a cap and trade law or a carbon tax. When a mobilized *advocacy coalition* wins enough support to form a majority government, it becomes able to control the central levers of the state, the law and policy-making process. From that vantage point, the new regime can establish the legal and policy conditions to bring about society-wide change in behavioral norms (by education, persuasion, inducement, regulation, new institutions and other means).

An international research project on national compliance to international environmental agreements, the Social Learning Project (SLP) led by William Clark of the Kennedy School of Harvard University, concluded with an hypothesis about the decisive type of social action needed to bring about national compliance. The SLP concluded that the key factor bringing about effective national response to global environmental problems was the *strength of the advocacy coalition*:

> *. . . . the motivating force for most of the changes we observed were coalitions of actors more or less loosely joined for the express purpose of affecting issue development. Many of the most influential coalitions were international in character (Social Learning Group 2001, 187).*

This concept of advocacy coalition conjures up an image of political contention, with opposed sides struggling to attain their favored goals. This may be the case, as the theory of the Treadmill of Production argues (Schnaiberg et al. 2003). If so, research would validate a *contention hypothesis*:

> *Attempts to create a climate of discourse favorable to strong measures against climate change will arouse such intense opposition that the only way to make change will be through powerful social mobilization, victory in elections and the implementation of government regulation.*

However, advocacy coalitions could also only be vehicles for persuasion and education transforming the society to a new point of view. This is the assumption of the theory of Ecological Modernization (Janicke 2002; Mol and Sonnenfeld 2000) and produces a *diffusion hypothesis*:

> *Social learning will come about through a gradual diffusion of new ideas and goals into a society in a non-politicized learning process where the eventual consensus will become so strong as to directly prompt large-scale voluntary changes in behavior and policies.*

The Social Learning Group (SLG) stressed the inadequacy of social science methods for explaining their advocacy coalition conclusion and expressed that they had arrived at this conclusion almost by accident after their long research project. They stressed that the Social Learning Group project was "not designed as an exercise in developing or testing propositions about the growth and impacts of such actor coalitions or interest networks" (187). Picking up this baton, the Compon project not only explicitly develops and tests such propositions but furthermore examines the conditions for their effectiveness through cross-societal comparison.

Action about climate change occurs within the set of organizations and persons directly agitated and concerned about the issue. Social scientists call this set of actors a *policy domain*—all the organizations in a society that direct their concerns and activities toward a specific issue (Burstein 1991). In these terms, the Compon project studies and compares the climate change policy domains of different countries. The organizations in a policy domain can come from many different social sectors: government agencies, political party committees, business associations, labor unions, scientific research centers, local governments, non-governmental organizations, mass media, religious organizations and social movements. They can also include individuals who serve as crucial leaders, mediators or knowledge brokers. Given the global breadth of climate change, national climate change domains include international actors from the same range of sectors. The different national climate change policy domains have in common a reference to the same global regime exemplified by the UNFCCC, the IPCC the Kyoto Protocol and post-Kyoto agreements. Each national Compon team constructs a list of relevant organizational actors for their country and interviews representatives of these organizations.

In the international debates around the Kyoto Protocol and the formation of the post-Kyoto regime, there are three major points of disagreement: targets and timetables (who bears what burdens of GHG reductions and by when?), technology transfer (should developed countries charge less developed countries for GHG reduction technology?) and financing mechanisms (how much should developed countries pay less developed ones to help reduce GHG levels?). Currently a fourth major point has emerged: how to attain reductions in deforestation and forest degradation (REDD). In general, developing and more immediately vulnerable countries argue that the developed countries are most responsible for problem, and thus should bear the major burden of fixing it. But net of development and vulnerability, nations exhibit considerable variation in their mitigation of climate change (Table 13.1).

Specific hypotheses about the causal factors conducive to effective societal mitigation of climate change, derived from previous theory and research and focusing on features of societal discourse, action and context guide our research. The hypotheses use the general term "take effective action to mitigate climate change (CC)" to refer to the specific actions most appropriate and possible for a given nation. Such actions range from the societal culture and the behavior of specific types of actors to the qualities of existing institutions. Response methods will vary by society with the bottom line being its trend in contribution to the reduction of global atmospheric GHG concentrations. The hypotheses are stated in terms directly testable by empirical discourse and policy network data. Space allows only a brief statement:

H1: *The more receptive the national culture to findings produced by the scientific method, the more the nation will assign high risk to climate change and find appropriate ways to mitigate CC.*

H2: *The more legitimate and politically engaged the domestic climate change science community of a nation, the more the nation will accept the dominant scientific consensus about CC.*

H3: *The more the national media promulgate the dominant scientific information and global norms about climate change, the more the society and government will mitigate CC.*

H4: *The more that norms in favor of the public good are embedded within social networks among organizations, the more the nation will mitigate CC.*

H5: *The more receptive the national culture to collaboration to enhance the public good, the more the nation will mitigate CC.*

H6: *The more powerful are interest groups that defend activities dependent upon fossil fuel use, the less will the nation mitigate CCs.*

H7: *The more that the national political institutions equalize the power and representation of different sectors of interest groups in the political process, the more the nation will mitigate CC.*

H8: *The more that the political system provides venues for broadly representative and egalitarian stakeholder participation in the formation of policies, the more the nation will mitigate CC.*

H9: *The greater the autonomous capacity of the civil society (NGOs and NPOs supported through fees and donations from membership), the stronger will be the advocacy coalitions in support of mitigating CC.*

H10: *The more that pro-mitigation domestic organizations can utilize existing social networks to mobilize support, the more the nation will mitigate CC.*

H11: *The more that domestic organizations participate in the international regime formation, the more the nation will trust and comply with the retime and mitigate CC.*

These hypothesized factors will present themselves in different mixtures depending on the case. The technique of Qualitative Comparative Analysis (QCA) allows the researcher to discern their additive and interactive effects upon the outcomes of interest: national contribution to the reduction of atmospheric GHG concentrations (by reduction of emissions or protection of sinks such as forests) (Ragin 1987). An illustrative QCA table follows just before the concluding section.

13.4 Research Methods

As the Social Learning Group noted, previous social science methods had proven inadequate to test their concluding advocacy coalition hypothesis. Previous social science methods use interviews, published materials and news media, historical records, census statistics, and representative random or more targeted surveys of individuals. These methods are not well suited to measuring *networks of actors* and discourses as they engage in attempts to change the behavior and politics of their society. In order to collect such data, the Compon project uses discourse and policy network methods. Network analysis focuses on the relationships among actors; the common possession or transfer of a certain belief from actor to actor is one type of relationship. When traced in its flow among many actors, it produces the image of a network. The policy network method applies this approach to the study of political processes. The policy network method grows out of quantitative network analysis, used in sociology since the mid-1970s (Freeman 2004; Wasserman and Faust 1994). Pioneering work comparing US and German community politics using quantitative network methods (Laumann and Pappi 1976) led to the quantitative policy network method (Laumann 1979; Laumann and Marsden 1979). Applied first in studies of the United States national political system (Laumann and Knoke 1987; Heinz et al. 1993), the method quickly spread to a wide range of studies (Knoke 1990; Anheier 1987). A comparison of the US, Germany, and Japan (Knoke et al. 1996), including the current author, accomplished the first cross-national comparison of the mature policy network method and provides the basis for the current study. The method has since blossomed in many qualitative and quantitative studies (Kenis and Schneider 1991; Marsh 1998; Raab and Kenis 2007; Schneider et al. 2007).

The Compon project radically expands the comparative scope of policy network research. It currently includes investigator teams from different disciplines representing 16 cases. The project includes the crucial BRIC bloc of developing and transitional countries, Brazil, Russia, India and China. Without their compliance, the world cannot mitigate climate change. The cases also include a variety of industrialized countries: East Asian examples (Taiwan, South Korea, Japan); European-style ones (New Zealand, England, Germany, Sweden, Austria, Greece) and North American cases (United States, Canada) and the transitional case of Lithuania, plus the global level networks among organizations influencing the formation of the post-Kyoto international regime as a distinct case. Developing countries, including Mexico, are currently in preparation. The cases vary on factors that influence capacities and propensities to mitigate GHG emission levels or protect sinks (forests), such as natural resource availability and geophysical vulnerability as well as many features of discourse and action fields and context. The Compon project is modular, so researchers can add new country cases at any time (contact the PI: broad001@umn.edu). The Compon survey will be repeated at 5–7 year intervals and produce a publically-available data set for the comparative study of changing national reactions to global climate change over time.

Each Compon country team will conduct a survey-based case study on its national (or international) case. As a first step, each team will use media content analysis and expert interviews to determine the list of organizations in its own national climate change domain, the major points of and protagonists in debates about climate change, and the main recent national and international policy-decisions. The total organizational list will consist of between 50 and 120 engaged or influential national organizations of all types per country, plus about 30 common key international organizations (including the IPCC). Compon data will come from three sources: media content and discourse network analysis of three leading newspapers of different political persuasions, in-depth interviews with experts and organizational representatives, and a quantitative network survey of the identified organizational actors.

To facilitate the data collection, following the model in Fig. 13.2, the Compon project collects data on national response processes occurring in and between the discourse and action fields as well as from news and other media, in-depth interviews and secondary sources (Fig. 13.3). The discourse field consists of a distribution of frames (expressions of belief and evaluation) relating to climate change. The action field, in contrast, consists of the activities of actors (organizations and important individuals) as they seek to persuade or dominate others and affect policy-outcomes. When actors advocate similar frames without necessarily knowing each other, they produce actor-discourse networks. When the actors hold the same frames and cooperate in mobilization and advocacy coalitions, they generate action networks. The distinction between two types of networks hinges on the presence or absence of direct social relationships among the actors.

For data on the discourse field, the Compon project will draw information from all three sources. Content analysis of newspaper articles in three major newspapers and important records such as legislative debates will reveal many of the debates and frames active in field of public discourse as well as the actors that espouse them. This task will utilize the relational software Discourse Network Analysis

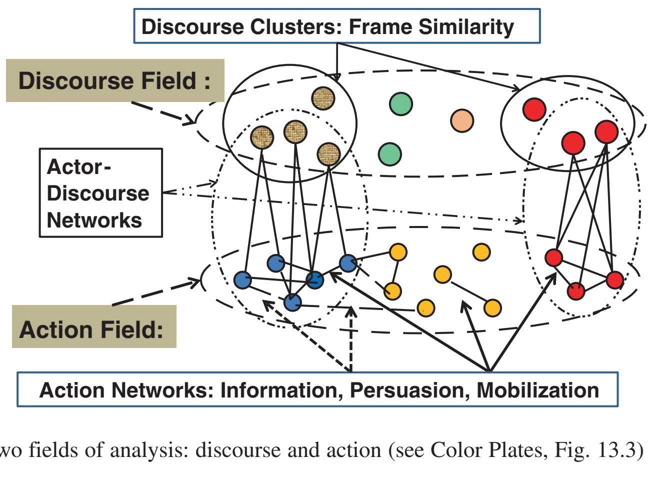

Fig. 13.3 Two fields of analysis: discourse and action (see Color Plates, Fig. 13.3)

(written by Philip Leifeld). The in-depth interviews and organizational survey will also procure data on the frames held by different actors.

As scientific information about climate change diffuses through the discourse field, evaluative norms come into play. Norms carry habitual criteria for evaluating climate change, from irrelevance to denial to worry about personal material loss to concern with its impact on humanity or the global ecosystem. Actors using different normative standards will necessarily disagree about what to do. Only some actors will accept sufficient responsibility to seriously think about, evaluate and act upon the issue.

For data on the field of action, the project will use in-depth interviews and the quantitative survey, as well as actor-discourse networks from the media analysis. The quantitative survey will gather information on the networks among organizations, including the transfer of vital scientific information, vital political information, and mutual engagement in negotiation or coalition. The network survey will also ask respondents to assess relative organizational influence in politics. In this way, the project will gather the empirical data needed to study the mutual shaping of discourse and action in the process of social mobilization around climate change.

Evaluative norms spread through discussion networks among organizations and individuals, as well as through mass and specialized media. Organizations learn through their networks and peer pressure about what evaluations (frames) to adopt. Some organizations can dominate the spread of frames, imposing frames upon obedient subordinates, or the diffusion can be interactive, through rational discussion among peers. The learning style will affect the quality of national response to climate change. Specially designed survey questions will trace these networks. For example, the Compon network survey will ask: "from which other organizations does your organization receive valuable scientific information about climate change?" And "with which other organizations does your organization mutually discuss the issue of climate change." To the degree that the two networks trace the same pattern, the findings will indicate a discursive style of learning.

Tracing the flow of information and norms through networks will help indicate the function of institutions. Agenda 21 and other sources argue that egalitarian forums for stakeholder participation are crucial for resolving environmental problems (Ruckleshaus 2005). With optimal function, such forums may help the diffusion of scientific evidence and risk evaluation. In the network data analysis, if a diversity of organizations have information networks to such a forum, and also hold scientific and action-oriented norms, it will indicate that the forums do indeed have the predicted function.

Other network questions will concern sources of political support (defined as a public display of solidarity with the respondent organization's policy stance on an issue). Partners in political negotiations and in advocacy coalitions are also important networks. Such networks often build upon longer existing relationships, such as the long-term exchange of mutual aid (reciprocity). These networks suffuse societies in different densities and patterns, helping give rise to different policy-making processes. For instance, the reciprocity network penetrates the full Japanese field of labor politics very thoroughly, but in the US is only present among labor unions (Broadbent 2001, 2008). In the Japanese case, the presence of reciprocity networks increased the likelihood that the so-connected actors would transfer information and political support. Other network questions will concern perceived influence, leadership roles, informal socialization partners, and organizations with determining influence over one's own organization's policy stances. In this way, network questions provide indicators of the relative power of organizations in the system (as indicated in Fig. 13.4).

In addition to network questions, the Compon survey will ask for other types of information in the following categories: levels of organizational effort in issue areas (i.e., energy technology, policy formation, scientific research, education, etc.); types of organizational activity (advocacy, legislation, providing discussion forum, etc.); organizational participation in policy formation processes (i.e., government discussion of cap and trade policy, political pressure tactics, level of satisfaction with outcome); and finally, the resources of an organization (i.e., membership, professional staff).

13.5 Illustrative Analysis of Information Network: Japan Case

Some initial findings from the Compon project Japan case as well as from an earlier analysis of Japan's global environmental policy network will give the reader a better grasp of the approach and how it can be applied to hypotheses about processes of social and political change. The illustrations here present some network images derived from the survey, but do not go into the more detailed statistical analyses that a full analysis will entail. The results from the Compon Japan case address initial findings the field of climate change discourse as it is indicated by the attention paid to the issue by three national newspapers over time.

These findings show the rise and fall of media attention to climate change over the years from 1997 to 2008 (Fig. 13.4). From a high point in 1997 at the time of the Kyoto Conference, media attention suffered a precipitous drop during the "lost decade" of severe economic recession, but a renewed surge with the issuance of the IPCC Fourth Assessment Report in 2007. The FAR stated with virtual certainty the anthropogenic causes and disastrous consequences of climate change. Figure 13.4 represents on the most superficial level of analysis of the discourse field, preceding more detailed media coding and survey data.

Turning to the field of action, data from the GEPON survey are useful. A team conducted a policy network survey of Japan's global environmental politics domain in 1997, just before the hosting of the Kyoto Conference (COP3) in Kyoto, Japan. Entitled Gepon (Global Environmental Policy Networks), the survey itself was modeled on the team members' previous policy network survey in Japan that concerned labor politics (Knoke et al. 1996). Along with global climate change, the Gepon project also considered acid rain, ozone layer depletion and other global environmental issues. While initially proposed by the author of this article, the survey was funded, designed and mostly carried out by Professor Yutaka Tsujinaka of Tsukuba University. About a year later, the author of this chapter conducted five

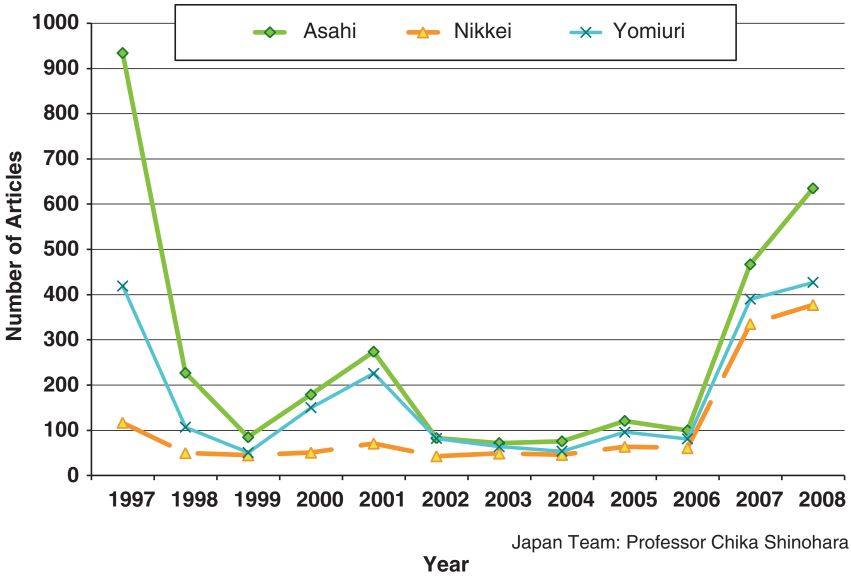

Fig. 13.4 Climate change newspaper articles annual number 1997–2008

additional interviews using the same survey form to supplement important organizational responses missing in the original survey.

The Gepon project identified the organizations active and influential in Japan's global environmental policy domain at that time. In this case, the organizational list included 122 domestic organizations all of which were surveyed. The list also included 30 international organizations that were not directly surveyed, but which domestic organizations could check as sources of information or other network relationships. The survey asked several network relations, one concerning the exchange of important information. The exact wording of the question was as follows:

> *Concerning the political process on global environmental issues, it is important to exchange scientific and political information. Over the past one to two years, with which of the following list of organizations has your organization exchanged that kind of information? Please check all organizations that apply.*

The responses to this question (and other network questions) from the 122 organizations were converted into a matrix of 122 rows by [122+30=] 152 columns (the 30 extra organizations represent international organizations such as the World Bank, the Climate Action Network, and others). Each cell in the matrix (122×152) represents a potential exchange of information between two organizations. The number of exchanges engaged in by an organization is indicated by its degree score. Since information exchange indicates a reciprocal transfer of information, ideally the in-degrees and out-degrees of a domestic organization should be equal. But sometimes two organizations do not both acknowledge the relationship (check each other). The data in the network image is based only on mutually-acknowledged exchanges of information, thereby helping its reliability (this does not include international organizations which were not surveyed directly). Since information can be exchanged or transferred without loss, information networks tend to be denser than networks of mutual aid in more material ways. Figure 13.5 well illustrates that density.

This network image is not hand-drawn; it was generated from the empirical network data by a computer algorithm in a network software program (Borgatti et al. 2002). Despite its initial impression of impenetrable complexity, a closer examination of Fig. 13.5 reveals some principles of its macro-formation or structure. These principles help explain Japan's information exchange system about global environmental issues in 1997. The colored geometrical objects (icons) within the network represent the 122 responding organization plus, on the outer periphery, the 30 international organizations. Each organization has its acronym label close by. The double triangles (yellow) represent business organizations, the squares (blue) government agencies, and the circles (green) environmental NGOs, all domestic to Japan. Among the governmental ministries and agencies (blue squares), those with internal lines cutting them into four sections represent departments within Japan's

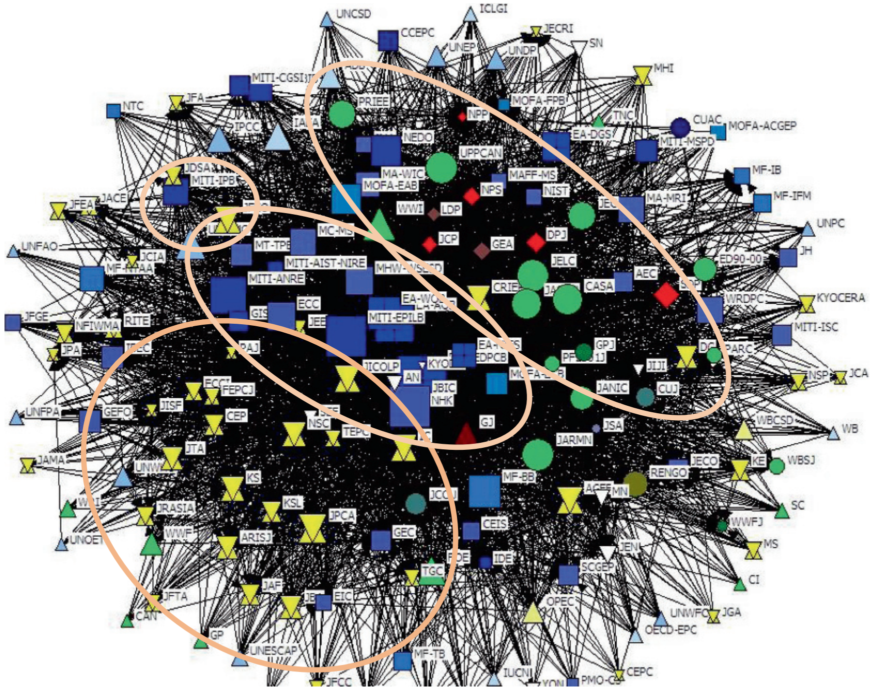

Fig. 13.5 Japan global environmental information network, 1997 (see Color Plates, Fig. 13.5)

Environmental Agency (*Kankyocho*). Single diamonds (brown or red) represent political parties, with the brown ones being the ruling Liberal Democratic Party and one of its agencies, and the red ones the parties out of power (Japan Socialist, Democratic Socialist, and Japan Communist Parties). Inverted triangles (white) represent news organizations. International organizations, which were not surveyed directly but have scores from being checked by domestic organizations, appear as upright triangles (their colors in the same typology as domestic ones, light blue for government, light green for environmental NGOs, etc.). Because the international organizations were not surveyed directly, they are mostly in the periphery of the formation. In this image, the size of the icon indicates its degree score – the number of times it was checked by other organizations as being a partner in information exchange. The bigger the icon, the more it exchanges information with other organizations. The relative centrality of a domestic-organizational icon in the network indicates its relative importance as a hub for conveying information among other organizations that do not directly exchange information themselves.[3]

What does this network diagram tell us about Japan's global environmental information flow pattern in 1997 just before the country hosted the Kyoto Conference? At this point, the entire political society was highly activated about hosting the Kyoto Conference, the third Conference of Parties to the UNFCCC. First of all, it shows that government agencies (the blue squares) were the biggest conveyors of information and occupied the central location in the entire information network. This is to be expected since the Kyoto Conference was a government sponsored event hosting delegations from many foreign governments. However, this may also reveal more persistent patterns in Japan's information flow system. Among the government agencies, the three largest ones, closest to the center, were the Global Environment Department, Planning and Coordination Bureau (GEDPCB) of the Environmental Agency (its title and icon partly obscured behind another icon), the Environmental Protection and Industrial Location Bureau of the Ministry of International Trade and Industry(EPILB-MITI), and the Japan Bank for International Cooperation (JBIC), which handles the financial aspects of Japan's international environmental development aid programs. Other government agencies cluster nearby forming a central blue axis to the entire figure. The two tiny white triangles (Asahi Newspaper-AN and Kyodo News Agency-Kyodo) embedded within the government sector illustrate the well-known dependency of the Japanese news media on the government bureaucracy to obtain information. However, the tiny size of the mass media icons indicates that they did not exchange information much with other organizations on the one to one basis. Rather, their major function in the information flow system was to inform the total society indirectly through their publications and broadcasts (Kabashima and Broadbent 1986).

In a society like Japan in which the formal government bureaucracy plays such a central role in the political process, with the major role in developing most national policies, their centrality in the information flow system should come as no surprise.

[3] For an explanation of network analysis concepts see (Wasserman and Faust 1994).

But to see an empirical map of these central actors ensconced within the entire information flow system and their relation to other actors and clusters helps define the operating principles of the system throughout the whole society. For instance, the figure reveals that business (yellow double triangles) and environmental NGOs (green circles) cluster on opposite sides of the central government actors and exchange a great deal of information within their respective clusters. Only one business organization takes a more central role in the whole pattern, the Japan Federation of Economic Organizations (JFEO or Keidanren) positioned at the top of the pattern near the government agencies. This network formation indicates that at this time, government agencies largely performed the role of intermediaries or bridge-keepers for the flow of information between business and NGOs and to the entire society.

The centrality of bureaucracy is in stark contrast to the relative marginality of the political parties as information hubs. The political parties, both the dominant one (Liberal Democratic) and those not in power (Socialist, Communist), are clustered together for information exchange. In Japan, the paucity of staff for Diet members reduces them to getting their information from the bureaucracy and other organizations, including business and NGOs, rather than researching and creating their own sources of information and analysis (as plentiful staff allow United States Congressional representatives to do). This figure of course places organizations according to their information exchange centrality, not to their policy decision-making capacity, which is quite a different concept. In that regard, the survey includes a measure of the perceived political influence of organizations in Japan's climate change policy domain which we will examine next.

The next figure extracts a specific network of interest to this chapter (Fig. 13.6). In this case, the network displays the set of organizations in Japan that directly received information from the IPCC. This is of course an extremely important set of organizations, because they function as the bridge-keepers between international and domestic information pools. They transmit information from the international scientific community into the domestic Japanese society and politics. Figure13.6 uses the score for perceived influence for the size of the nodes. This score is simply the number of respondents that checked off the organization as being either very influential or somewhat influential (appropriately weighted).

The network image of Fig. 13.6 shows a large and diverse set of organizations that directly received information from the IPCC in 1997. They are in their same placement as in the full network. These organizations include a large number of government agencies (blue squares), and large number of business organizations (yellow double triangles), some political parties (the brown and red diamonds), two environmental NGOs (green circles) and many media companies (white triangles). The remaining brown triangle is Globe Japan, an international association of national politicians concerned about global environmental issues. The size of the icons reflects their perceived level of influence in Japan's domestic politics of global environmental issues (as determined by the number of respondents checking that organization as being "especially influential"). The centrality and size of government agencies and their closeness to the media helps explain the precipitous drop in media attention to climate change after 1997 revealed in Fig. 13.4.

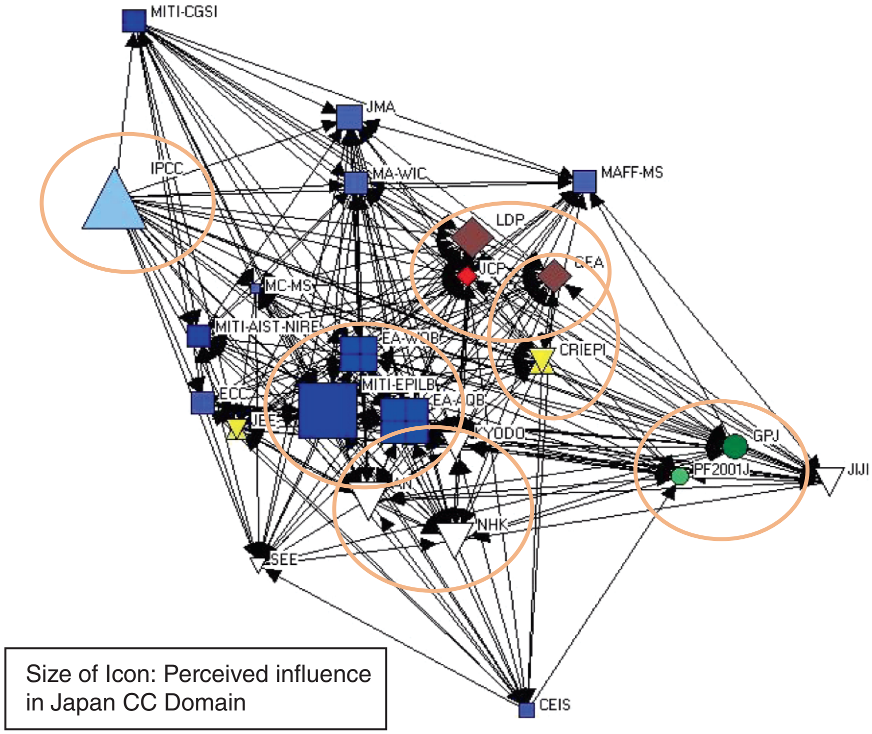

Fig. 13.6 Domestic organizations receiving information directly from IPCC (see Color Plates, Fig. 13.6)

Evidently, media attention is closely tied to government engagement in the issue, which also declined after 1997.

As compared to the information centrality held by government agencies in Fig. 13.5, the network image in Fig. 13.6 reveals a somewhat wider dispersion of political influence (indicated by the size of the icons). The network image indicates the very surprising conclusion that in the 1997 Japanese global environmental policy domain, the IPCC was among the big three influential organizations! The other two are the JFEO or in Japanese, *Keidanren* and the EPILB-MITI (noted in Fig. 13.6 as MITI-EPILB). Among the government ministries and agencies, the Air Quality Bureau of the Environmental Agency (AQ-EA) is second to the MITI bureau. The network image also reveals strong levels of perceived influence for the three news media clustered close to the government agencies. The Liberal Democratic Party is also assessed as highly influential, while the Japan Communist Party is diminutive. Business associations have almost entirely dropped out of the picture because they do not receive climate change information directly from the IPCC. Rather, businesses hand over this information gathering task to a specialized business research institute, the Research Institute of the Electric Power Industry

(CRIEPI), from which they probably get most of their information (a proposition for testing with this data). In another surprise, almost all of the domestic environmental NGOs do not receive information directly from the IPCC. Instead, the Japan branch of Greenpeace International serves as the primary information bridge-keeper to the domestic NGO community. This network figure indicates that in Japanese society the information bridge-keepers between outside and inside are relatively few, and those that perform this role have relatively high levels of political influence. This finding is in line with the network theory that being a bridge-keeper over a structural hole (a gap between clusters of organizations) gives power to the bridging actor (Burt 1992).

This brief review of one network in one country and one subset network within it only takes the first, most superficial step into the analytical capacities of the policy network method and indicates findings relevant to our hypotheses. We would want to examine the other networks, of course, such as political support, and their relationship to each other. For instance, do political support networks overlap with (predict) information flow networks or not? We would also want to examine the relative policy success of the different organizations, and the coalitions they forged to produce those outcomes. There are many techniques of network analysis that can be brought to bear in such an analysis. Matrix correlation, for instance, will enable us to examine the degree to which one network overlays another, indicating a confluence of two types of relationships. Using the other sorts of data in the survey we can probe the effect of organizational resources and networks upon the relative political effectiveness of different coalitions. Previous policy network surveys have not included the attitudes, beliefs and frames that the Compon survey will tap. With this data, we will be able to cluster actors by their beliefs and frames, and investigate how these affect the formation of advocacy coalitions. In short, the preceding illustration of policy network analysis was just to indicate the orientation of the method to the inter-organizational relationships and patterns that are the life blood of larger political structures and institutions.

Compared to the heuristic analysis of the Swedish and US cases analyzed above, the empirical data just presented provides a more empirical basis for estimating the validity of the hypotheses for the case of Japan. Like Sweden, at a crucial phase, Japan played a central role in the formation of the global regime by hosting the Kyoto Conference, even later opposing US behavior by ratifying the Protocol. However, Japan has not been able to meet its own GHG reduction target under the Kyoto Protocol (Fig. 13.1). During the current commitment period of 2008–2012, Japan shows an increase of 14% in GHG emissions over 1990, while its goal was a reduction of 6%. The industrial sector succeeded by voluntary measures in keeping its GHG emissions stable over the period since 1990, but the consumer sector, buying bigger cars and more air conditioning, has greatly increased its GHG emissions. Concerning the knowledge phase of reaction to climate change, Japanese culture is very receptive to the logic of scientific evidence – indeed the culture is enamored of technology and very successful in its innovation – and relatively free of powerful belief systems that would militate against accepting such logic. Compared to US media, Japanese news media are closely dependent upon government ministries for information (see Fig. 13.4) and have rarely presented views questioning the validity of the IPCC findings and assertions (this claim will be tested by Compon data). Japan's climate change science establishment is closely tied to and funded by the government. It seems that Japanese climate scientists rarely act as autonomous knowledge brokers among different sectors or in the policy-making process, nor do they directly address the public contrary to current government policy (unlike, for instance, top climate scientist James Hansen in the US) . In the nation's action phase, advocacy coalitions have played a weak role in influencing national climate change policy. Frames concerning national prosperity and energy sufficiency formulated by the Ministry of Economy, Trade and Industry have dominated debates about climate change, rather than fears about the future disasters that climate change will bring such as presented by the Environment Ministry. The close alliance between the ruling Liberal Democratic Party and the corporatistic business sector led by the JFEO (Keidanren) have further buttressed a weak political posture toward climate change insisting on voluntary action by business and no carbon tax on consumption rather than the imposition of regulations by government.

Using the method of Qualitative Comparative Analysis (Ragin 1987) described above, the very tentative findings on the three nations described in the body of this paper indicate values on the eleven hypothesis as shown in Table 13.2. Presented in a table, if the hypothesized factor works to reduce a society's contribution to global atmospheric GHG concentrations, it receives a+, if the factor works to increase that society's contributions to GHG levels, it receives, a –, and if the factor is irrelevant, a 0. The combination of positively and negatively bearing hypothesized conditions indicates the causal mixture bringing about a society's effect on global atmospheric GHG concentrations. The specific policies a society uses to achieve its effect may vary widely by society and constitute a subsidiary research focus within the Compon project.

This QCA table allows the researcher to look for patterns of causation. In this example, the table reveals the hypothesized factors that distinguish the one positive case (that lowered its GHG emissions over the 1990–2004 period), Sweden, from the two negative cases that did not lower their emissions. The most relevant pattern consists of Hypotheses 6, 7 and 8, as their differences parallel the differences in case outcomes. These hypotheses concern: powerful interest groups defending the use of fossil fuels, national institutions that equalize power and representation between different interest groups, and the presence of venues for broadly representative egalitarian stakeholder participation. One could expound upon the implications of this finding. However, due to the lack of data and analysis,

Table 13.2 QCA comparison of three cases

Case	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	Outcome (Δ GHG)
Sweden	+	+	+	+	+	–	+	+	+	?	+	+
Japan	+	–	+	+	+	+	–	–	–	?	+	–
United States	–	+	+	–	–	+	–	–	+	+	–	–

at this point, this kind of comparison can only serve heuristic purposes to illustrate the method. As the national and international teams complete their work, this kind of comparative analysis based on much more solid empirical data will give more reliable results.

13.6 Conclusion

This chapter has reviewed the construction and logic of the Compon research project as an attempt to clarify the social and cultural factors affecting the formation of national fields of discourse and action around climate change, within and as they connect to the international climate change regime. Starting with the advocacy coalition hypothesis, the chapter has presented a number of hypotheses and offered an illustrative comparative test of them by examining three cases: Sweden, the United States and Japan. The analysis of the Japan case begins to use some empirical data for these tests. The chapter illustrates the great potential of the network and other data being collected by the Compon project. The chapter represents an introduction not only to the Compon project but also to the wider field of comparative social science and its use for understanding variation in national behavior. Hopefully, as a project enjoying the participation of many social scientists around the world, and open to new participants as well, the Compon project can sharpen humanity's understanding of the social and cultural factors that facilitate or hinder the capacity and propensity of national societies to mitigate climate change, and in that way, also contribute to the stabilization and reduction of this threat to our collective possibilities, hopes and well-being.

Acknowledgments This chapter was made possible by generous support from the United States National Science Foundation "HSD: Collaborative Research: Social Networks as Agents of Change in Climate Change Policy Making" (BCS-0827006); the Abe Fellowship (Japan Foundation and Social Science Research Council); and the University of Minnesota Consortium on Law and Values in Health, Environment and the Life Sciences. The chapter contents represent the fruits of 2 years of discussions among the members of the Compon teams, advisors and staff, including (in alphabetical order) Anna-Liisa Aunio, Iosef Botetzagias, Moses Boudourides, Marcus Carson, Mario Diani, Christofer Edling, Dana Fisher, Tim Forsythe, Giouzepas "George" Georgios, Monica Di Gregorio, Koichi Hasegawa, Jasmine Harris, Klaus Jacob, Jun Jin, Richard Klein, Dowan Ku, Myanna Lahsen, Ho-Ching Lee, Philip Leifeld, Tze-Luen Alan Lin, Stephan Price, Joerg Raab, Ewald Rametsteiner, Leonardas Rinkevicius, Clare Saunders, Irina Shmeleva, Volker Schneider, David Tindall, Philip Vaughter, Yoshiki Yamagata, and Sun-Jin Yun.

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Chapter 14

Environmental Communication Aimed at Household Energy Conservation

Chizuru Nishio

14.1 Introduction

The first commitment period of the Kyoto Protocol started in 2008. Japan is required to cut down on greenhouse gases (GHGs), which have been the cause of global warming, by 6% on average, starting from 2009 and continuing until 2012. However, the carbon dioxide (CO_2) emissions in Japan have been showing a tendency to increase every year. According to the annual report of the Ministry of the Environment in Japan (2007), the industrial sector accounts for 35% of the total CO_2 emissions in Japan; however, the amount of emissions has been decreasing for the past few years largely owing to the active introduction of environmentally friendly techniques. On the other hand, the CO_2 emissions caused by the residential sector, such as consumers, which make up more than 10%, have increased by 37% compared to the emissions in 1990. Now the urgent problem is to reduce energy consumption not only in the industrial sector but also in ordinary households. To achieve that it is essential to shift the consumers' existing sense of values and lifestyles, which involve mass consumption and mass disposal, in the direction that leads to global environmental protection and resource cutting.

Various products and services are being developed to reduce the environmental load and/or promote environmental protection by a number of business corporations under legal restrictions, and various communications are being actively undertaken to penetrate and diffuse those actions (e.g., environmental reports, labels, advertisements). In Japan, for example, the "Top-Runner System" was introduced in April 1999, aiming to reduce electricity consumption in ordinary households. It keeps the energy-saving capacity of energy-consuming equipment assigned by the Energy-Saving Law (a law concerning the rationalization of energy usage) above a certain level. This triggered, between 1997 and 2004, a positive development of

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products with better electricity efficiency for family use, such as air conditioners 67.8%, electric refrigerators 55.2%, televisions 25.7%, and videocassette recorders (VCRs) 73.6%.[1]

Furthermore, following the introduction of a new system called the "Energy-Saving Labeling System," which indicates whether each product achieves a certain level of the energy-saving standard and/or relative amounts of energy-saving efficiency, the enforcement of the policy to promote the sale of these products with good energy-saving efficiency is about to commence.

As many of the study examples have shown, however, some consumers still have biased views about the relation between environmental protection and quality/efficiency; and/or they lack knowledge about environmental problems. Moreover, we cannot say that the level of practice of energy-saving behaviors is necessarily high. Thus, to encourage consumers' ecological behaviors, it is essential to make them understand the relation between their consuming life and environmental problems and to communicate to them precisely the effects their ecological behaviors would have on the global environment through environmental communications and/or use of ecological products.

Therefore, in this study, we first analyzed the mechanism of consumers' energy-saving behavior. Then, we examined what kind of messages we should communicate to promote the purchase of energy-saving products and the use of energy-saving behaviors in ordinary households – in other words, the direction of environmental communications.

14.2 Factors that Influence the Ecological Behavior of Consumers

We are going to explain the factors that influence consumers' ecological behaviors according to the models of Nishio and Takeuchi (2006) as shown in Fig. 14.1.

14.2.1 Perceived Consumer Effectiveness

Perceived consumer effectiveness is a domain-specific belief that the efforts of an individual can make a difference in the solution to an environmental problem. If a consumer, by using certain energy-saving electrical appliances, can feel that it would lead to a reduction in domestic electricity consumption and protection against resources drying up, that consumer would actively use those energy-saving electrical appliances. Many studies have indicated that this perceived consumer effectiveness is the most important factor that influences consumers' ecological

[1] The consumption efficiency for television and VTR is based on the data between 1997 and 2003.

attitudes and/or behaviors (e.g., Antil 1984; Webster 1975; Ellen et al. 1991; Hopper and Nielsen 1991; Berger and Corbin 1992; Taylor and Todd 1995).

14.2.2 Norms of Social Groups

Many environmental problems are linked to social dilemmas. A social dilemma means that despite the fact that a consumer, based on his or her taste, took an action to gain the best results the action ends up with a negative result, losing in terms of the common benefit to the whole society – ending up as a counter-productive action and a worse situation than would have resulted if the consumer had not taken any action in the first place. For instance, each individual's action is important for energy-saving behaviors, but it does not lead to energy saving for the whole household unless everybody in the family cooperates and acts in the same way. Energy-saving behaviors, though, in many cases involve some inconvenience and discomfort, as it is often difficult to obtain the support from everyone in the family to put it into action. In this way, it is reported that many of the ecological behaviors (e.g., energy-saving actions) are affected by the norm of reference groups (e.g., friends, acquaintances, family) regarding environmental problems (Granzin and Olsen 1991; Hopper and Nielsen 1991; Oskamp et al. 1991; Jackson et al. 1993; Taylor and Todd 1995; Nonami et al. 1997).

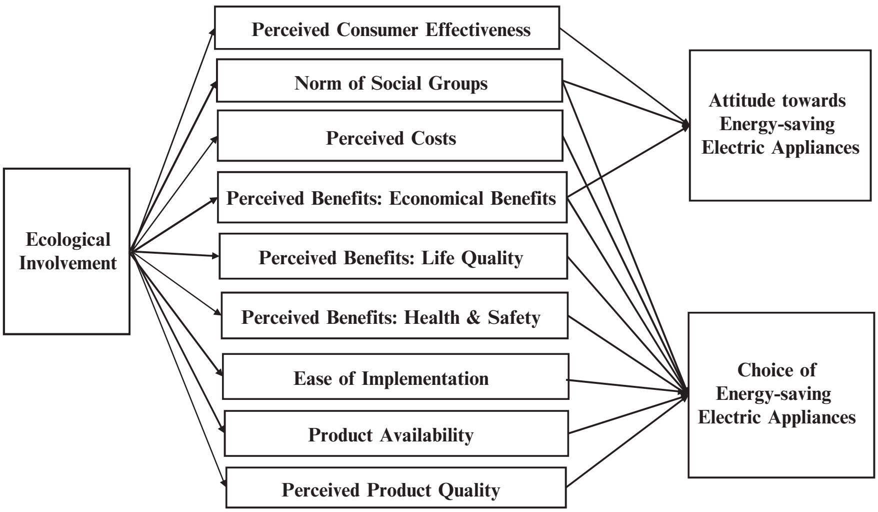

Fig. 14.1 Factors affecting the consumer's choice of energy-saving electrical appliances

14.2.3 Perceived Costs

It is said that global environmental problems are caused by the lifestyles of mass production, mass consumption, and mass disposal. Therefore, behaviors such as practicing energy-saving actions – recycling instead of disposing, for example – that are different from the existing lifestyles require economic expenses such as recycling costs as well as additional efforts and labor. It is reported that perceived costs such as cost increase, burdensome feeling, inconvenience decrease the ecological attitude and/or behaviors (Crosby et al. 1981; Vining and Ebreo 1990; McCarty and Shrum 1994).

14.2.4 Perceived Benefits

Reusing and choosing refilling products not only will protect the environment, it will bring beneficial effects, such as stopping unnecessary consumption and reducing living costs. Using air conditioners and heaters in moderation can have a good influence on one's health as well as reduce living costs. Choosing organic or low-pesticide vegetables is effective in protecting soil from pollution, but it also satisfies the needs for consumers' health and safety. As these examples suggest, quite a few ecological behaviors bring benefits not only for environmental protection but also to consumers' individual lives. Werner and Makela (1998) suggested that as recycling is an important but boring subject we can enhance the degree of participation for that action by showing some new views that are beneficial to consumers and make them think it is an interesting and attractive subject.

If consumers could identify the ecological behaviors connected with their lifestyles and find some benefits there, the receptive capacity toward ecological behaviors should increase. Then, what kind of benefits would increase the receptive capacity? Nishio and Takeuchi (2006) suggested three benefits – economic benefits, such as living cost reduction; life quality benefits, such as comfort, enjoyment, and fulfillment; and the basic benefit of satisfaction regarding health and safety needs for individuals or families – and confirmed the level of their influence on ecological behaviors.

14.2.5 Ease of Implementation

As already mentioned, ecological behaviors tend to require additional work and/or money. Therefore, having systems that are easy to practice (e.g., easy rules to follow, maintenance of a resource collecting base, and easily-accessible environmental programs) have a great influence on people's attitude and actions (Taylor and Todd 1995; Berger 1997; Nishio and Takeuchi 2005). Nishio (2002) and Nishio and

Takeuchi (2006) suggested that not only the "system receptive capacity, such as rules receptive capacity and accessibility of products, but having high 'self judgment,' such as 'individually practicable (I can do it by myself)' and 'self-paced (I can do it at my own pace),'" are also factors that strongly encourage ecological behaviors.

14.2.6 Perceived Product Quality

Even if a product has a low environmental burden, consumers will not choose it if it is inferior in terms of quality and/or efficiency. In the same way, consumers will not cooperate with recycling programs if there is no credible system constructed for effective reuse of the collected waste. In other words, the quality of the ecological products and credibility of the systems behind ecological actions are also the motivating factors (Nishio and Takeuchi 2006).

14.2.7 Ecological Involvement

We hypothesized that ecological involvement is an activated state evoked simply because practicing ecological behaviors is deeply linked with realization of values that are more central and more important in a consumer's value system.

In many consumer behavior studies, consumer involvement has been discussed as the moderator to explain the condition or individual differences in consumer behavior and/or information processing (e.g., Laaksonen 1994; Aoki 2004). Perceived social responsibility such as the importance of an environmental problem or level of interest or sense of duty is one of the key moderators that influence consumers' ecological behaviors (e.g., Antil 1984; Hines et al. 1987; Webster 1975; Oskamp et al. 1991; Shrum et al. 1994). Studies by Nishio and Takeuchi (2005, 2006), however, confirmed that ecological involvement – simply because the concept is to show how much a consumer can connect the environmental problems with his or her own values and lifestyle (which means the level of connections between the environmental problem and the consumer him/herself) – directly affects the perceived costs, perceived benefits, norms of social groups, and ease of implementation, to name a few.

Figure 14.1 shows the results applied to behavior when choosing energy-saving electrical appliances. In other words, the "attitude" that choosing energy-saving electric appliances is a good thing is formed when the following perceptions are increased: Choosing energy-saving electric appliances means reducing family expenses; it leads to solving environmental problems (consumer effectiveness); and the family and friends recommend it (norms of social groups). However, it does not mean that the attitude directly increases the rate of choosing energy-saving electrical appliances. The factors affecting the consumer's choice of energy-saving electrical appliances are the following: It leads to reducing family expenses (perceived benefits); the choice itself is interesting and fun (perceived rewards); it is easy to buy at local shops (receptive capacity toward the system); friends and/or family recommend it (norms of social groups); and the product's quality and efficiency have credibility. Also, if the "perceived costs" are higher compared to choosing energy-saving electrical appliances, the choice rate goes down.

Nishio and Takeuchi (2006) also applied this model to the following examples: choosing products with an eco label, choosing organic or low-pesticide vegetables, use of recycling shops, use of public transportation, energy-saving behaviors related to air conditioners and heaters, repair behaviors, and recycling behaviors. The outcome mainly confirmed similar results regarding other behaviors apart from choosing energy-saving electrical appliances.

14.3 Design for Environmental Communications

Generally, communication consists of five basic factors: (1) who, (2) what, (3) how, (4) communicated to whom, and (5) what was its effect. These factors are also called the (1) sender factor, (2) message factor, (3) channel factor, (4) recipient factor, and (5) effect factor. Hence, this study examines the communication methods to promote environmentally conscious behaviors by focusing on the message factor and recipient factor.

14.3.1 Influence of the Message Factor

An environmental problem may be just that – an environmental problem; but it varies from the global warming problem to the depletion of energy resources, air pollution, water pollution, acid rain, garbage disposal problems, and the decreased numbers of wild animals. Also, it has not necessarily been made clear about the causality between industrial activities and consuming life. This makes it difficult for consumers to link the relation between their day-to-day living and environmental problems. As mentioned in the last section, many of the preceding studies already pointed out that to encourage consumers to practice ecological behaviors it is important to enhance "perceived consumer effectiveness," which claims the effectiveness of each ecological behavior for the solution of environmental problems (e.g., Antil 1984; Webster 1975; Ellen et al. 1991; Hopper and Nielsen 1991; Berger and Corbin 1992; Taylor and Todd 1995). Therefore, most of the "environmental protection effects appeal type" of communication are the ones that indicate how much of a burden to the global environment we could reduce by changing our consumerist lifestyle to an environmentally protective style. In other words, the main communication is the one that aims to increase consumers' perceived effectiveness. However, as clarified by Nishio and Takeuchi (2006), although "perceived consumer effectiveness" helps form a positive attitude toward behaviors and/or products, it does not directly affect the actual behavior. For the formation of behavior, it is important to know whether the ecological behaviors and/or use of products would have a positive effect on consumers in terms of enhancing their quality of living. Therefore, in the communications to promote energy-saving behaviors, it is more effective to appeal to the quality benefits of consumers' individual lives than social benefits such as environmental protection. In this study, we set the following hypothesis.

Hypothesis 1

It is more effective to appeal to personal benefits rather than to stress the social benefits of environmental conservation.

14.3.2 Influence of Recipient Factor

Abrahamse et al. (2005) pointed out the importance of "tailored information," which means giving information to match the consumer's personal ability or interests when carrying out an information-giving type of communication about energy-saving behaviors. Also, Enomoto (1994) analyzed the relation between consumers' prior knowledge and their degree of behavior practice and reported that the degree of consumers' ecologically friendly behavior practice differs between knowledge regarding the global-scale environmental problems and knowledge regarding familiar environmental problems. Nishio and Takeuchi (2005, 2006) reported that the degree of the consumer's ecological involvement affects his or her perception about effectiveness, costs, and benefits of the same ecological products or environmentally friendly behaviors.

As explained before, the consumer's ecological involvement, which is the level of perceived personal importance and/or interest evoked by an environmental problem and/or behavior, affects how ecological information is processed and the impact of this information. Consumers who have high eco-involvement generally have good knowledge about environmental problems and have already tried to carry out energy-saving behavior. Thus, the impact of ecological messages will not be high for these consumers. Ecological messages will have a stronger impact on consumers with low eco-involvement than those with high eco-involvement. Therefore, we hypothesized that:

Hypothesis 2

The improvement effect is different among consumers. Consumers who have a low level of ecological involvement display improved daily energy-saving behavior after being exposed to one of the messages.

14.4 Method

14.4.1 Communication Design

The purpose of this study was to clarify what kind of environmental communication should be carried out to urge consumers to practice energy-saving behaviors. Although there are many types of environmental communication, in this study we focused on the information-offering type of communication and analyzed the effects of the following three types of message (Fig. 14.2): "environmental protection appeal type"; "living quality benefits appeal type"; and "economic benefits appeal type."

As mentioned earlier regarding persuasive communications, it is important to specify the sender factor, message factor, channel factor, and recipient factor. In this study, as shown in Fig. 14.2, we fixed the sender factor as a researcher (meaning specialist) and the channel factor as sending pamphlets by post. Also, as the recipient factor, as indicated in Hypothesis 2, we used the consumers' ecological involvement. We analyzed the effects on four energy-saving behaviors in family living. In other words, we employed the survey method: The consumers each received one of the three pamphlets about the four energy-saving behaviors sent in the name of the specialists and answered the questions.

The pamphlets we prepared are the equivalent of four A4 size papers. We used many photographs and illustrations to help the consumers understand the articles and used A3 size paper, color printed on both sides. In the first two pages, we explained about global warming and energy-saving problems using data generally available through the reports of Ministry of the Environment, Ministry of Economy, Trade and Industry, Ministry of Education, Culture, Sports, Science and Technology,

Sender	Scholar (professor)		
Channel	Sending out an educational pamphlet by post		
Message	A Pro-environmental (philosophy of altruism, contributing to environmental conservation)	B Personal Benefits on Life Quality (improved health and comfort)	C Personal Economic Benefits (lower household expenses)
Recipient	Ecological Involvement		
Effect	Intention of 4 energy saving behaviors: "Lighting", "Food choice", "Housing", "PV systems"		

Fig. 14.2 Communication design of this study

and other organizations. This part is common to all three pamphlets. Pages 3 and 4 are different depending on the pamphlet. Pamphlet A is the "environmental protection appeal type," with the appeal that behaviors leading to energy saving are effective for environmental protection and practicing these behaviors is one's responsibility as a global citizen. Pamphlet B is the "living quality benefits appeal type," with the appeal that practicing the behaviors that lead to energy saving will effectively lead to an enhanced quality of personal living. Pamphlet C is the "Economic benefits appeal type," with the appeal that practicing behaviors that lead to energy saving will effectively lead to personal economic benefit. In every message, specifically, the following four domestic energy-saving behaviors in a family are explained: lighting (e.g., choosing energy-saving, efficient lighting appliances, how to use lights); food (e.g., choosing foods that were produced and/or transported in an energy-saving, efficient way); housing (e.g., behaviors that enhance the house's insulation effect and one's way of life); and choosing a solar power system (e.g., choosing the system and the purpose of its use).

We had the examinees read one of the messages from A, B, or C and then give their behavior intentions toward energy-saving behaviors before and after reading the message. We measured all the behavior intentions toward energy-saving behaviors using a seven-point scale (1 = strongly disagree, 7 = strongly agree).[2]

The ecological involvement scale by Nishio and Takeuchi (2005)[3] consists of four items, and we measured all of them using a five-point scale (1 = disagree, 5 = agree).

14.4.2 Manipulation Check of the Pamphlets

To examine whether the three prepared types of pamphlet, with the three different appeal messages, had any discrepancies in terms of the length of the sentences, difficulty of understanding, credibility, uncomfortable feeling, and so on we carried out a presurvey.

The target group of the survey comprised 37 men and women between 25 and 60 years of age who lived in the Tokyo metropolitan area. We had them read the three pamphlets and then answer the questionnaire. The survey was carried out in February 2007.

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[2] The measures of behavior intentions towards four energy saving behaviors are the following: "I will choose energy saving lighting products"; "I will choose food that is produced and/or transported by energy saving technologies"; "I will act considering heat-insulation performance of housing"; "I will purchase and use solar powered electricity systems."

[3] Ecological involvement was measured in the following four items: "When choosing products, I think about their effects on and/or suitability to the environment"; "I try to make various efforts in order to live an ecologically-friendly life"; "I try to behave in an environmentally friendly way in my day-to-day living"; "I feel good when I do something good for the environment." The credibility factor of these four categories is $\alpha = 0.871$, which means these scales show high internal consistency.

First, we measured the responses to the question about the degree of appeal for environmental protection: "The materials show energy-saving behaviors and a tendency toward environmental protection," on a five-point scale (1 = strongly disagree, 5 = strongly agree). As a result, the mean values were A 4.47, B 3.47, C 3.65. The results of an analysis of variance (ANOVA) test showed a significant difference between the scores of A, B, and C [$F(2,106) = 10.44$, $p < 0.001$]. Based on the results of a multiple comparison by Scheffé's method, the score for A was significantly higher than that for B ($p < 0.001$), and the A score was significantly higher than the C score ($p < 0.001$). This confirmed that A, compared to B or C, is more appeal for environmental protection. Likewise, the mean values for the degree of appeal for personal living benefits were A 3.06, B 4.35, C 3.81. The results of the ANOVA showed differences between the scores of A, B, and C [$F(2,106) = 14.88$, $p < 0.001$]. As the result of the multiple comparison, the score of B was significantly higher than that of A ($p < 0.001$), and the score for B was significantly higher than that for C ($p < 0.01$). The mean values for degree of appeal for economic benefits were A 3.27, B 2.81, C 4.16. The results of ANOVA showed a difference between the scores of A, B, and C [$F(2,107) = 15.27$, $p < 0.001$]. Results of the multiple comparison showed that the score of C was significantly higher than those of both A ($p < 0.001$) and B ($p < 0.001$). In other words, it was confirmed that the examinees have correct understanding of the differences in the appeal points of the three pamphlets.

Subsequently, to confirm the appropriateness of the pamphlets, we examined if there were any differences in scores in terms of the length of sentences, difficulty of understanding, credibility, and uncomfortable feeling among the three pamphlets. The mean values of responses for "length of sentences (sentences are too long to read)" were A 2.57, B 2.73, C 2.60 (1= disagree, 5 = agree), and the scores were all low. Also, the ANOVA results showed no significant difference between the scores of A, B, and C [$F(2,106) = 0.168$, $p > 0.10$]. Likewise, "difficulty of understanding" were A 2.49, B 2.32, C 1.92 [$F(2,108) = 2.403$, $p = 0.10$]; "lack of credibility" scores were A 2.00, B 2.22, C 2.14 [$F(2,106) = 0.523$, $p > 0.10$]; "uncomfortable feeling regarding the content" were A 2.00, B 1.78, C 1.84 [$F(2,108) = 0.463$, $p > 0.10$]. All the scores were low and "not applicable." As these results confirmed that the pamphlets are appropriate in terms of easiness of reading and credibility, we opted to use them in the main survey. As an example, the solar power system was given as described in the three pamphlets shown in the Appendix.

14.5 Results

14.5.1 Data

As the targets of this survey we chose people who live in Shizuoka Prefecture. They were all female and lived in a detached house with a total occupancy of two or more people. They were chosen 360 households who were 25–69 years of age using quota sampling to suit the component ratio of the national census from about 200,000 mailed monitors of survey agencies. The survey was held in February and March 2007, and by using the mailing detention method we collected responses from 315 households (valid response rate 87.5%).[4]

The reason for choosing the Shizuoka region is the following: The amount of energy consumption largely depends on climate and/or the type of building. If the amount of energy consumption differs a lot, there would also be a large difference in energy saving. Therefore, we chose Shizuoka Prefecture, which has Japan's average climate. We also opted to limit the type of housing to detached houses.

Before the analysis, we carried out a homogeneity examination in terms of demographic attributes for message groups A, B, and C. The results of the various categories were age [$F(2,312)=0.64$, $p=0.938$], number in household [$F(2,311)=0.215$, $p=0.806$], and income [$F(2,289)=0.414$, $p=0.661$]. There was no difference regarding household attributes between the groups, so we did the following analysis based on each group's homogeneity.

14.5.2 Effects of the Message

We had the people targeted in the survey read one of the messages from A, B, or C and had them indicate their behavior intentions toward energy-saving behaviors before and after reading the message. The results are shown in Table 14.1.

Table 14.1 Differences in energy-saving behavior intentions before and after exposure to the message

		Mean		Difference	
	Parameter	Before	After	(after – before)	p
Lighting	5.11	6.12	1.01	***	
Food choice	4.58	5.75	1.17	***	
Housing	4.69	5.61	0.92	***	
PV systems	3.43	4.23	0.80	***	

Note: Behavior intention was measured on a seven-point scale (1 = strongly disagree, 7 = strongly agree)
***$p<0.01$
**$p<0.05$
*$p<0.10$

[4] The attributes of the respondents are: age; 21–29 9%, 31–39 24%, 41–49 21%, 51–59 23%, 61–69 23%. Number in household was 3.9 per household on average, this is bigger compared to the average of Japan as a whole (2.7 per household) including single occupancy households. This survey targeted households who live in detached houses and comparatively in suburban areas, which probably made the household occupancy figure slightly bigger. As to household income, though the biggest number was 4–6 million yen per year, it is close to the distribution shown in the result of the national census. In terms of occupation, housewife 35%, part-time34%, office worker/public servant 20%, self-employed in the area of commerce and industry 5% and unemployed 4%.

It was demonstrated that for each behavior the behavior intention was positively improved after exposure to the message.

Subsequently, we carried out one-way ANOVA, setting message contents (A, B, C) as independent variables and communication effects as dependent variables. As a result, regarding energy-saving behaviors related to housing, we could not find any statistically significant improvement effects between the messages [F(2,310) = 0.189, NS]. However, the energy-saving behaviors related to food [F(2,312) = 2.861, $p < 0.10$] and to solar power [F(2,295) = 3.665, $p < 0.05$] showed significant differences, in terms of message effects between messages A, B, and C (Table 14.2). In other words, message B ("living quality benefits appeal type") was recognized to have a tendency of having higher communication effects than message A: ("environmental protection appeal type") or Message C: ("economic benefits appeal type"), which supported Hypothesis 1.

14.5.3 Interaction Effects Between Message and Ecological Involvement

To examine Hypothesis 2, we calculated the ecological involvement score of each examinee and classified the ones who scored higher than the mean value as the "high involvement group" and the ones who scored lower as the "low involvement group." Then we carried out one-way ANOVA, setting ecological involvement (high/low) as the independent variable and communication effects as a dependent variable (Table 14.3). As a result, regarding energy-saving behaviors related to solar power, we could not find any difference in terms of communication effects by degree of ecological involvement [F(1,296) = 1.283, $p > 0.10$]. However, the energy-saving behaviors related to lighting [F(1,311) = 18.827, $p < 0.001$], to food [F(1,309) = 6.916, $p < 0.01$], and to housing [F(1,309) = 3.798, $p < 0.10$] showed differences

Table 14.2 Effects of the three types of message on energy-saving behavior intentions

	Mean differences (after – before)				
Parameter	A Proenvironmental	B Benefits on life quality	C Economical benefits	F	*p*
Lighting	1.10	1.13	0.79	2.861	*
Food choice	1.31	1.23	0.94	2.439	*
Housing	0.91	0.97	0.87	0.198	
PV systems	0.58	1.02	0.88	3.665	**

Note: Numbers were calculated as "intention after message exposure" minus "intention before message exposure." Positive numbers show the magnitude of improvement of four energy-saving behavior intentions

***$p < 0.01$

**$p < 0.05$

*$p < 0.10$

Table 14.3 Effects of the messages as a function of ecological involvement

	Mean differences (after – before)			
	Eco-involvement		F	*P*
	High	Low	Value	Value
Lighting	0.76	1.31	18.83	***
Food choice	1.00	1.38	6.916	***
Housing	0.81	1.06	3.798	*
PV systems	0.76	0.91	1.283	

Note: Numbers were calculated "intention after message exposure" minus "intention before message exposure." Then, positive numbers show magnitude of improvement of four energy saving behavior intention

***$p<0.01$

**$p<0.05$

*$p<0.10$

in terms of communication effects by degree of ecological involvement; and the stratum with the lower ecological involvement showed higher improvement effects of energy-saving behavior intentions. This supports Hypothesis 2.

Furthermore, we analyzed the interaction effects between ecological involvement (high/low) and message contents (A/B/C) as shown in Table 14.4. As a result, for energy-saving behaviors concerning lighting and housing, the main effect of ecological involvement was significant. In other words, it (message B – "living quality benefit appeal type") was indicated to be more effective than the other messages for people with low ecological involvement. For energy-saving behaviors concerning food, the main effect of ecological involvement and the interaction effects between ecological involvement and message contents were significant. In other words, also concerning food, the improvement effects to the stratum with low ecological involvement is generally high, but particularly there was a tendency that message B ("living quality benefit appeal type") had a strong positive effect on improving behavior intention. On the other hand, for energy-saving behaviors concerning solar power, the main effects of message contents were significant; and it was confirmed that message B triggers even bigger improvement effects than the other messages.

14.6 Conclusion

Aiming to examine the different types of environmental communication methods that are effective in diffusing and expanding energy- and resource-saving lifestyles, we measured the effects of energy-saving behaviors by offering different types of

Table 14.4 Improved intentions as a function of ecological involvement and exposure to three types of message

		Message A			Message B			Message C		
		Before	After	Difference	Before	After	Difference	Before	After	Difference
Lighting	Eco-high	5.77	6.57	0.80	5.42	6.33	0.90	5.80	6.38	0.58
	Eco-low	4.42	5.93	1.51	4.23	5.57	1.34	4.64	5.74	1.10
Food	Eco-high	4.82	6.10	1.28	5.31	6.12	0.81	5.50	6.37	0.87
	Eco-low	3.78	5.13	1.36	3.65	5.28	1.63	4.12	5.20	1.08
Housing	Eco-high	5.32	6.07	0.75	5.23	6.00	0.77	5.08	6.03	0.95
	Eco-low	3.98	5.11	1.13	3.91	5.11	1.20	4.17	4.98	0.81
PV systems	Eco-high	4.10	4.55	0.45	3.54	4.35	0.81	3.68	4.63	0.95
	Eco-low	3.09	3.82	0.73	2.83	4.00	1.17	3.12	3.83	0.71

Note: Behavior intention was measured on a seven-point scale (1 = strongly disagree, 7 = strongly agree) environmentally friendly information. To be specific, as information-offering types of environmental communications, we prepared three types of message (A, "environmental protection appeal type"; B, "living quality benefits appeal type"; and C "economic benefits appeal type") and measured their effects. The results showed a tendency that the "living quality benefits appeal type" of message yielded higher improvement effects. Also, the analysis of effects of the recipient factor revealed an important fact that the stratum with low ecological involvement in every message showed high improvement effects and actively practiced behaviors.

The information-offering types of communication, which have been done at state and local government levels, are mainly the "environmental protection appeal type." However, it was demonstrated that the "living quality benefits appeal type" better enhances the communication effects.

The contents of the pamphlets that we prepared as environmental communications for this study were limited when we considered the burden to the examinees. We focused on four energy-saving behaviors, but the survey was not designed to examine each pattern of behavior. Some energy-saving behaviors strongly appeal because of their economic benefits and some because of living quality benefits. Also, some behaviors are easy to practice, and some are not. More detailed studies are required for each environmentally friendly behavior. Furthermore, this survey was confined to the change before and after the communication, which is a short-term effect. Whether the responses to the questionnaire will actually be practiced as behaviors and whether this attitude and change in behavior will be maintained should be monitored. It is important in the future to examine their long-term effects.

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1.Message A: ‘Environmental protection appealing type’

Solar power is an eco-friendly way to generate electricity. Because the light of the sun is changed directly into electricity, carbon dioxide (CO_2) can be greatly reduced.

- The amount of CO_2 emissions generated by solar photovoltaic electrification is about 73g/kwh.
- The amount of CO_2 emissions generated by electric power bought from electric power companies is about 378g/kwh.

The solar power system can generate electricity with only one-fifth the level of the CO_2 emissions generated by electric power companies.

“Let's start energy saving now for global environmental protection !”

2.Message B: 'Living quality benefits appealing type'

Solar photovoltaics transform the light from the sun directly into electricity. Therefore, we don't need to worry about emissions of CO_2, sulfur oxides (SOx) and nitrogen oxides (NOx) that are major causes of global warming. The solar panels neither vibrate nor cause noise. They produce very clean and safe energy.

Solar photovoltaics can supply electricity to a house without being linked to the national grid and is an independent source which becomes an important lifeline during or after a major disaster such as earthquakes and typhoons.

The solar photovoltaic system provides strong benefits for you in an emergency.

"Let's start energy saving now for a comfortable life!"

3.Message C: 'Economic benefits appealing type'

Solar power is an eco-friendly way to generate electricity. Solar photovoltaic systems can provide more than the household electricity needs.

In addition, the surplus electricity can be sold to the electric power company.

In poor lighting conditions or at night, when electricity cannot be generated by solar power, the household can of course use electricity from the electric power company.

- The amount of electric power consumed in an average home is 4819kw a year. If you set up a solar photovoltaic system generating about 4kwh-5kwh, the household electricity needs can be covered.
- You can recoup the investment in about 20-30 years by selling the surplus electricity to the local electricity company every month, though you need to pay the initial cost for installing a photovoltaic generation system.

"Let's start energy saving now to save your money !"

Chapter 15
Bridging the Gulf Between Science and Society: Imperatives for Minimizing Societal Disruption from Climate Change in the Pacific

Patrick D. Nunn

15.1 Introduction

For more than 20 years, richer countries have donated funds to the governments of developing nations in the *Pacific Islands* region to help them prepare for the multi-sectoral challenges associated with future climate change. It was expected that these funds would be used to raise awareness about the nature of these challenges and to develop and mainstream appropriate *adaptation* solutions but neither of these goals has been achieved. It appears that the current preparedness of Pacific Island countries for future climate change is little or no better than it was two decades ago (Nunn 2009). It is incumbent upon all concerned, especially aid donors, to understand the reasons for the failure of these initiatives if only to ensure that future assistance is targeted more appropriately and helps embed sustainable solutions to future challenges.

The failure stems from a lack of appropriate knowledge on the part of most concerned (Nunn 2009). Specifically,

1. There has been a failure on the part of most *aid donors* (and the organizations through which aid was filtered) to inform themselves of which pathways for assistance were most effective and which were not. Thus most funding has been given for policy development and associated environmental legislation, neither of which has proved effective in the developing nations of the Pacific Islands.
2. There has been a failure on the part of most *regional agencies* serving the Pacific Islands to develop proactive plans independent of either international or national agendas that take into account *either* the special needs of Pacific Island nations *or* the importance of developing adaptive solutions that acknowledge their singular cultural and environmental contexts. Instead such agencies have been

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largely reactive, uncritically imposing the priorities of international organizations on Pacific Island nations, and focusing on short-term pilot studies rather than mainstreaming the lessons learned from these.

3. There has been a failure on the part of many *governments* to use the money they received to develop long-term sustainable adaptive solutions, instead using it to fund ancillary needs, short-term positions, and studies that have largely proved impracticable and unhelpful. There remains a widespread ignorance among most decision-makers in Pacific Island governments about the nature of future climate change, the ways in which it is likely to impact Pacific Island peoples, and the potential adaptive solutions available.

Climate change threatens the Pacific Islands in many ways, the net outcome of which may be widespread loss of environmental productivity, disruption of economic development strategies, significant infrastructural damage, and massive socio-cultural impact. Forthright anticipatory action to tackle these emerging problems may reduce their impact but there is currently no sign of such action among key decision-makers in Pacific Island countries.

This chapter focuses not on the failures of the past but on the opportunities for the future that Pacific Island countries have to prepare themselves for the challenges arising from twenty-first-century climate change. It begins with a discussion of what the main challenges are (Sect. 15.2) and what the objectives of adaptation are (Sect. 15.3). It then evaluates the available pathways for linking climate-change science to Pacific Island societies (Sect. 15.4) before discussing the ways in which knowledge about adaptive solutions is best disseminated and sustained (Sect. 15.5).

15.2 Challenges from Climate Change

Most Pacific Island nations are classified as developing, disadvantaged by reason of their insularity, their remoteness, and their generally poor resource bases. Most people in the Pacific Islands depend on the natural environments in which they live for the food that they routinely consume. This makes such people innately vulnerable to variations in natural environmental productivity associated with climate change or unsustainable interactions with natural systems. The effects of future climate change will be imposed on systems that are already under stress in the more populous Pacific environments, typically as a result of overexploitation of natural products (e.g. overfishing, overgrazing), pollution (land, air and sea), or intentional interference with natural systems (e.g. urbanization, infrastructure construction, shoreline artificialization) (Hay et al. 2003; Barnett 2005; Mataki et al. 2007; FAO 2008a).

Climate change is an umbrella term for a range of future general threats to environments and human societies as well as specific threats to regions and nations and small spatial units. For the Pacific Islands region, there have been numerous studies that attempt to either downscale global threats or upscale local-area problems. Perhaps the most comprehensive is the "Small Islands" chapter in the Fourth Assessment Report of the IPCC (Mimura et al. 2007) which identifies the following as specific threats to tropical Pacific islands.

1. *Temperature rise* – at least 2.5°C higher in 2100 compared to 1990, but perhaps even more (maximum of 4.17°C in 2069 compared to 1990).
2. *Sea-level rise* – a maximum increase for 1990–2100 of 58 cm was projected in the IPCC Fourth Assessment but it is now widely accepted that this figure was based on incomplete model predictions and that the more likely figure is around 120 cm (Rahmstorf 2007).
3. *Storminess* – the most important cause of storminess in the tropical Pacific Islands is tropical cyclones (hurricanes/typhoons) which are likely to become more frequent and stronger in a warmer world.

The critical unknown remains *precipitation*, with the current generation of general circulation models (GCMs) unable to agree even on whether future mean annual precipitation will increase or decrease on tropical Pacific islands. This remains a major issue for Pacific Island nations and others trying to draw up effective adaptive responses to future climate change in the region because, given the general poor quality of water management, direct precipitation is the major cause of agricultural success or failure (Salinger et al. 1995; Lal 2004). Linked to this are future developments in the El Niño-southern oscillation (ENSO). It is unclear how ENSO variability, particularly the recurrence, duration and severity of El Niño events which most affect tropical Pacific Islands, is going to alter in the future (Timmermann et al. 1999; Mimura et al. 2007).

This section now goes on to discuss each of these four variables in turn, explaining the specific stresses that they are likely to pose for Pacific Islands and their inhabitants.

Temperature rise will have significant effects on food production in the Pacific Islands, both terrestrial and marine. Land-based food production is likely to be affected directly by temperature rise, but also indirectly through such changes as lowland flooding and groundwater salinization associated with sea-level rise and increased storminess. This reflects the fact that most terrestrial food production in these islands is carried out almost wholly in coastal and riverine lowlands (Hay et al. 2003; FAO 2008a). More serious is the prospect for nearshore marine ecosystems as ocean surface waters acidify and sea-surface temperatures rise causing corals to become bleached and die, resulting in a sharp drop in the biodiversity of reefs and lagoons, on which many Pacific people routinely depend for food (Hoegh-Guldberg 1999; Donner et al. 2005; Silverman et al. 2009).

Sea-level rise is likely to have severe and widespread effects, ranging from coastal *flooding* and inundation (permanent flooding) to accelerated *erosion* of soft-sediment shorelines, which will combine to re-shape coastal areas (and in some cases, entire islands), requiring sometimes radical responses from their human inhabitants.

Storminess is one of the major short-term causes of environmental (including infrastructural) and economic damage in the Pacific Islands. The prospect of more such storms, against which it is very difficult to effectively adapt, will likely have a range of impacts that will continue to hinder both economic growth and environmental sustainability.

The same applies to future changes in *ENSO* periodicity because more tropical cyclones usually develop during El Niño events in the tropical Pacific. Yet for their demonstrable ability to produce long droughts and extended periods of low sea level, the understanding of the future of ENSO in this region remains a priority.

It is also clear that future climate change does not pose challenges to Pacific Island nations in isolation from other types of challenges or is even automatically more important than these. For example, in countries like Solomon Islands and Vanuatu, where population is predicted to double in 25–35 years (www.spc.int), there are serious challenges associated with this that may understandably demand more urgent attention than some aspects of climate-change adaptation. In addition, although the effects of the global economic recession have yet to be fully felt by Pacific Island countries, many have registered negative economic growth for several years and most economies will likely be in recession in 2010. There is a good case for holistic (whole-island) rather than sectoral adaptation in the Pacific Islands (Barnett 2001).

In the Fourth Assessment Report of the IPCC, freshwater quality and quantity was identified as the top sectoral priority of island nations (Mimura et al. 2007) but it could be argued that this reflects the short-term vision of planners rather than the longer-term vision that many scientists have. Such a vision would undoubtedly rank the two priorities of land loss (from sea-level rise) and food insecurity (from *coral bleaching* and ecosystem deterioration) as equally if not more important for tropical islands (FAO 2007, 2008a, b; Barnett 2007). In this context, the key adaptive solutions that are appropriate to island nations such as those in the tropical Pacific are shown in Table 15.1.

Table 15.1 Key adaptive solutions appropriate to island nations

Problem	Solution(s)
Freshwater shortage	Improved water management
	Improved rainwater storage
	Reduced pollution of freshwater
	Affordable desalination of seawater
Sea-level rise	Reafforestation of shorelines with mangrove forest
	Relocation of vulnerable activities
Food insecurity	Diversification of food supply
	Introduction of heat/salt-tolerant crops
	Increased aquaculture
(All)	Reduced population pressure
	Improved environmental management
	Enhanced awareness of environmental change

15.3 Prerequisites for Successful Adaptation

Although some Pacific leaders have highlighted scientific uncertainties as reasons for insufficient progress in anticipatory action for climate change, an unbiased evaluation of the available information must inevitably lead to the conclusion that action is urgently required (Mimura et al. 2007; FAO 2008a; Nunn 2009). Even were climate not changing, the Pacific region is currently beset with unsustainable environmental practices that would need to be addressed if growing populations are to be sustained in the future in ways similar to which their ancestors were sustained in the past; there are no alternatives to this in the Pacific Islands where imports are excessively costly and there are fewer reserves of natural resources than in larger countries.

Yet climate is changing, and is predicted to change even more rapidly in the future. So Pacific leaders must take the lead in understanding the nature of both present and future challenges. They must put in place adaptation strategies that address current unsustainable practices as well as the problems that will arise as a result of future climate changes. This needs to be done in order to minimize the impacts of these on their constituents and to develop future environmental demands that match likely future changes in environmental productivity and economic development.

Adaptation is a word that is used in every part of the world in relation to climate change but it does not mean the same thing in every place. For while there are undeniably adaptive responses that almost every country can make, there are numerous environmental and cultural contexts that must be considered by scientists and planners when they develop specific *adaptive solutions* for particular areas. In the Pacific Islands, it is important to recognize both the constraints and the opportunities afforded by the region's singular environments and cultures. For example, it is difficult for governments to both disseminate information and enforce environmental legislation in archipelagic countries; yet, given that most people in these countries are regular churchgoers, there is a great opportunity for information about environmental stewardship and appropriate adaptation to be disseminated effectively through church leaders.

Appropriate adaptation to future climate change in the Pacific Islands involves three requirements, summarized below:

1. *Willingness to adapt* – national and community leaders must be willing to adapt. In order for this to happen, they first need to be convinced of the imperative of adapting, even to the extent of setting aside short-term development plans. The latter is perhaps the most challenging issue for geographically-disadvantaged developing countries with small populations and resource bases because economic growth can usually only be linked with unsustainable practices. The situation is compounded by the democratic nature of many island governments which are elected every few years and understandably therefore focus on short-term economic goals rather than longer-term environmental sustainability.
2. *Means to adapt* – countries must have the means to adapt. This means that not only should they be able to access sufficient funds to underwrite the costs of

sustainable adaptation but that they should also have sufficient people in-country who can both develop and drive forward the blueprint of *appropriate adaptation*. Both of these requirements are problematic at present.

(a) First, most Pacific Island nations use recurrent budgetary surpluses to fund revenue-generating projects rather than those notionally concerned with *environmental sustainability* (which is perceived as non-revenue generating). Most environmental demands are funded from external sources, typically from donor partners who fund specific projects in specific places because this is all that their funding allows them to do.
(b) Second, in-country (indigenous) professionals are generally few and often quite mobile, in the sense that they are readily persuaded to move by the promise of far-higher salaries elsewhere. There is consequently a high turnover of professionals with key meetings being attended by lower-level officials who are ill-equipped either to understand the issues or to provide sound advice to higher-level decision-makers.

3. *Sustaining appropriate adaptation* – it is not enough to simply develop and implement appropriate adaptation solutions for, if these are not sustained indefinitely, then they cannot be effective. Presently in the Pacific Islands, many donor-funded aid projects are "pilots" or sustained for only a few years with little thought as to what happens when they end. Clearly, because climate change is going to continue for the foreseeable future (at least to 2100), effective adaptation must involve solutions that are sustainable. In the Pacific Islands context, this generally means that local communities, who have a long-term vested interest in the sustainability of the environments they occupy, must be engaged in the development and implementation of any adaptive solution. It also means that governments must begin to fund environmental sustainability from its own revenues rather than continuing their current high dependence on external sources.

15.4 Pathways Linking Science and Society

Scientists know the adaptive solutions that are needed both to attain sustainability of current environmental interactions and to meet the many challenges of future climate change in the Pacific Islands. Many in-country decision-makers are also aware of these solutions but lack either the political support and/or the means to implement them effectively. In contrast, many donor partners/agencies and regional/international advisory bodies appear to make broad assumptions about both the nature of the climate-change challenges faced by Pacific Island nations and the pathways by which these challenges should be met (Turnbull 2004; Nunn 2009).

A good illustration of the way in which broad assumptions have been made about the nature of climate-change challenges is the popular assumption that sea-level rise is THE problem for island nations, as if islands per se had no resilience to this or that other issues are subordinate by definition for islands (Nunn and Mimura 2007). This assumption points to an ignorance about islands in general, something that is made worse for Pacific Islands by the belief implicit in some statements that most such islands are *atoll islands* and therefore on the “front line” of climate change. The focus by some on the iconic atoll islands has provided a reason for leaders of high-island nations in the Pacific to sideline climate change and has also led to equally vulnerable areas (such as densely-populated river *deltas* on larger Pacific islands) being overlooked in estimates of future climate-change impacts in the Pacific (Solomon and Forbes 1999).

Yet it is perhaps the naiveté regarding the pathways of effective assistance for Pacific Island (and other developing) countries that is most regrettable, for this underpins the widespread failure of more than two decades of external assistance for the purposes of climate-change adaptation in the region. Most external aid for these purposes has been directed to Pacific Island governments who have clearly been regarded by donors as responsible stewards and effective managers of the environments of their countries. Much of the aid has been given for the purposes of policy development to underwrite sustainable solutions for climate change. This system, which undeniably works well in many developed countries, is shown in Fig. 15.1. It has failed in developing Pacific Island nations because legislation cannot be effectively enforced, largely because it is not effectively promulgated, because there are insufficient enforcement officers, and because communities generally regard the lands they occupy as being under their exclusive control (Turnbull 2004; Barnett 2008; Nunn 2009).

This situation is unlikely to change in the foreseeable future so donors need to engage with existing pathways of effective communication between science and society, however unfamiliar these pathways appear to be, in order that future assistance for climate change will have the intended outcomes. Yet more than this pragmatic reason, there is also an ethical reason for adopting this less-orthodox approach, namely that Pacific Island peoples are facing serious environmental problems with the potential for widespread loss of livelihoods and even societal unrest. In the light of this, donors have an ethical responsibility to follow effective pathways of assistance even if these might be considered radical, politically hazardous, and even without precedent.

The recommended pathway for effective assistance to Pacific Island countries for climate change adaptation is shown in Fig. 15.2. This involves funding community-level decision-makers directly because they are both the people who have the most effective decision-making power over particular environments and those with the long-term interests of particular places (and their inhabitants) at heart.

This pathway involves donors effectively bypassing governments and targeting persons-of-influence at community level. It also involves governments committing their own recurrent funds (internally-generated revenue) to the same empowerment of community leaders.

These leaders are best classified as persons-of-influence. They include hereditary chiefs (the traditional unelected leaders of clan groups), religious leaders (mostly church ministers, pastors, lay preachers), elected district leaders, and a range of other people depending on the particular context. It should be understood that in traditional societies of the Pacific Islands there are few traditions of democracy

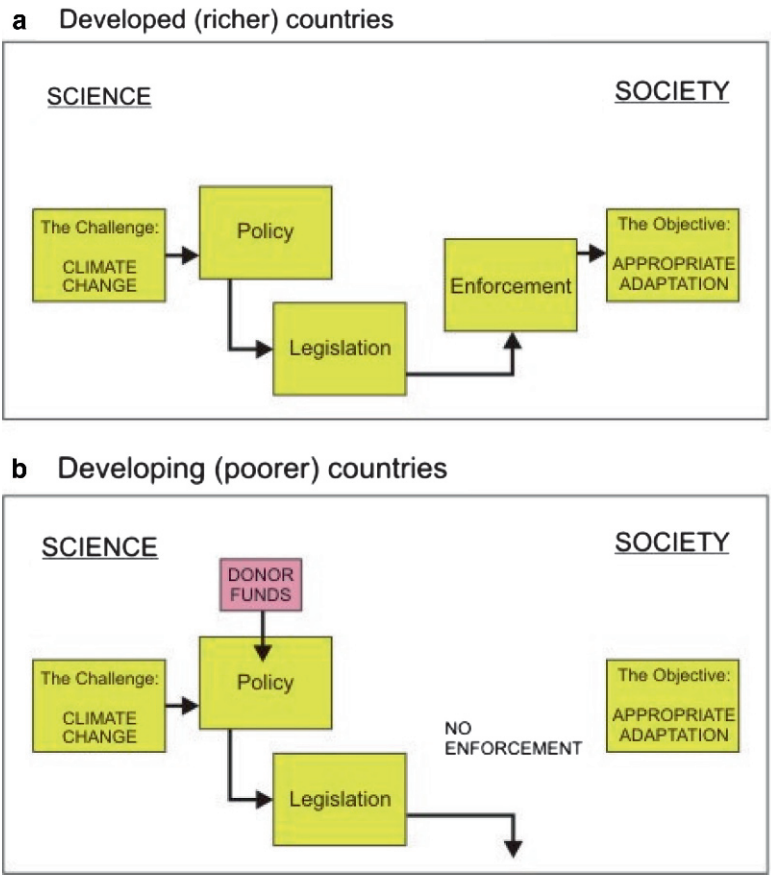

Fig. 15.1 Schematic diagrams showing how the gulf between science and society is bridged in developed countries and why this solution fails in developing countries of the Pacific Islands region. (**a**) National governments in developed (richer) countries recognize the challenge, research strategies for meeting this, develop appropriate policies and enact legislation which is effectively enforced resulting in appropriate adaptation. (**b**) National governments in some developing (poorer) countries are informed of the challenge, access donor (external) funds for developing policy and legislation that generally emulates those in donor countries. This legislation is unable to be effectively enforced, no appropriate adaptation occurs

or gender equality, such as underpin more modern structures here and elsewhere. The hierarchical nature of these societies means that most decisions are made by persons, generally elderly, whose rank puts them close to the top of the hierarchy. Those at the bottom of the hierarchy – school-age children, for instance – are rarely able to contribute to decision-making. In addition, most such societies are male-dominated, a few female-dominated (matriarchical). In such societies, the views of persons of the subordinate gender are rarely sought, however valuable they might be.

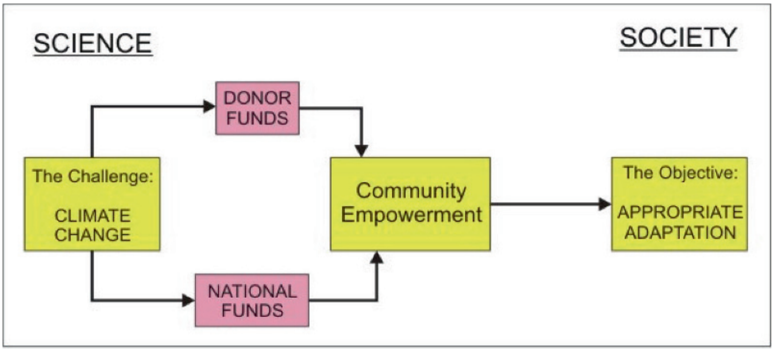

Fig. 15.2 Schematic diagram showing how the gulf between science and society can be effectively and sustainably bridged in developing countries of the Pacific Island region. The challenge is recognized and understood by both donors and governments who both use their own funds to directly empower communities – persons of influence within communities – resulting in appropriate and sustained adaptation

It is suggested that, given the pressing need for effective adaptive solutions in most parts of the Pacific Islands, aid donors and national governments work with existing systems, however anathemic their structures and their values seem to outsiders, in order to achieve the necessary goals.

15.5 Disseminating and Sustaining Adaptive Solutions

When the reasons for the failure of past *climate-change adaptation* initiatives in the Pacific Islands are examined, it is easy to fault a lack of understanding of the problem (Sect. 15.2) as well as the objectives of adaptation (Sect. 15.3). It is also easy to see why assumptions made about the pathways of linking science to society may have been wrong (Sect. 15.4). Yet there are also issues of communication. These fall into two categories:

1. *Community perceptions*. First, there is the way in which particular adaptive solutions are perceived by communities who are expected eventually to take ownership of them. Many such adaptive solutions are superimposed uncritically on Pacific communities by persons/agencies which expect these solutions to succeed simply because they have done so elsewhere and therefore "make sense". In fact, many such solutions fail in the Pacific Islands (and elsewhere in the developing world) because they are presented in ways that are culturally inept and are therefore interpreted as something alien and unneeded. Pacific communities may therefore ignore such solutions, perceiving them as foreign, and instead fall back on traditional practices.

2. *Effective communication*. Second, there is the issue of effectively communicating information about adaptive solutions. Much of the language surrounding issues of climate change is the language of science, something that is a hindrance in bridging the gulf between science and society on this important topic. Yet not only is it the language of science but it is generally also the English language. For persons like many community leaders in the Pacific Islands, who generally know little of science and who are generally uncomfortable speaking (or listening to) English for long periods of time, there is a huge challenge in simply establishing effective communication. Added to this is the issue of conceptualization for, while climate-change scientists may believe that western science invented concepts like adaptation and mitigation, many community leaders in the Pacific Islands find when they have listened long enough to explanations of these concepts that they have been practicing them for thousands of years. Adaptation and mitigation are among the processes that have underwritten the survival of societies of mid-ocean islands like these for generations (Johannes 1981; Nunn 2007). They are not new.

15.5.1 Dissemination of Information

With this in mind, it is now important to discuss how best to disseminate information about climate-change adaptation amongst communities in Pacific Island countries. This is particularly challenging (compared to other parts of the developing world) because of both the geography of island countries as well as the steep developmental gradients that commonly exist between their cores and peripheries.

Pacific Island countries lie within the world's largest ocean, covering nearly one-third of the planet's surface. So most such countries are difficult and costly to reach. In addition, given that most such countries are archipelagic, there are additional challenges involved in reaching every part of them, something that compounds the difficulty of disseminating practical information of any kind.

Less-commonly acknowledged are the steep developmental gradients that exist in larger (particularly archipelagic) Pacific Island countries between their cores, where most better-educated people live and where most revenue is generated, and their peripheries, where lifeways are generally more traditional, where cash is less necessary, and where environmental problems are in consequence generally less acute (Kumar 2007).

Yet climate change is an issue that is going to affect all Pacific islands, irrespective of their remoteness or their location within cores or peripheries, and there are therefore both practical and ethical imperatives in ensuring that appropriate information is disseminated to communities in all parts of all Pacific Island nations. Any scheme for dissemination of information about appropriate adaptive responses to climate change (and associated problems) must therefore acknowledge the geography and cultures of the region being targeted.

Problems associated with both geography and cultures are best overcome by persons resident in the region (ideally in the target country/ies) who are culturally competent to engage with its peoples. While television is available in most Pacific Island countries, it is generally less-respected than radio as a medium for communicating important information. Yet the most effective form of communication is face-to-face by a person (or persons) who sits with people, who follows traditional protocols, and communicates information in culturally-acceptable ways and words. The latter is perhaps most important. For Pacific Island people to take ownership of appropriate climate-change adaptation, this needs to be discussed largely in *vernacular languages* not in those regarded as foreign.

It is preferable for persons-of-influence in communities to be targeted, ideally within these communities where the environment being discussed can be referred to readily. Rather than direct contact, it is also possible to use proxies, such as religious leaders or schoolteachers in particular communities, who can be trained centrally and can then disseminate the message themselves.

15.5.2 Sustaining Adaptation

Many attempts at persuading communities of the efficacy of a particular adaptive solution have failed because they have evidently not been sufficiently engaged to sustain it. The most common situation is where a particular solution (like a seawall) is funded for a particular vulnerable community from sources external to that community. When the *seawall* collapses, as most do after 18–24 months along rural Pacific island coasts (Mimura and Nunn 1998), the money to rebuild it is unlikely to be forthcoming from the same sources. Communities may therefore use their own resources to rebuild the seawall and, when it fails again, it may simply stay that way (Fig. 15.3a).

A comparable scenario can be envisioned for the future in the Pacific Islands region, whereby donor funding for adaptation gradually dwindles relative to the sharply-increasing demand over the next few decades. It is therefore imperative that communities own adaptive solutions which they can sustain for the foreseeable future from their own resources. Such solutions must therefore be affordable, given the relative poverty (in cash terms) of the communities which own them, and they must be of a kind that can be managed by these communities. A good example is the re-forestation of eroding shorelines by *mangrove forest*, which is an effective low-cost form of *shoreline protection* that can be managed easily and almost indefinitely by communities that recognize its value (Fig. 15.3b).

Over the past two decades in the Pacific Islands, there has been little emphasis on the sustainability of adaptive solutions for climate change, but this would now appear to be a priority. It is likely that climate (and sea level) will change faster in the next 30–50 years than it has in the past 30–50 years, resulting in an acceleration of associated environmental problems like shoreline erosion, *flooding*, and *salinization* of lowland groundwater. Scientists, planners and community decision-makers all need to question whether the adaptive solutions they are proposing are actually sustainable in the long-term. There is an understandable preference on the part of many such people to recommend solutions that appear to be effective but are actually the least disruptive and the least costly (Perch-Nielsen et al. 2008). Many such solutions are actually only short-term ones that will be redundant in 10–20 years.

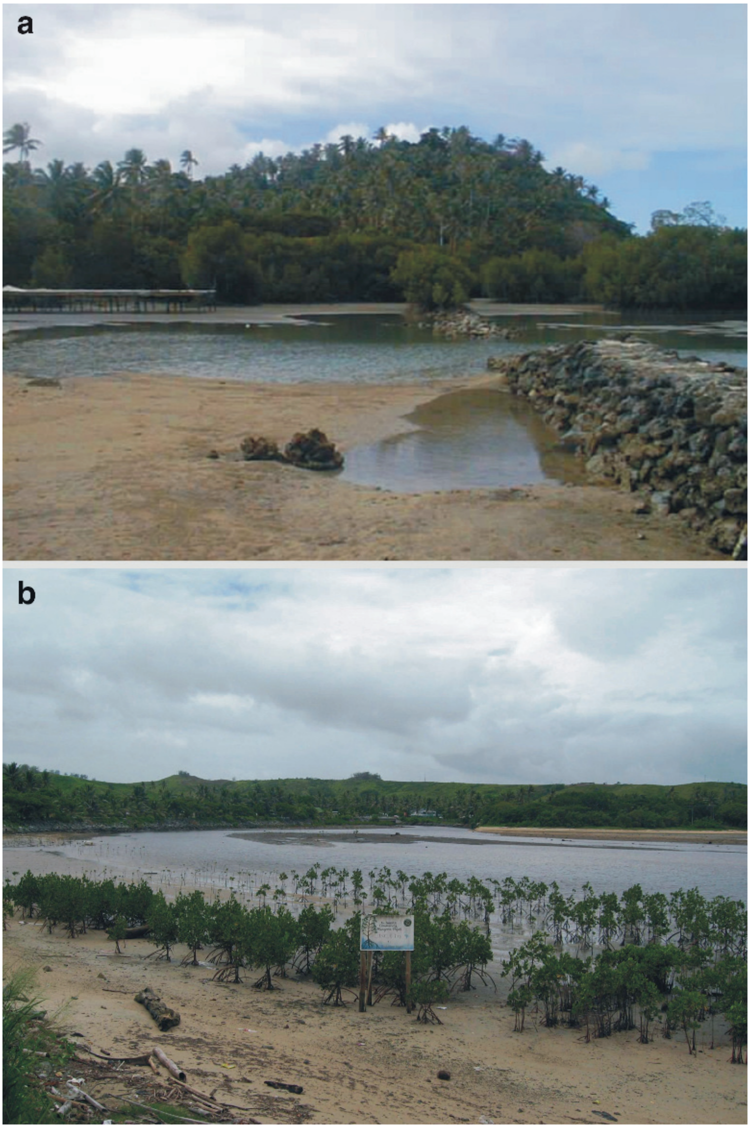

Fig. 15.3 Artificial and natural adaptation along Pacific Island shorelines. (**a**) Most local communities, unaware of how else they can respond to increasingly frequent sea flooding and beach erosion, build seawalls made from locally available materials and constructed using local labour. The positioning and design of these structures is generally only instinctive. Where seawalls do protect coasts effectively, this usually lasts only for less than 24 months before rebuilding is needed. In other cases, such as that illustrated, a lack of funds has prevented completion of the seawall (*right*) across the front of the coastal village (*left*) so that this is as effectively as vulnerable as ever (photo by author). (**b**) Some coastal communities have been persuaded by non-government organizations that planting mangroves along the front of vulnerable shorelines is a solution that is more effective, more sustainable and ecologically beneficial. This mangrove replanting scheme is a decade old and will need at least another 15 years before the mangroves are mature enough to protect the shoreline (photo by author)

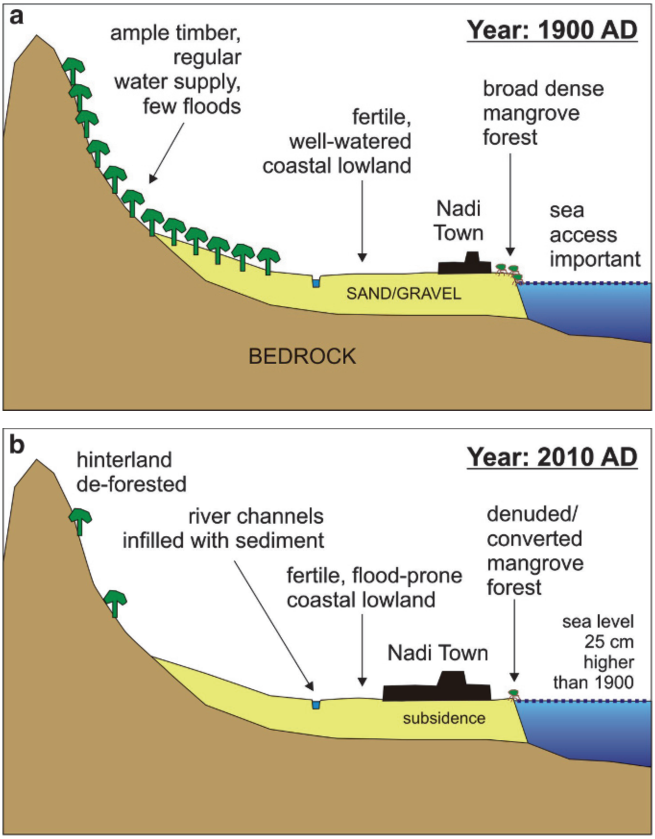

Fig. 15.4 Nadi Town (Fiji), an example of a town that will be severely impacted by sea-level rise in the next few decades. (**a**) Nadi Town was built more than 100 years ago at a time when roads were few in Fiji and trade depended on sea transport. In the early years of Nadi's development, the location appeared sustainable because there were few floods owing to well-vegetated catchments. Sea level was lower than today so that sea flooding, particularly during storms, was not as much of a problem as it is today. A broad mangrove forest existed along the shoreline, adding to the resilience of the location. The fertile well-watered coastal lowland was ideal for commercial agriculture. (**b**) Today the situation of Nadi Town is quite different. The hinterland is largely deforested so that floods have become more frequent and attain higher average magnitudes than they did 100 years earlier. Lowland river channels have become choked with sediment. Sea level has risen significantly. Much of the former mangrove forest has been removed, often for tourism or for infrastructure purposes. Like all river deltas, the land on which Nadi is built has been subsiding as a result of sediment compaction, de-watering (groundwater extraction), and possibly structural (geological) downbowing. Despite all these problems, Nadi Town is growing and becoming more prosperous.

A good example is that of *Nadi Town (Fiji)*, which has experienced floods of increasing magnitude and duration over the past five years (Fig. 15.4). The first response has been to dredge the nearby river channels, the latest to divert the course of the Nadi River a short distance away. Neither solution is likely to be an effective

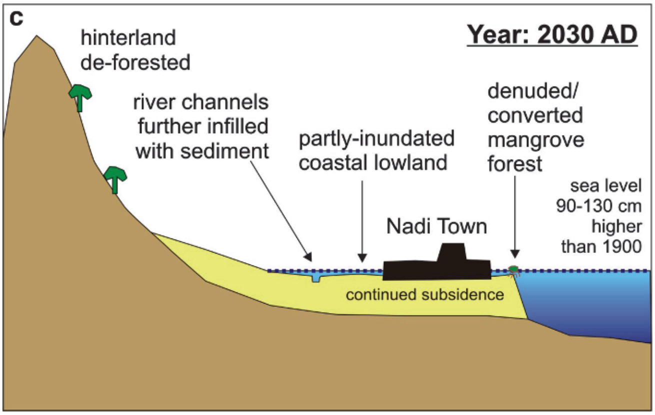

Fig. 15.4 (continued) (**c**) Thirty years from now, large parts of Nadi Town will be permanently underwater. The main reason for this is that sea level will be significantly higher so that town drains will be unable to carry flood waters away. Many rivers will be in a permanent state of flood because of the higher sea level. Storm surges will have far greater impact than they do today. The only realistic option for Nadi Town is to relocate as soon as possible

long-term strategy for this delta-edge town. The only effective long-term solution is to re-locate Nadi Town – and hundreds of other Pacific Island settlements in equally vulnerable locations – to places where they are beyond the reach of expected twenty-first-century sea-level rise.

Yet *re-location* is an expensive solution and one that is inherently unpalatable to people who have occupied the same place for what they perceive to be a long time. The socio-economic benefits of re-location today (anticipatory adaptation) are huge yet not understood by people occupying vulnerable locations like Nadi Town. It is likely that 10 years from now, there will be a flood so damaging and enduring in a Pacific island town like Nadi that a decision will be taken to re-locate it at once. And once this move is seen as successful by other vulnerable coastal communities, there will then be a rush by them to move to less-vulnerable locations.

Of course on some islands, there are no less-vulnerable locations to which vulnerable communities can re-locate and it is likely that within the next 15–30 years, environmental refugees from low-lying Pacific islands will be looking outside their home islands/countries for new homes (Brown 2008).

15.6 Conclusion

Future climate change threatens the way of life of Pacific Island peoples as well as the fabric of the islands themselves. Despite two decades of good information about future impacts, little decisive or enduring action has been taken in the Pacific Islands, exemplifying the 2008 comment by the Chair of the IPCC that human responses to threats from climate change have been "weak and inadequate … even as changes in climate become more serious" (www.ipcc.ch).

Science has most of the solutions that Pacific Island peoples need to reduce (as far as possible) the impacts of future climate change but there is a gulf between Science and Society that has not yet been effectively bridged in this region. Donor agencies/countries, regional organizations and national governments all have responsibilities to ensuring that such bridges are built and effectively maintained. At present, there is little sign of this happening in the Pacific Islands region.

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Chapter 16
Science, Culture, Education, and Social–Ecological Systems: A Study of Transdisciplinary Literacies in Student Discourse During a Place-Based and Culture-Based Polynesian Voyaging Program

Pauline W.U. Chinn

16.1 Introduction

As the world's most isolated islands with the highest number of endangered species per square mile anywhere on earth (Bishop Museum 2003), Hawai'i provides a unique setting for exploring questions concerning science, technology, and society. For reasons ranging from issues of health, safety, and schedules to adoption of science curricula developed for national audiences to science teacher education, relatively little of the science students learn in school relates to Hawai'i or connects to students' familiar environmental experiences and knowledge. Conventionally presented as a body of universal knowledge discovered through objective, impersonal, and culture-free experimentation, students perceive school science as largely unrelated to their places, practices, and personal knowledge.

16.1.1 Teaching, Learning, and Knowledge Building as Socially Situated

In reality, the doing of science is both a place-based and cultural activity as researchers take local contexts into account and communicate using the language and conventions of particular disciplines. Meyer's (1998) interviews with Native Hawaiian elders about indigenous knowledge building led her to conclude that "Sites of practice, where the product, process and context were Hawaiian – that

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(*sic*) was where both information and practice synergized and strengthened the threads of cultural continuity" (p. 143). If the word *scientific* replaces *Hawaiian* and *cultural*, it becomes apparent that the ongoing development of science knowledge, the continuation of science as a culture, and the processes of incorporating new members are active social processes, situated in places where participants' *shared practices*, tools, and language (i.e., discourse) (Gee 2004, 2005) develop and sustain particular ways of understanding (Bourdieu and Passeron 1977).

What are the connections among cultural and scientific knowledge building, cultural continuity, and social–ecological systems (SESs)? Research in Hawai'i suggests that transdisciplinary learning communities that include indigenous practices and knowledge are critical to building the capacity to respond to ecosystem changes (Kaneshiro et al. 2005). Folke's (2004) overview of the role of traditional knowledge in *ecosystem management* notes that knowledge systems that develop through a community's daily and long-term ecosystem interactions address "interactions across temporal and spatial scales and organizational and institutional levels" and may provide models for adaptive capacity, characterized as learning and responding during "periods of rapid change, uncertainty, and system reorganization." Davidson-Hunt and Berkes (2003) cited Folke et al.'s (2003) synthesis of four principles for building *adaptive capacity* in SESs: " (1) learning to live with change and uncertainty, (2) nurturing diversity for reorganization and renewal, (3) combining different types of knowledge for learning, and (4) creating opportunity for self-organization." Liu et al.'s (2007) synthesis of six coupled human and natural system studies across five continents underscores the importance of explicitly addressing "complex interactions and feedback between human and natural systems" to gain "unique interdisciplinary insights into complexities that cannot be gained from ecological or social research alone" (p. 1513).

This case study from Hawai'i illuminates the complexities of one such coupled human and natural system. Until a recent revision, Hawaii's science content standards included *Mālama I Ka 'Āina, Sustainability*, incorporating a Hawaiian perspective on active stewardship. Kanahele (1986) explained its cultural significance: "If we are to be truly consistent with traditional Hawaiian thought … we are but stewards of the *aina* and *kai,* trusted to take care of these islands on behalf of the gods, our ancestors, ourselves, and our children (pp. 208, 209)." *Konohiki*, a category of individuals with recognized expertise actively managed the SESs that sustained Hawaiian communities (Kumupono Associates 2008):

> Acknowledging the relationship of one environmental zone (*wao*) to another is rooted in *traditional land management* practices and values…These traditional *wao* or regions of land, districts, and land divisions included: *1–Ke kuahiwi,* the mountain*; …7-8–Ka wao ma'u kele and Ka wao kele,* the rain belt regions*; …10–Ka wao la'au,* the forested region*; 11–Ka wao kanaka,* the region of people below*;…14–Ka pahe'e,* the place of wet land planting*;…18–Ka po'ina nalu,* the place covered by waves [shoreline]*; 19–Ke kai kohola,* the shallow sea [shoreline reef flats]*;...23–Kai popolohua-a-Kane-i-Tahiti,* the deep purplish black sea of Kane at Tahiti (Kihe in *Ka Hoku o Hawaii*, September 21, 1916; Maly, translator).

Values of respect and care for nature that indigenous Hawaiians view as sustaining their existence are also found in American Indian and Alaskan Native cultures

(Cajete 1999, 2000; Kawagley and Barnhardt 1999). Davidson-Hunt and Berkes (2003) described how individual learning becomes part of community knowledge among the Anishinaabe, a First Nations people located near the border of Ontario and Manitoba, Canada. Among the Anishinaabe, social processes exist for incorporating individuals with new knowledge into recognized categories of holders of social memory. Through extensive life experiences that develop detailed, place-based knowledge, an individual may be recognized as especially competent and knowledgeable and become an elder, a socially designated role that recognizes certain individuals as a source of authority and "legitimate social memories."

The mapping of the Hawaiian social–ecological landscape into the 23 *wao* described above provided a cultural framework for constructing, organizing, and transmitting knowledge and values supportive of *socio-ecological resilience*. These knowledge-processing frameworks enabled individual and group memory to be consolidated into a dynamic body of cultural knowledge able to respond to changes in the SES. For example, the *Makahiki na o Lono,* an important island-wide, annual ritual dedicated to *Lono*, god of crops and bringer of rain began in late fall at the first new moon following the appearance of the Pleiades. For 2 months, war as well as fishing, planting, and other forms of work ceased as the island's ruling chief, *mōʻi*, chiefly retinue, and priests made a complete circuit of the island, visiting each *ahupuaʻa* and receiving tribute. In effect, the *Makahiki* (meaning year, yearly) served as an institutionalized, annual island-wide monitoring of a range of SESs, enabling consolidation of cross-scale, cross-temporal information for resource management oriented to sustainability.

Abbott (1992) suggested that the *Makahiki's* biological significance lay in the "two-month period when the land could rest, plants could grow without being harvested, and the ocean could replenish itself" (p. 22). When the *Makahiki* was not in force, lesser chiefs serving as resource managers, *konohiki,* in each largely self-sustaining resource unit, *ahupuaʻa,* enforced appropriate behavior with strict sanctions, *kapu*, that structured the lives of all classes of society. In twenty-first century Hawai'i, indigenous ways of thinking about SESs continue to provide a framework for a responsible relationship of people to place.

16.1.2 Reconnecting School Science to Place, Culture, and Practice

Davidson-Hunt and Berkes (2003) warned that the loss of indigenous values and the institutions that authorized and legitimized construction and transmission knowledge can lead to loss of resilience that is both social and ecological in nature. Unfortunately, the perception of many science teachers that science is objective and culture-free contributes to insensitivity to the sociocultural contexts of teaching and learning (Greenfield-Arambula 2005). The absence of authentic, personalized, *experiential learning* is a critical factor in successful schooling of Native Hawaiian students (Kawakami and Aton 2000) and in the persistence of underrepresentation of female students in college physical science and engineering programs (Chinn 1999).

The gap between Hawaiian ways of learning that lead to transdisciplinary, situated, active knowledge and conventional school learning that leads to decontextualized science knowledge suggests that delegitimization of traditional knowledge systems, values, and ways of learning may contribute to the underrepresentation in science of Native Hawaiians. Ten years ago, the goal of removing or narrowing this gap motivated the writer to design a science education course, EDCS 433 Interdisciplinary Science Curriculum, *Mālama I Ka ʻĀina,* Sustainability with a place-, culture-, and inquiry-based focus.

Summer EDCS 433 courses allowed teaching and learning to be situated primarily in transdisciplinary, culture–science learning communities in which expert peer teachers, scientists, and community members provided models of place-based science programs. Course assignments asked teachers to view their communities as resources for writing lessons meeting the criteria of rigor (content-rich, standards-based), relevance (significant issue, meaningful to learners), and relationships (learning community). When external funding permitted, overnight *culture–science immersions* in school and community settings provided opportunities for diverse participants to learn from and to teach each other. The teacher in the case study reported below developed her place-based program into an exemplary model with the support of several years of funding from *Pīkoi Ke Kaula Kualena*, Focus on the Essential Core, an award to the Consortium for Hawai'i Ecological Engineering Education from the U.S. Department of Education, Native Hawaiian Education Act.

16.1.3 Theoretical Framework and Research Questions

The theoretical framework for this qualitative study is located in social learning research and theory associated with Bourdieu and Passeron (1977), Lave and Wenger (1991), Wenger (1998), and Gee (2004, 2005). Lave and Wenger's (1991) theory of knowledge acquisition is based on studies of learning situated in communities of practice focused on specific outcomes. A *community of practice* (Wenger 1998) has the characteristics of joint enterprise and mutual engagement among "people who engage in a process of collective learning in a shared domain of human endeavor." The reciprocal and dynamic nature of teaching and learning is captured in the Hawaiian word *aʻo*, meaning instruction, teaching, doctrine, learning, advice, and counsel (Pukui and Elbert 1986).

Social learning theories acknowledge the role of modeling, observational learning, subjectivity, intentionality, and a plurality of sociocultural contexts productive of multiple identities and literacies. Learning is viewed as a social process with implications for identity-building that occurs over an individual's lifespan in formal and informal situations.

A sociolinguistic approach suggests that insight into learning may be gained in settings in which students use vernacular or home language and practices while learning and practicing academic and content area communication practices and skills. The analysis of *Discourse* – defined by Gee (2005) as "ways of combining and integrating language, actions, interactions, ways of thinking, believing, valuing and using various symbols, tools, and objects to enact a particular sort of socially recognizable identity" (p. 21) – is discussed below as a way to study teaching and learning.

Gee's (2004) critique of schooling relevant to equitable access to knowledge is based on the distance between "academic varieties of language connected to content areas" (p. 19) and the vernacular language of home and community. His research shows that children from nonmainstream cultural backgrounds learn forms of language that are discouraged in schools, whereas those from middle class homes learn forms that parallel academic speech valued in schools (e.g., providing explicit detail on a single topic). Gee thinks entry into a Discourse community with specialized language and practices (signified by a capital D) involves a trade-off between loss of vernacular, everyday language and gain of specialized language:

> So a crucial question in science education, for example, ought to be: *"What would make someone see acquiring a scientific variety of language as a gain?"* … People can only see a new specialist language as a gain if: (1) they recognize and understand the sorts of socially situated identities and activities that recruit the specialist language; (2) they value these identities and activities …; and (3) they believe they (will) have real access to these identifies and activities.... Thus science in school is learned best and most deeply when it is, for the learner, about "being a scientist" (of some sort) "doing science" (of some sort) (p. 93).

A view of *learning* as socially situated, supporting development of a new *identity* through the acquisition of an integrated set of language/knowledge/skills and occurring in sites of practice provides a research agenda that looks for evidence that language, identity, and knowledge change as a result of this type of learning. Gee's (2005) approach to discourse analysis is used to explore the following questions:

- What socially situated identities and activities are enacted?
- What Discourses are involved?
- What relationships appear among different Discourses?
- How does intertextuality function in texts?

16.2 Study Setting and Participants

Project Ho'olokahi is a school-based Polynesian Voyaging program led by Michelle Kapana-Baird, a certified physical education teacher and canoe paddler associated for many years with the Polynesian Voyaging Society. She was motivated to study Maunalua Bay by Myron Thompson, a prominent educator and leader in the Hawaiian community and Polynesian Voyaging Society. He had remarked on the appearance of alien seaweeds in Maunalua Bay, where her students applied their learning with the support of the canoe club and Polynesian Voyaging Society. Michelle enrolled in EDCS 433 in 2002 with the goal of developing a plan to restore the bay.

Maunalua Bay is located in the Waikiki *ahupua'a* between the tuff volcanoes of Diamond Head, *Leahi*, and Hanauma Bay. Its name, Maunalua, two mountains, signifies its position between two mountains. The eastern section is connected by two dredged channels to the remnants of the largest precontact fish pond in Hawai'i. In 1959, the 500+ acre fishpond was designated private property in a landmark court case, permitting the development of a marina community designed for 50,000 but now home to 60,000 residents. Long-time residents observe that the number of hammerhead shark pups found in the 200-acre marina has declined over the years. The development of a park, boat ramp, and a large parking lot on the ocean side of the marina support year-round use by residents and tourists. Commercial activities include paddling, kayaking, jet and water skiing, scuba diving, coastal boat tours, snorkeling, and fishing. Michelle's canoe club, *Hui Nalu*, houses its canoes on one side of a channel; a bird sanctuary is on the other.

Students in *Project Ho'olokahi* learn and practice cultural protocols, Polynesian navigation, sailing, and a core *cultural value*, caring for the land that feeds, *mālama i ka 'āina*. Students are 15–18 years old and become lifeguard-certified as a prerequisite to ocean activities. Most who enroll in this elective course are Native Hawaiians. As often found with courses that provide active, hands-on learning, special education students were overrepresented in Michelle's class compared to their percent in school. The culture–science immersion documented by students occurred during the 2005–2006 school year.

The author-researcher was born and raised in Hawai'i. She used to fish and collect edible seaweed at Maunalua Bay, and she taught science at Michelle's school before becoming a university instructor. EDCS 433, an interdisciplinary place- and culture-based science curriculum course was underwritten by the Native Hawaiian Education Act, U.S. Department of Education.

16.3 Methodology

This qualitative case study seeks to understand how students in Project *Ho'olokahi* construct meaning and express themselves through journal excerpts and video clips they select as most important to telling the story of their culture–science immersion. Data sources include the videotape and transcript from *Na Pua O Maunalua*, The Youth of Maunalua. The researcher was a participant-observer during one of the three culture–science immersions, conducted site visits at the school and in the community prior to and following the immersions, and attended the community meeting announcing the establishment of the nonprofit *Mālama Maunalua*. Michelle Kapana-Baird reviewed the paper to ensure cultural and interpretive validity (Cohen et al. 2007).

Discourse analysis (Gee 2005) was applied to the transcript of a student-made video describing their 24-h culture–science immersion. The analysis examines sites of practice, language, activities, actors, and tools to detect Discourses that suggest learning and identity building; social languages associated with home, school, and disciplines; intertexuality of words as relating to words spoken by others; "and conversations" that relate to "themes, debates, or motifs that have been the focus of much talk and writing in some social groups … or society" (p. 21).

16.4 Results

Two years after beginning her culture–science program in 2003, Michelle led three community-based immersions at Maunalua Bay. The 24-h agenda received by students and parents revealed extensive integration of culture and science. Students would learn from graduate students, U.S. Geological Survey and Fish and Wildlife agents, science teachers, and a Master Navigator. Expertise spanned marine biology, Global Positioning System (GPS) mapping, water testing, Polynesian sailing, and navigation. Indigenous contexts for learning were seen in the frequent use of Hawaiian words and the following of Hawaiian protocol in *pule*, prayers or blessings, that focus attention on the place, activity at hand, and key participants and serve to connect natural, cultural, and spiritual worlds at key transition points. The agenda overall exemplified school *Discourse*, and the agenda content, Hawaiian and science words, tools, and activities exemplified cultural and science Discourses.

The author attended one of the three 24-h culture–science immersions from morning through the early afternoon. Michelle had divided her class into three groups as the *Hokulea*, the voyaging canoe on which they would spend the night did not have adequate space. Students paddled out to the reef flat to remove alien seaweeds in the company of botany graduate students and agency scientists. Each canoe held six paddlers, including an adult steersperson from the *Hui Nalu* Canoe Club. A small skiff towed by one of the canoes carried collecting bags, scoop nets, and other supplies necessary for site work. At all times students and adults were in close contact, working and learning together in various roles. The author observed an adult-to-student ratio of one adult to three students, in contrast to the 26 students to one teacher ratio in public schools.

16.4.1 Discourse Analysis of Transcript of Na Pua O Maunalua

Students' journal entries provided the narrative of a 5-min videotape of the October 2005 immersions. Students completed the 16-stanza videotape in May 2006. Different students spoke each stanza, defined by Gee (2005) as "sets of lines devoted to a single topic, event, image, perspective, or theme" (p. 127). Selected stanzas are elaborated upon below to highlight the way situated culture–science learning appears to support the simultaneous development of students' cultural and scientific literacy. (See Appendix for the complete transcript.[1])

Stanza 1 introduces a key role model and program mentor, master navigator Nainoa Thompson, who in 1980 became the first Native Hawaiian navigator in many centuries to navigate a double-hulled voyaging canoe between Hawai'i and Tahiti without instruments (http://pvs.kcc.hawaii.edu/finney80.html). He was given

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[1] The program description, "Invasive Alien Algae Removal Efforts Aim at Restoration of Maunalua Bay" and *Na Pua O Maunalua*: A Video Documentary may be viewed at http://www.kaiser.k12.hi.us/minisites/catarticle/CAT.html.

this title by indigenous navigators following a series of long distance voyages. The dominant Discourse is academic discourse, providing descriptive detail of a single topic, the 24-h immersion.

Stanza 2 reveals the dual *Discourses* of school and Hawaiian culture that establish a Hawaiian context for the community-based activity. Using English at the beginning of the stanza to describe the purpose of the immersion establishes the activity as a school event but a shift to Hawaiian midway through emphasizes the cultural role of stewardship. The impersonal label and role "environmental stewards" becomes the culturally contextualized *haumana*, students, who will *mālama i ke kai o Maunalua,* care for Maunalua, the area of the sea they know, use, and enjoy and therefore must care for it. The canoe club's *hālau* houses canoes and gear and has served as their learning site since the project began. (*Hālau* is also associated with meetinghouse and place of learning.) The final phrase "*experiential learning*" in English returns to school Discourse but conveys place-based, purposeful, active Hawaiian ways of learning.

Stanza 3 is a hybrid of school, science/technology, and cultural Discourses. It opens with school Discourse (first activity of the day) and then shifts into science/technology Discourse when describing uses of GPS tools for scientific data collection and communication. The only use of Hawaiian/local cultural Discourse is to introduce an agency scientist as Aunty Annie. This positioning of a scientist as a member of an extended family, *'ohana*, establishes a pattern noted in succeeding stanzas that suggests the students' familiarity with scientists as role models.

Stanza 4 shows the blending of informal discourse with school, science, and cultural Discourses. The overall format, a detailed description of a single activity, clearing alien *limu*, reflects school and science Discourse. "Quadrate, square meter, scoop net, floating fragments, because, generate, colony" – representing the tools, terms, ways of seeing and measuring an objective world – indicate the students' scientific literacy.

The Hawaiian word *limu,* seaweed, is used four times and *kuleana*, right/responsibility, is used once without elaboration in English. The ability of video to convey meaning through action of *kuleana* – a core Hawaiian ethic oriented to personal responsibility and sustainability – indicate that it would be well known to the audience. This is an example of Gee's (2005) Conversations, themes that are generally known to particular social groups, in this case, Native Hawaiians, most residents of Hawai'i, and those familiar with *Mālama i ka 'āina, sustainability*, a former science content standard. Students' voices and feelings are expressed in the words "amazing how much there was in one square meter" and "a big patch of alien *limu*." Informal discourse recognizes the importance of affect, personal experience, and engagement in learning.

Stanza 5 continues the blending of school, cultural, and science Discourses. Aunty Kim and Aunty Dawn, botany graduate students, help students learn unfamiliar science in familiar settings and contexts. Alien *limu*, shown in photographs taken by Michelle (Fig. 16.1a, b), are given informal and scientific names, linking everyday discourse to scientific and school Discourses. Students wear gloves as they handle the *limu*, following safety procedures used by researchers. (In Stanza 6, a student

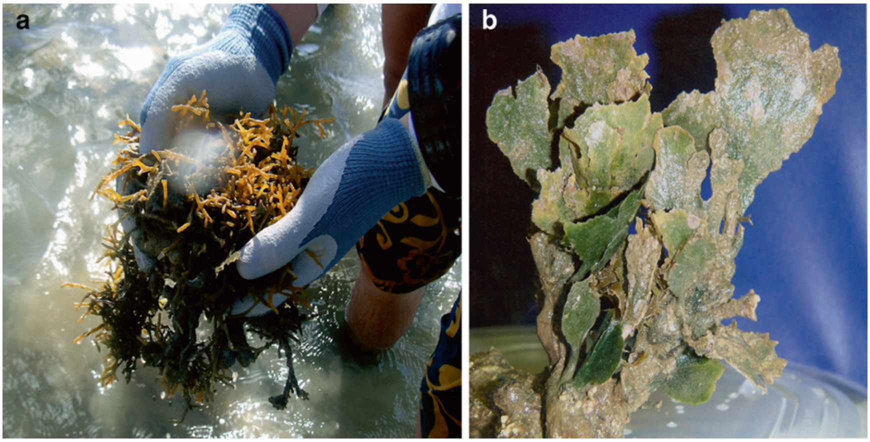

Fig. 16.1 (**a**) Gorilla *ogo,* or *Gracilaria salicornia*. (**b**) Leather mudweed, or *Avrainvillea amadelpha*

holds a bristly polychaete worm as the student narrator says: “Fire worms are the centipedes of the sea because when they sting you it feels like fire.”)

In Stanza 7 a student evaluates personal experiences in scientific language, “Our class collected over 450 lb of alien *limu*,” and affective language, “It was awesome to do something that was good and benefited nature.” The student feels good that problem-based, active learning benefits a familiar SES. This Hawaiian way of learning produces active *science literacy*, “knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (p. 22, National Science Education Standards 1996).

Stanza 8 makes a direct connection between students’ reef-monitoring activities and the practices of ancestors. As students paddle an outrigger canoe toward a coral reef, the student narrator evaluates paddling as “hard work [that] brought many of us back to the routes traveled by our ancestors in ancient Hawai’i.” The use of outrigger canoes as research vessels produces insights that support simultaneous identification with hard-working ancestors and scientists.

Stanzas 10 and 11 are particularly revealing of the co-construction of indigenous, school, and scientist *identities*. The video shows students, instructors, and community members conducting water tests for salinity, dissolved oxygen, and nitrates and using dyes to examine current flows. Participants wear informal beach clothes and are sun-tanned; and many appear to be of Hawaiian ancestry. In contrast to conventional school science laboratory activities with predetermined outcomes, participants are engaged in authentic science inquiry with outcomes of interest to their real world concerns. The phrase “Uncle Eric turned the *hālau* into a science lab” conveys the reality of culture–science identities, knowledge, and practices coexisting in the same places and bodies.

These stanzas show that scientific Discourse, typically characterized by passive grammatical construction and tight connection of evidence, analysis, and possible outcomes, may be situated in cultural and informal contexts. The claiming of science Discourse as personal/informal and cultural is seen in placement of the student-as-scientist into the text as "we" and "us," the positioning of the science teacher leading the water and current tests as "Uncle Eric," and the carrying out of science activities at the *hālau.* The visuals and text indicate that doing science in this way is meaningful and that anyone can engage in authentic science inquiry oriented to informed care for familiar ecosystems.

Stanzas 12 and 14 reveal that ending the day with a sail in Maunalua Bay, "the reward for all this hard work" of doing science, is deeply cultural. "It truly was an honor" to sail on the *Hokulea*, learning to steer from "Uncle Nainoa," the Hawaiian navigator famous for developing a noninstrumental way-finding system. In the video, several students grasp the steering sweep as the *Hokulea* sails in the open ocean. Steering the *Hokulea* is cultural work able to be simultaneously described in physics terms. Learning to be a Polynesian voyager is also "hard work" as the student reported: "it was very challenging to keep control of the large steering sweep which weighs over 500 pounds." The theme of learning as hard work occurs in stanzas 3 (twice), 8, 12, 13, 14, and 16.

Master Navigator Nainoa Thompson in stanza 1 has become Uncle Nainoa in stanza 14, suggesting a familial yet respectful relationship grounded in interpersonal, *joint activity*. As for other uses of "aunty" and "uncle" in the transcript, the terms represent relatedness, respect, and imply reciprocal responsibility instead of the distancing and status recognition expressed by formal institutional roles and titles.

In final Stanza 16, language shifts from referring to instructors as aunties and uncles who shared thoughts and ideas, *mana'o,* to "leaders" and "planners." Positive evaluations of *experiential learning* are captured in the phrase, "This was one day that we all wished would never end." The use of Hawaiian terms, cultural references, and final video footage, a lingering shot taken from the *Hokulea* of the sun setting directly over *Leahi* (Diamond Head) convey the message that new knowledge and experiences are firmly situated in shared place- and culture-based learning activities.

A student recognizes that "By working together we developed a memorable experience that will last a lifetime." "Working together" suggests the Hawaiian word *lokahi*, unity and harmony, a word found in *Ho'olokahi*, the project's name. Meaningful learning as "memorable experience that will last a lifetime" is constructed through working together, co-planning, and willingness to share *mana'o*, the thoughts, ideas, meanings, and theories presented that day. In positioning the immersion as learning to care for the sea and land, *mālama i ke kai a me 'āina*, science learning is integrated with culturally responsive, place-based learning.

16.5 Discussion

A view of learning as socially situated looks for evidence that language, identity, and knowledge change as a result of this type of learning. Gee's (2005) approach to discourse analysis is used to explore the following four questions.

1. What socially situated identities and activities are enacted?
   Michelle told the author a few years ago that she was initially put off by the first EDCS 433 classroom presentation that interpreted Hawaiian resource management practices through the lens of science. Her comments, echoed by other Native Hawaiian teachers, indicate that *learning about* science has much less value that *doing science* in the context of problem-solving and application in the real world. She and her Native Hawaiian colleagues who knew from personal experience that human activities often had negative ecological consequences appropriately evaluated science knowledge and technologies through the lens of cultural relevance and utility.

   Conducting science activities outdoors at the canoe *hālau* and from canoes serving as research vessels supports the simultaneous enactment and construction of science and indigenous identities. Students enact these identities through their use of science and Hawaiian terminology and appropriation of school, science, and indigenous Discourse patterns. The activities (*limu* identification, *pule*, paddling, sailing) and tools (GPS, quadrates, water test kits, canoes) allow multiple identities to develop and strengthen as participants with different knowledge and backgrounds teach and learn (*a'o*) together. Stanzas in which a student reports, "Uncle Dave taught us how to identify the fish, and it was neat to actually know their names" or in Stanzas that discuss water tests and *limu* species suggest that doing science with scientists enables students to think about, experience being like, and even identify with scientists even as the cultural and place-based contexts of the activities support indigenous meanings and identities. (See Appendix for a complete transcript.)

2. What Discourses are involved?
   Evidence from the videotape and transcript suggests that *hybrid Discourses* of culture, science, and schooling are learned by students. Even when science Discourse dominates, a word or phrase, such as calling a science instructor "aunty" or "uncle," conveys a cultural Discourse. The overall language pattern of each stanza reveals academic Discourse in the description of a central topic. Possibly an outcome of revising journal entries during storyboarding, the process reinforces the use of academic Discourse as students learn to revise informal, expressive language toward the expected forms of disciplinary discourses.

3. What relationships appear among different Discourses?
   The context for Michelle's science activities is the cultural imperative to study and care for (*mālama*) community resources for current and future generations. Thus, the student transcript suggests that both the wisdom of ancestors and Western science are valued as providing tools for teachers, students, and community to learn about and care for the sea and land, *mālama i ke kai a me 'āina*. Her program conveys and her students learn an adaptive cultural Discourse that includes scientific and academic Discourses as appropriate to the purposes of the activity and participants.

   Through her situatedness in diverse settings over the years, Michelle has successfully established a transdisciplinary *knowledge network* that includes agency and university scientists engaged in conservation biology and community-based management. As someone with access to place-, culture-, and community-based knowledge, her relationships with researchers appear egalitarian and collegial. She has developed a unique, science-based understanding of Maunalua Bay and in 2006 won the Hawai'i's Living Reef Program's Educator award (http://www.hawaiireef.net/awards/winners.shtml).

In the 713-word transcript, the number of terms associated with the Discourse of science and technology exceed those associated with Hawaiian language/culture/activities, which greatly exceed terms associated with school and classroom learning. The student selection of learning logs for the transcript suggests that they recognized the potential for science and technology to support and inform indigenous practices oriented to sustainability.

4. How does *intertextuality* function in these texts?
   The texts generated by students exemplify intertextuality in their borrowing of words and phrases from other Discourses. The first two lines in stanza 4, above, show language associated with Hawaiian (*limu, kuleana*), science (quadrate), and academic (focus on a single topic) Discourses. It also contains informal, expressive discourse in the nonscientific description of "a big patch" of alien *limu*.

   Intertextuality involving Hawaiian words functions to interrupt dominant Discourses and images of science in stanzas 10 and 11, giving science a Hawaiian voice and sensibility. Intertextuality in student writings thus connects cultural identity to emerging science and academic identities. Intertextuality also shows the origins of language used by students when words and phrases echo those used by the teacher, as in the use of "immersion." Similarly, the student who spoke of voyaging in the "routes traveled by our ancestors" echoed Michelle's words in her project overview that reflect the phrasing used in Polynesian Voyaging Society texts. The shaping of language through affiliation suggests the socially situated shaping of identities and construction and continuity of culture.

16.5.1 Implicvations for Teacher Education and Student Learning

Michelle modified the EDCS 433 model of a school- and community-based culture–science program into a version appropriate to her site and Project *Ho'olokahi*. The range of participants and experts involved in her immersions showed that she established a social network that shared her interests in monitoring and restoring *Maunalua* Bay. Analysis of student texts suggests that science done in the context of real world cultural and environmental issues is engaging and meaningful. Michelle's original interest in incorporating science into her culture-based program is reflected in her students' assessment of their learning and experiences.

This case study suggests that place-based professional development in science that is congruent with Native Hawaiian knowledge, values, and practices has the potential to empower teachers as curriculum designers. Teachers who utilize the resources in their students' communities in their lessons engage students in richly contextualized, personally meaningful learning that supports access to academic content. In Michelle's program, co-learning with community members and scientists is central to this process. Participating in a *transdisciplinary learning community* composed of diverse participants who share a common purpose enables students to explore different Discourses in authentic contexts. Students recognize that learning to be a member of a Discourse community is hard but meaningful work. One of Michelle's expectations is that her students learn in order to teach others who come to Maunalua Bay to help and learn.

Gee's (2004) position that learning science (or other Discourse) is noted as the gain of socially situated, specialist language and identity appears to be supported in this study. The transcript video, and researcher's site visits indicated that students "recognize and understand the sorts of socially situated identities and activities that recruit the specialist language … and value these identities and activities" (p. 93). Some of Michelle's students have entered into activities that indicate their experiences supported "real access to these identifies and activities" (ibid, p. 93). In 2008, I met one of several of her students participating in summer youth conservation programs.

The evidence from this study suggests that learning another Discourse need not involve loss of vernacular language and identity, but new languages and identities are gained, each appropriate to its Discourse community. Participating in a transdisciplinary learning community enables learners to become knowledgeable about, able to communicate with, and potentially identity with and become members of multiple Discourse communities.

16.5.2 Implications for Adaptive Learning Relevant to Social–Ecological Systems

This case study of school and community-based management suggests that teacher education oriented to place-based curriculum development supports teachers as leaders in curriculum innovation. Two years after Michelle began incorporating monitoring and restoration into her Polynesian Voyaging program, and shortly after her series of 24-h immersions, community supporters including the Polynesian Voyaging Society and Hui Nalu Canoe Club established a nonprofit *Malama Maunalua* "dedicated to creating a more culturally and ecologically healthy Maunalua."[2]

Although this study reports on one teacher's development of a diverse community of learners, other community-based monitoring and restoration programs have been initiated or strengthened by Native Hawaiian teachers following their participation in EDCS 433 (Chinn 2006). Community-based efforts led by Native Hawaiians

[2] See *Malama Maunalua* website for historical information and current projects: http://malamamaunalua.org.

such as Uncle Henry Chang-Wo's *limu* restoration efforts on Oahu and former EDCS 433 teacher Alyson (Napua) Barrows on Maui are sustained by those who consider it their *kuleana* to respond to changes in their local ecosystems.

The twenty-first century presence of indigenous Hawaiian knowledge/practices/values and cultural frameworks connecting ecological information to real-time human behavior suggests that place- and culture-based professional development in science can provide teachers with the tools to write and teach lessons that develop active science literacy.

However, challenges to place-based science education and teacher empowerment in Hawai'i include continued reliance on science texts designed to meet the needs of large U.S. mainland states, school policies and schedules that impede off-campus learning during the school hours, and accountability systems focused on narrow, test-based measures of student learning.

16.6 Conclusion

Discourse analysis reveals that transdisciplinary, place-based programs such as Michelle's Project *Ho'olokahi* help students develop *multiple literacies* as they become familiar with the tools, language, values, and identities of scientists and indigenous ancestors. These findings indicate that situating teacher education and student learning in communities that incorporate indigenous, local, and science knowledge supports educational, scientific, and cultural literacy.

Including indigenous and/or local, place-based practices and values in *teacher education* has the potential to prepare teachers with the situated scientific, cultural, and place-based knowledge to engage all students, particularly indigenous students, who tend to be underrepresented in science in Hawai'i, as well as other states and countries, in meaningful academic and scientific Discourses oriented to adaptive learning in a time of rapid and uncertain ecosystem change.

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Appendix: Transcript of *Na Pua O Maunalua* Videotape

Completed in May 2006, the student videotape won a second place award in a high school environmental video competition and has been broadcast on public access cable television. The following narrative, divided into stanzas read by various students, was compiled from student journal entries.

1. In October the Kaiser HS Ho'olakahi Voyaging class began a series of 24 immersion sails with *Hokulea* master navigator Nainoa Thompson.
2. The purpose of this immersion was to help us become environmental stewards who *mālama i ke kai o Maunalua*. The *haumana* met at the *Hui Nalu* Canoe Club's *hālau* to begin this experiential learning.
3. The first activity of the day was to learn how to use a GPS, or Global Positioning System. Aunty Annie taught us how to track points on a map so that later on we would be able to tell others exactly where we had worked on the reef. The GPS sends a signal out every 5 s to a satellite that tells us where we are in the world.
4. We paddled out to a sandbar about 100 yards from shore to do a *limu* cleanup, continuing the work we had begun last year. We placed our quadrate on a big patch of alien *limu*. Our *kuleana* was to clear the *limu* in our quadrate. It was amazing how much there was in one square meter. We used the scoop net to catch floating fragments of *limu* because the smallest piece could generate a whole colony of alien *limu*.
5. Aunty Kim and Aunty Dawn helped us to identify the different types of *limu*. One of the major *limu* that we had to get rid of was gorilla *ogo*, or *Gracilaria salicornia*. Another is leather mudweed, or *Avrainvillea amadelpha*, and *Acanthophora spicifera*. These are the alien *limus* in Maunalua Bay.
6. We also had to chart the fish and invertebrates. We found *opa'e*, mantis shrimp, and fire worms. Fire worms are the centipedes of the sea because when they sting you it feels like fire. We also looked for crabs and sea cucumbers. We recorded the data of all the fishes and invertebrates that we found.
7. It was awesome to do something that was good and benefited nature. Our class collected over 450 lb of alien *limu*. It felt great to clean up Maunalua Bay. The spaces that we cleared will become homes to native species of *limu* that we will plant in the future.
8. Then we paddled out to Blue Hole to do a reef check. The paddling experience was hard work and brought many of us back to the routes traveled by our ancestors in ancient Hawai'i. Blue hole is truly a big hole of sand surrounded by a reef of very beautiful, low coral.
9. Uncle Dave taught us how to identify the fish, and it was neat to actually know their names. Like *manini*, yellow tang, Moorish idol, surgeon fish, goat fish, and baby saddle wrasse. We also saw a spotted puffer fish.
10. After lunch back at the *halau* we tested for water quality at three different locations at the canoe site. Uncle Eric turned the *halau* into a science lab. The tests showed that the salinity, dissolved oxygen, and nitrates were at safe levels.
11. Bright green dye showed us which way the current was flowing since this can affect the growth of *limu*. We discovered that there were more than five different currents all flowing into one area of the bay.
12. The reward for all this hard work is that we got to sail on the *Hokulea*. It truly was an honor.

13. Aunty Catherine taught us the safety procedures before we sailed. Experienced crew members provided hands-on training on how to open and close the jib and mainsail. As we worked with the ropes, we learned about the bronco lines for the sails.
14. Uncle Nainoa taught us how to steer the canoe. If you pull to the left the boat goes to the right and vice versa. It was very challenging to keep control of the large steering sweep, which weighs over 500 pounds.
15. We could see all the different *ahupua'a* on shore. After Niu Valley we made a port tack and threw the escort boat a towline, which took us back to Maunalua Bay.
16. By working together we developed a memorable experience that will last a lifetime. We are grateful to our leaders who planned this immersion and were willing to share their *mana'o* to *mālama i ke kai a me 'āina*. This was one day that we all wished would never end.

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Part IV
Resource and Technology Governance for Sustainability

Chapter 17
Adaptive Governance: Proposals for Climate Change Science, Policy and Decision Making

Ronald D. Brunner and Amanda H. Lynch

17.1 Introduction

Adaptive governance is a pattern that began to emerge from conflicts over natural resources in the American West a few decades ago, as a pragmatic response to the manifest failures of *scientific management*. Around the turn of the twentieth century, "Scientific management aspired to rise above politics, relying on science as the foundation for efficient policies made through a single central authority – a bureaucratic structure with the appropriate mandate, jurisdiction, and expert personnel" (Brunner et al. 2005, p. 2).[1] But during the last century it became increasingly clear that effective control was dispersed among multiple authorities and interest groups, that efficiency was only one of the many goals to be reconciled in policy decision processes, and that science itself was politically contested. Scientific management typically leads to gridlock in these circumstances. Adaptive governance addresses these twenty-first century realities by proceeding principally but not exclusively from the bottom up rather than the top down. Each local community can integrate scientific and local knowledge into policies to advance its common interest, recognizing that politics are unavoidable. Many communities working in parallel can harvest their collective experience, to make successful innovations anywhere in the network available for voluntary adaptation elsewhere, and to clarify their common needs for higher-level authorities. The emerging pattern of adaptive governance is *not* limited to natural resource problems.[2]

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[1]For more on scientific management, see also Brunner et al. (2002).

[2]For example, variants of adaptive governance can be found in Smith (1995), Schorr (1997), and Petzinger (1999). Packer (2006) emphasizes disaggregating (or factoring) security problems.

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In *climate change*, however, the established frame relies on scientific management. For example, in the 1995 Synthesis of the Second Assessment Report, the *Intergovernmental Panel on Climate Change* (IPCC 1995, sec. 1.9) presents climate change as an “irreducibly global problem.” This global framing acknowledges that carbon dioxide and other greenhouse gases, regardless of their geographic origins, are dispersed more or less uniformly in the atmosphere through the global circulation. But this global framing also implies that the important decisions on climate change are made by national governments working together as the Conference of the Parties to the *UN Framework Convention on Climate Change* (UNFCCC) and working separately to implement their commitments. This global framing also supports climate change research that addresses the concerns of national and international authorities exclusively.[3] In our judgment, the establishment of this global frame a few decades ago is a major reason why worldwide damages from the most extreme weather events have escalated rapidly in recent decades, and global greenhouse gas emissions have continued to increase.[4] By defining climate change as an irreducibly global problem, the established frame leaves out of the picture the citizens of diverse local communities whose support and cooperation are necessary for effective international and national mandates. In short, the established frame does not play in “Peoria,” a symbol of mainstream local communities worldwide.

Adaptive governance suggests an opportunity to factor the global problem into many local problems, each of which is much simpler than the global problem and can be addressed concurrently, in parallel with other efforts. The recommendation is to open up the established frame to enlist people in local communities as active participants in the global effort to reduce near-term damage from extreme weather events and longer-term damage from climate change. Consistent with that recommendation, the present purpose is to introduce some proposals inspired by adaptive governance for climate change science, policy, and decision making. For the sake of concreteness, we will use examples from *Barrow, Alaska*, where we have applied and field-tested insights from adaptive governance since August 2000. Barrow is a community of several thousand, mostly *Iñupiat Eskimos*, located within the *Arctic* Circle on the North Slope coast of Alaska about 1,100 miles from the North Pole.

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[3] The IPCC may be the most authoritative source on the established framing, but it is not the first or only one. Elements can be traced back to the International Geosphere–Biosphere Programme (IGBP 1990) which began meeting in September 1986; to the Committee on Earth Sciences (1989a, b), and to a special issue of *Scientific American* introduced by Clark (1989). For an early critique of the established framing by the former Director of Research of the Royal Netherlands Meteorological Institute, see Tennekes (1990).

[4] Worldwide damages from major hurricanes increased from $24 billion in the 1980s to $113 billion in the 1990s and $272 billion in this decade through 2005, according to the Earth Policy Institute (www.earth-policy.org/Updates/2006/Update58) using data from Munich Re. Current UNFCCC data on national trends show that greenhouse gas emissions increased 13.4% from 1990 to 2003 in the US, and by almost as much on average in other industrial countries outside the former Soviet bloc (http://ghg.unfccc.int/). Another major reason for these disappointing outcomes is the lack of political will to enforce targets and timetables for greenhouse gas reductions.

Climate change is not an issue there; the signs are obvious for all to see. Thus Barrow is a microcosm of things to come as signs of climate change become more obvious at lower latitudes. We focused on the least tractable of Barrow's climate-related problems, its *vulnerability* to coastal erosion and flooding from big storms. Since then we have endeavored to help the public and public officials in Barrow reduce their vulnerability. Much of what we have learned in Barrow has been corroborated by other climate change researchers working independently.[5]

17.2 Science

First, in terms of science, we propose more *intensive research* centered on *case studies* of local communities and extreme events. Each extreme event and each community is unique under a comprehensive description, and differences among them must be taken into account to understand past damages or reduce vulnerabilities. In contrast, in the established frame, the priority is to generalize across events and communities, either to aggregate statistical data for higher-level authorities or to abstract relationships for numerical models designed to make predictions.

As an example of intensive research, consider the great storm that struck Barrow on October 3, 1963, still the most damaging on record and in living memory there. Little damage would have been done if the storm had followed the normal track north from Siberia, *or* if it had generated normal winds, *or* if it had occurred when shore-fast sea-ice protected Barrow, as was usually the case in early October. As it happened, the storm tracked eastward, generating unusually strong WNW winds of long duration in Barrow, and the long fetch (that is, the distance of open water to the edge of the sea-ice) allowed the build-up of a significant storm surge and waves. Material damage from the storm surge and waves was contingent on local geology and geography and building locations, designs, and construction. The loss of many buildings, fuel oil, and other supplies and equipment was greatest in low-lying areas between Browerville and the main part of town and NE of town at the Naval Arctic Research Laboratory (NARL). The bluffs at the SW edge of town eroded about 10 m during the storm, but helped provide high ground for evacuees. An early warning of the approaching storm would have reduced the potential for loss of life and limb. As it happened, there were many close calls but no fatalities, in part because of a host of quick-thinking improvisations – including a neighbor's rescue of children left home alone, a teenager's rescue of his grandfather from the surf, and

[5] The most recent summary of the Barrow research is Lynch and Brunner (2007). The most extensive is Lynch et al. (2004) which includes Chap. 6 on "Policy Responses," pp. 67–132. On policy, see also Brunner et al. (2004). For further information on the project, see http://nome.colorado.edu/HARC/index.html. The integrative and policy aspects of this research were based on the policy sciences (Lasswell 1971); there was no need to create another conceptual framework. Among the partial corroborations of our substantive findings and proposals, the most comprehensive is Rayner and Malone (1998). Representative of other contributions is Morgan et al. (2005).

the use of heavy earth-moving equipment for evacuation from low-lying areas. A blizzard following the storm delayed emergency relief. Because the storm destroyed the landing strip at NARL, emergency and longer-term relief was flown into the airport under construction. Recovery also was assisted by local reserves of fuel oil, backup generators, and alternative sources of water to replace those contaminated by sewage, fuel, and sea water. The alternative sources included large blocks of sea ice driven ashore by the blizzard.

The point is that no single factor tells the story of the great storm. The significance of each factor for understanding damage depends on its interactions with other factors in the same context. The context is centered on the extreme event and the community, and includes external sources of relief. Some of the important factors are not quantifiable, including casualties averted by quick-thinking improvisations. Moreover, the great storm cannot be used as a surrogate for understanding other major storms that have damaged Barrow since 1963. The storm most similar to the great storm struck on August 10, 2000, but because of its shorter duration, damage was limited primarily to a dredge sunk and a bridge and culvert washed out on the coastal road to NARL. Similarly, Barrow cannot be used as a surrogate for other Native Alaska villages down the coast such as Point Hope or Shishmaref. The research problem – understanding past damages from big storms and how to reduce vulnerability – differs in each community. Furthermore, Barrow's past damages and vulnerabilities cannot be inferred from generalizations that may be valid elsewhere. For example, one might hypothesize that the accumulation of greenhouse gases in the atmosphere since 1963 may have increased damages from storms in Barrow. Similarly, one might expect from studies elsewhere that the tripling of Barrow's population and the financing of new infrastructure through property tax revenues from Prudhoe Bay may have increased damage from storms in Barrow since 1963.[6] However, despite Arctic warming and community development since then, no lives have been lost to storms in Barrow and inflation-adjusted total damage from the great storm of 1963 may still exceed the total damage from all subsequent storms there.

Intensive research is warranted because the great storm of 1963 and Barrow are each unique when the many factors relevant to understanding past damages are considered comprehensively. This is an empirical result easily understood in terms of the conjunction rule of probability; we expect it to hold for other extreme events and other communities. This implies that *predictability* is quite limited: *uncertainties* in each of the many vulnerability factors in an extreme event are compounded in their conjunction, and no conjunction is replicated even in the same community. Predictability is still quite limited even if the complexity of extreme events is reduced to one factor. The long-term trajectory of atmospheric pressure at sea level, for

[6] The Alaska Native Claims Settlement Act of 1971 opened the door to development of the oil industry around Prudhoe Bay. Incorporation of the North Slope Borough in 1972 authorized the Borough to levy property taxes. Most of the Borough's property tax revenues come from Prudhoe Bay, which is located in the Borough about 200 miles east of Barrow.

example, is less predictable in the vicinity of Barrow than for the Arctic region as a whole. But even for the Arctic region, models of similar scientific quality project quite different patterns of sea level pressure for the future. There is no scientific method to choose between these projections until after the fact.[7] Such profound uncertainties are better called "indeterminacies" to challenge the assumption that they can be eliminated through further scientific research.[8] In any case, we have avoided making predictions or projections for Barrow. But our integration of historical observations on Barrow have been useful and used in Barrow, as explained later.

Among other climate change researchers, Rayner and Malone (1998, p. 134) corroborate what we have learned in Barrow: "Empirical local-level studies reveal such complex mosaics of vulnerability as to cast doubt upon attempts to describe patterns and estimate trends at the global or even regional scales." We expect case studies to be more prominent in the IPCC's Fourth Assessment Report than in the Third. The integration of case-based information and insights is best left to community representatives and their advisors, as proposed later. At a deeper level, those who study evolution understand that "Invariant laws of nature … set the channels in which organic design must evolve. But the channels are so broad relative to the details" of interest, that "contingency dominates and the predictability of general form recedes to an irrelevant background" (Gould 1989, pp. 289–290).[9] Allowing for human choice, *evolution* is a better metaphor for climate change science than mechanics. Polythetic classifications in numerical taxonomy document *contingency* in evolutionary outcomes. "No single property is required for the definition of a given group [of specimens] nor will any combination of characteristics necessarily define it" (Sokal 1974, p. 1117). Thus the significance of each observed property varies with the context; it is not exhausted by the operational definition of a variable.[10] Policy scientists recognized this long ago in the *principle of contextuality*: "If modern historical and social scientific inquiry has underlined any lesson, it is that the *significance of any detail depends upon its linkages to the context of which it is a part*. Hence the evaluation of the role of any institutional practice calls for a vast labor of data gathering and theoretical analysis" (Lasswell et al. 1952, p. 11; their emphasis). The context and linkages must be constructed, not assumed or taken as given. Policy scientists also hold that "the role of scientific work in human relations

[7] Sea level pressure drives atmospheric circulation, which in turn is a "key determinant" of not only weather, but ocean transports, sea ice drift, and water mass formation. See Walsh et al. (2002, sec. 3a), and Zhang et al. (2002). More generally, on the challenges of prediction in the Arctic system, see Walsh et al. (2005) and Cassano et al. (2006).

[8] Indeterminancy is used in about the same sense by Rayner and Malone (1998, p. 120).

[9] Gould (1989, p. 283) takes contingency as the "the central principle of all history" including natural history. A solid-state physicist and Nobel Prize laureate, Philip Anderson as quoted in Horgan (1995, p. 109), concurs that "life is shaped less by deterministic laws than by contingent unpredictable circumstances." See also Anderson (1972) and Frodeman (1995).

[10] For more on context-sensitive methods and epistemology, see Brunner (2006).

is *freedom* [through insight] rather than prediction."[11] Scientific insights free us from past ignorance of unconscious or unknown factors in making future choices and decisions.

17.3 Policy

Second, in terms of policy, we propose a *procedurally-rational* approach, one that accommodates inevitable uncertainties, integrates scientific and local knowledge into policies to advance the common interest, and relies on incremental learning from experience – especially through policy appraisal and the termination of failed policies. In contrast, the established frame relies on planning that takes policy goals as given and presumes that the scientific reduction of uncertainty is a prerequisite for rational policy decisions.

Barrow's history illustrates how uncertainties arising from human factors, social and political, compound uncertainties in the natural environment. Barrow's first major response to its coastal *erosion* and *flooding* problems was a beach nourishment program with many characteristics of scientific management. Among other things, it was designed by technical experts as a single comprehensive solution. Planning for the program was initiated by the loss of cultural artifacts to big storms on September 12 and 20, 1986. As an index of uncertainties, consider differences between projections in the program plan in April 1989 and actual outcomes in August 2000, when a big storm damaged and sank the program's custom-designed dredge and effectively terminated the program:

- In the 1989 projection, 3–5 years of operations in Barrow would be completed in 1996. But the dredge did not arrive in Barrow until 1996, and it completed only one full season of operations in the summer of 1999.
- In the 1989 projection, a total of 800,000 cubic yards of material would nourish Barrow's beach at a unit cost of $15.27 per cubic yard. The full season of operations in 1999 produced only 64,000 cubic yards of material at a unit cost of $77.80.

Without going into other details, it is clear that the program plan failed to accommodate many contingencies that mattered. The most favorable local appraisal concluded that the program helped protect Barrow during the August 10, 2000 storm, but acknowledged that the storm removed most of the dredged material from the beach. The least favorable appraisal likened the program to throwing buckets of gold into the Arctic Ocean. The point is that such programs are matters of trial and error in some degree, and surprises are inevitable – even if uncertainties are "absorbed" up-front in the planning process.

[11]Lasswell (1951, p. 524, his emphasis), which elaborates and concludes that "it is the growth of insight, not simply of the capacity of the observer to predict the future operation of an automatic compulsion, or of a non-personal factor, that represents the major contribution of the scientific study of interpersonal relations to policy."

Considered in broader context, however, Barrow's beach nourishment program is part of a learning process consistent with adaptive governance, even though it was not conceived as such. The failure of the program contributed to persistent local opposition to beach nourishment, a factor in the recent termination of the beach nourishment alternative in a joint feasibility study still underway.[12] When the *US Army Corps of Engineers* proposed the joint feasibility study to the North Slope Borough in May 2001, the initial alternatives for protecting Barrow from big storms required from two to three times as much beach nourishment material as the original program. The study aimed to find and implement a comprehensive solution to Barrow's coastal erosion and flooding problems through a schedule of milestones. The alternatives still under study, a revetment to protect the bluffs and a dike to protect everything else, depend on a number of contingencies including Congressional appropriations sufficient to cover most or all of the cost. Even if everything works out as originally scheduled, important vulnerabilities will remain until 2012. These vulnerabilities include cultural artifacts at the old Barrow townsite.

Meanwhile, outside the joint feasibility study, various different people and organizations in Barrow have taken the initiative on distinguishable parts of the overall problem. This is distributed processing, which multiplies opportunities for learning from experience and makes good use of specialized expertise and other limited resources, particularly time and attention. Consider some initiatives that already have made progress in reducing Barrow's vulnerability:

- An old landfill site has been protected with a seawall and capped with a tarp and tundra to prevent dispersion of hazardous materials buried there by the US military.
- The new $62 million Barrow Global Climate Change Research Facility is constructed on a pad and pilings high enough to withstand an equivalent to the October 1963 flood.
- Barrow's new hospital will be located on higher ground outside the area flooded in October 1963.
- An inland road has been platted and partially funded to serve as an evacuation route when the coastal road is washed out by big storms, as it has been repeatedly in the past.
- An *emergency management* exercise based on the great storm of 1963 has been conducted to train local officials.

Other distinguishable parts of the overall problem have risen on the agenda in recent years. These include planning and zoning to prevent further building in coastal areas subject to erosion and flooding, and the possible relocation inland, on higher ground, of buildings damaged or destroyed by future storms. More recently, officials have begun to single out Barrow's major vulnerability, a utility corridor

[12] The termination was announced in the Army Corps' briefing on the Barrow Storm Damage Reduction Project in Barrow on August 23, 2006.

buried in the permafrost that began providing potable water, sewage service, and other amenities in 1984 at an initial cost of $270 million; since then it has been expanded. To maintain services and avoid freezing miles of pipes, the "utilidor" depends on electrical motors and controls for pumping. But these devices are vulnerable to flooding through a pump station and manholes on low ground near the ocean, and to loss of electricity. The natural gas line that fuels the power plant rests on a deteriorating dam across the lagoon between Barrow and Browerville, where it is exposed to storm surge and waves. The point is that progress in reducing vulnerability does not depend on a single master plan to force action on a predetermined schedule of milestones.

Barrow's policy decisions, implemented or pending, are not simply a matter of reducing its vulnerability to big storms, or adapting to climate change, as outsiders sometimes assume. Instead these decisions integrate or balance multiple other interests in the community. For example, an interest in providing more local jobs was a major factor in the approval of the beach nourishment program by the North Slope Borough Assembly in the early 1990s, when the Borough could afford an expensive program. After the dredge was sunk, the Assembly terminated the program in part because it was too expensive in view of declining property tax revenues from Prudhoe Bay. An interest in preventing further loss of artifacts and cultural heritage led to the beach nourishment program. An interest in sustaining subsistence hunting that is central to Iñupiat culture lies behind protection of the landfill site. A big storm that released hazardous material into the sea could harm bowhead whales, especially, but also other marine mammals and fish that have cultural and subsistence value in the community. Control over land use decisions is apparently an interest behind resistance to planning and zoning measures and relocation in various forms since the early 1990s. Integrating or balancing diverse community interests, each subject to change on various time scales, is inevitably a political process. "*Politics*" as the giving and withholding of support in making important decisions is necessary to advance the *common interest* of community members. Politics need not serve *special interests* exclusively.

In climate change policy, "no regrets" and "mainstreaming" are recognized strategies that rely on accommodating other interests to advance mitigation and adaptation. Similarly, Shellenberger and Nordhaus (2004) underscored the futility of targeting climate change mitigation – the environmental interest exclusively – while ignoring other interests that could be mobilized on its behalf. More generally, behavioral theories of rationality recognize that decision in the face of uncertainty is primarily a matter of adaptation rather than prediction. Herbert Simon, a Nobel laureate, concluded that "human problem solving, from the worst blundering to most insightful, involves nothing more than varying mixtures of trial and error and selectivity" (Simon 1996, p. 195). Thus "It is procedurally rational to act on the most promising alternative in a situation, despite projected uncertainties in costs and benefits – provided the alternative is modest enough to assess in an appropriate time frame, to fail gracefully if it does fail, and to learn from the experience" (Brunner 1999, p. 75). Selectivity is guided by previous experience. Behavioral theories recognize that real people are boundedly rational at best, and often lack the knowledge and information necessary to make full use of their reasoning capacity. It is more constructive to help people make fuller use of their reasoning capacity in particular situations than to insist they live up to an abstract ideal. In contrast, the established frame in climate change draws heavily on normative theories of rationality that postulate how people *should* behave if they were perfectly rational and informed.

17.4 Decision Making

Third, in terms of decision-making, we propose structural changes that begin with harvesting experience from the bottom-up, to make policies that have worked anywhere on the ground available for voluntary adaptation by similar communities elsewhere, and to inform state, national, or international officials about resource needs on the ground. In contrast, the established frame relies on higher-level authorities, advised by experts with information aggregated or abstracted from many contexts, to make important decisions that are supposed to be implemented down through the layers of bureaucratic hierarchies.

Experience in Barrow and other Alaska Native Villages illustrates the basic rationale for this proposal. In each community the problem of understanding damage and reducing vulnerability is sufficiently different, complex, and dynamic that only people on the ground and their advisors can have the information and knowledge necessary to make procedurally rational and politically-feasible policy decisions. Moreover, people on the ground are also responsible because they must live with the consequences of their decisions. State, federal, and international officials cannot know enough to mandate policies appropriate for the many local communities under their jurisdiction, even if they are interested.

One genuinely interested official is Sen. Ted Stevens of Alaska, who initiated a study of his Native constituents' flooding and erosion problems. The US General Accounting Office reported in December 2003 that 184 coastal and inland Alaska Native Villages experienced some erosion and flooding, and focused on nine of them: Shishmaref and three others "are in imminent danger from flooding and erosion and making plans to relocate…. The five villages not planning to relocate [including Barrow] are in various stages of responding to their flooding and erosion problems" (US GAO 2003, p. 4). GAO also reported that the villages seldom qualify for federal assistance on these problems under the two principal federal programs. Sen. Stevens followed up the GAO report with testimony from representatives of villages and state and federal agencies in field hearings in Anchorage in June 2004. Apparently, this continued his search for a legislative solution that would obviate the need for "one-off" (village-by-village) solutions, a search that so far has not succeeded. The closest approximation may be a provision in the FY 2005 Consolidated Appropriations (P.L. 108-447, sec. 117) authorizing "at full Federal expense, structural and non-structural projects for storm damage prevention and reduction, coastal erosion, and ice and glacial damage in Alaska, including relocation of affected communities and construction of replacement facilities."[13] The significance of this new authority is contingent on major increases in appropriations, and on the effective adaptation of projects to local vulnerabilities, such as Barrow's utilidor, by the US Army Corps of Engineers.[14]

The field hearings in Anchorage indicated structural problems in adapting external resources to the particular needs of local communities. *Shismaref*, for example, is located on a barrier island less than a quarter-mile wide in the Chukchi Sea, and has lost 20–50 ft of land in each of a series of big autumn storms since 1973.[15] After identifying more than a dozen agencies contacted by the Shishmaref Erosion and Location Commission for help in reducing its vulnerability, the chairwoman of the Commission concluded: "Our experience has shown that there is a lack of continuity between the various federal and State programs and agencies…. For the most part we have found that none of the agencies have programs that cover the full range of our needs" (Eningowuk 2004, p. 3). The structure of multiple agencies and programs, each with a narrow mandate and jurisdiction, is a remnant of scientific management. Only communities like Shishmaref, aware of their vulnerability to extreme weather events, have the requisite commitment, knowledge, and information to function effectively as "boundary organizations," integrating and adapting external resources to their own particular needs. But local communities often depend on external resources to implement promising alternatives to reduce their vulnerability. These resources include authorities and expertise as well as funds.

This presents an opportunity for a networking strategy, *both* to expand the range of promising alternatives for communities like Shishmaref, Point Hope, and Barrow, *and* to make better use of external resources available for adaptation. A networking strategy would begin with harvesting experience from each community on what has worked to reduce storm damage from coastal erosion and flooding, what has not worked, and why; and by sharing that experience with other communities periodically and intermittently. Barrow, for example, could be informed by Shishmaref's experience with incremental relocation when and where big storms dictate. "After the 1997 fall storm… FEMA and state matching funds were used to help move 14 homes along the coast to another part of [Shishmaref], and in 2002, the Bering Straits Housing Authority relocated an additional 5 homes out of harm's way" (US GAO 2003, p. 32). Other communities in turn might be interested in Barrow's

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[13] The US Army Corps of Engineers cited this authority in a Section 117 Project Fact Sheet (May 17, 2006) for a project in Shishmaref, along with a section from the Senate Report 109-84 (p. 41) for the Energy and Water Development Appropriations Act of 2006 (P.L. 108-103): "The Committee has provided $2,400,000 for Alaska Coastal Erosion. The following communities are eligible recipients of these funds: Kivalina, Newtok, Shishmaref, Koyukuk, Barrow, Kaktovik, Point Hope, Unalakleet, and Bethel. Section 117 of Public Law 108-447 will apply to this project."

[14] It is questionable whether the dike under consideration in the joint feasibility study – with four breaks to provide Barrow residents with access to the sea – will protect the utilidor effectively or efficiently from flooding and erosion. The dike may be better adapted to what the Corps is able to do than to what Barrow needs.

[15] On Shismaref, see US GAO (2003, pp. 32–34).

experience with beach nourishment, which is rare in the Arctic. At the same time, communities working together would be in a position to clarify their collective needs for external resources and to inform interested state and federal officials accordingly. In short, this *networking strategy* would attempt to inform decision makers and integrate their interests across levels. But so far a field test of the strategy falls between the stovepipes of established programs for climate change research.

In climate change research, Rayner and Malone (1998, p. 120) asked: "If decisionmakers cannot predict the unpredictable, how can society face the prospect of profound change occurring at an accelerating pace?" Their answer was "to build responsive institutional arrangements to monitor change and maximize the flexibility of human populations to respond creatively and constructively to it." A networking strategy is a step toward more responsive institutional arrangements, and potentially a means of coordinating existing institutions. To inform this step, partial precedents, behavioral theory, and practical advice are available.[16] A networking strategy also factors the global problem into more tractable parts, and harvests more experience for decision makers throughout the decision-making structure. Experience informs the selection of more promising trials, an important factor in accelerating progress through trial-and-error (Simon 1996, pp. 195–196). Progress does not depend on the success of any particular trials, but on cumulative learning from a diversity of many trials. A networking strategy also facilitates democratic participation without compromising competence and economy in decision making. A leading democratic theorist (Dahl 1970, p. 102) concludes that "If a matter is best dealt with by a democratic association, seek always to have that matter dealt with by the smallest association that can deal with it satisfactorily."[17] Adapting to climate change is best dealt with by democratic associations, and the smallest association that can deal with it satisfactorily is the local community – Barrow and other "Peorias" worldwide.[18]

17.5 The Common Interest

We have been developing proposals for opening up the established frame in climate change science, policy, and decision making. Perhaps it is clear that a choice between defending the established frame and opening it up is not value-free. Both alternatives answer to "the facts," although to different sets of facts; hence values

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[16] On precedents, see especially Chaps. 4–6 in Brunner et al. (2005). On theory, see Rogers (1995). For practical advice, see Wenger and Snyder (2000).

[17] Compare McDougal et al. (1981, p. 209): "In some contexts, decentralization may maximize the potential for democratic participation at lower levels of interaction, permit the most rapid decision, encourage the establishment of appropriate specialized arenas, be most sensitive to the special circumstances and conditions prevailing in sub-arenas, and allow for the widest range of diverse cultural forms in constitutive decision." For more on other constitutive criteria, including representative and responsible participation, see pp. 201–222 in the same volume.

[18] Compare Rayner and Malone (1998, pp. 113–114): "Adaptation is by nature a variegated response…. That is to say, adaptation is a bottom-up strategy that starts with changes and pressures experienced in people's daily lives."

necessarily are implicated in any choice between them. Moreover, the choice has social consequences – among other things, leaving people on the ground as mere "stakeholders" in an international regime or enlisting and supporting them as active participants taking primary responsibility for their own climate-related problems. Thus as a matter of professional responsibility, each of us might make our values explicit and consider the social consequences of a choice. Our recommendation is to work on behalf of the common interest, not special interests, of the community involved – whether local, national, or international. The common interest is not to be assumed or taken as given; it must be constructed in the particular context.[19]

In the Barrow project we have attempted to serve Barrow's common interest in an advisory capacity. Before we submitted a proposal to the National Science Foundation, we agreed among ourselves that helping the people of Barrow make better policy decisions was our primary goal; scientific publications were important but secondary. We began with a week of conversations in Barrow in August 2000 to identify the least tractable climate-related problem from the standpoint of people living there. Then at least annually we reported our findings on coastal erosion and flooding to the public and public officials in Barrow through various meetings, public lectures, and interviews on local public radio (KBRW), and sought their guidance on directions for further research. We focused initially on understanding the great storm of 1963 and subsequent extreme events, and then gradually on constructing their significance in the context of Barrow's social development and policy history.[20] The extreme events provided a common focus of attention for Barrow residents, project principal investigators, and our collaborators from many disciplines. Personal interactions with people in Barrow and the examination of local historical records both were essential for understanding how to adapt our research to the community's needs.[21] Early in the project we determined that it would be irresponsible to make predictions in the face of profound uncertainties. But predictions were not necessary. Rather, we expanded the range of informed choices available to the community by integrating historical information and insights on the many factors relevant to Barrow's coastal erosion and flooding problems.

Whether we have served the community's common interest satisfactorily is a judgment best left to the people of Barrow. However, we can report that our research has been used in and for Barrow.[22] For example, the Army Corps cited our photometric

[19]For an introduction to the common interest, see Brunner et al. (2002, pp. 8–18), and the literature cited there.

[20]There was no need to divert attention to creating frameworks for contextual, problem-oriented, and multi-method inquiry. A satisfactory framework already existed in the policy sciences. See Lasswell (1971) and related works.

[21]Compare Rayner and Malone (1998, p. 126): "Effective communication about climate change issues requires understanding of the frames of reference being used by all participants."

[22]For purposes of comparison with research not adapted to Barrow's unique needs and capabilities, the lead author showed a copy of the Arctic Climate Impact Assessment (2004) to ten people involved in addressing some part of Barrow's vulnerability to big storms in March 2006. Only two were aware of the assessment; none had read it.

measurements of coastal erosion from 1948 to 2002 as reason for deleting the beach nourishment alternative from the joint feasibility study. Our documentation of climate change in Barrow during the last half century, indicating profound uncertainties, may have influenced the Army Corps' decision to substitute a relatively robust scenario-based method for its customary cost-benefit analysis. Our numerical-model simulations of historical extreme events provided a scientific answer to a question asked by subsistence hunters in Barrow: Do storms track the edge of the sea-ice? Other simulations produced rules of thumb, to be field-tested by local weather forecasters, to gauge the damage potential of approaching storms. Our reconstruction of the great storm of 1963 was used in locating the new hospital, designing the new research facility, and perhaps in reinforcing the community's need for an inland evacuation route. In addition, our policy history brought back to the agenda various non-structural alternatives – especially planning and zoning and relocation – that were briefly considered and prematurely dropped in the planning and promotion of the beach nourishment program funded in 1992.

What is the common interest of the world's communities with respect to climate change? In our judgment it is reducing the vulnerability of things we value – not in stabilization of greenhouse emissions per se. Specific values differ across communities and over time, but typically include people, property and other cultural artifacts, and the natural environment, in addition to reducing the costs of protecting them. The common interest can be served in the near term through adaptation to extreme events that have damaged or threatened things of value, and in the longer run through mitigation of climate change by reducing greenhouse gas emissions. Adaptation and mitigation are both strategies for reducing vulnerability at reasonable cost, not ends in themselves. More emphasis on adaptation in the near term can be justified on pragmatic grounds: Nearly two decades of international and national efforts to reduce greenhouse gas emissions have yielded disappointing outcomes to date, although opposition to mitigating global climate change is waning even in the United States (Barringer and Revkin 2007). Meanwhile, each damaging storm, drought, heat wave, or other disaster identified with climate change tends to motivate if not force action, providing opportunities to field-test promising policies to reduce vulnerability, and to evolve better policies. In this sense a disaster is a terrible thing to waste.[23] To capitalize on these opportunities, it is sufficient to focus selectively on recently damaged or vulnerable communities already motivated to address their own problems. It is neither necessary nor feasible to address all communities at once. But networked communities working together, with external support as needed, can capitalize on their differences and similarities to evolve better policies without a global master plan imposed from the top down.

A near-term emphasis on disaster-related adaptations can contribute to mitigation of climate change in the longer term. Perhaps it already has, through news coverage and editorial comment linking global warming to Hurricane Katrina,

[23] This paraphrases Stanford economist Paul Romer who is quoted in Friedman (2005).

which devastated New Orleans and other parts of the US Gulf coast in August 2005. Similarly, during the present drought in Victoria, Australia, a Melbourne newspaper observed that "Water saving has emerged as the most palpable sign that ... we finally get it – the climate is changing and we have to adapt" (Editors 2007). Meteorologists and climate scientists still debate physical and statistical linkages between weather and climate. Without projecting the outcome of that debate, it appears that the distinction between weather and climate has been blurred in public opinion. Major *disasters* bring home to ordinary citizens the need for mitigation of climate change, and can do more in this regard than decades of scientific reports or political promotions. Even localized disasters like the big storms of September 1986 in Barrow can motivate action, as noted earlier. Rayner and Malone (1998, p. 113) among others anticipated that "Accumulating some experience with adaptation could provide a complementary, even perhaps an alternative, model for pursuing emission reductions."

17.6 Conclusion

In conclusion, intensive research in Barrow brings back into the picture important considerations all but deleted in the framing of climate change as an irreducibly global problem. Similar research on any other local community, we believe, would also demonstrate:

- that differences and changes on the ground must be taken into account for effective adaptation and mitigation policies;
- that for policy purposes these differences and changes are unknowable in sufficient detail among scientists and policy makers working only at the national or international level; and
- that the top-down bureaucratic hierarchies assumed in the established frame are not designed for adapting to differences and changes on the ground.

Bureaucracies are designed for the efficient application of standardized rules and procedures. But "'One-size-fits-all' seldom fits at all" (Rayner and Malone 1998, p. 129). In a dynamic world of global change, adaptability is a requirement for the sustainability of things we value.[24] The emerging pattern of adaptive governance is an opportunity to open up the established frame to reduce the vulnerability of things we value, by field-testing in parallel thousands of promising alternatives for adapting to those changes we cannot avoid, and for mitigating those changes we can.

[24] Farrell and Hart (1998, p. 7) offers a working definition of sustainability that is compatible with the common interest as defined here: "improving the quality of human life while living within the carrying capacity of supporting ecosystems." But both the quality of life and the carrying capacity of supporting ecosystems are contingent on differences and changes in contexts.

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Chapter 18
Environmental Technology Policy in the US, from the 1970s into the Twenty-First Century

George R. Heaton Jr.

18.1 Introduction

Since the time when this chapter was written – some 3 years before publication – the context for US environmental technology policy has been transformed. Three seminal developments stand out: the Administration of President Obama; the economic recession, and consequent government rescue package; and a new commitment in the US to craft climate change policies. What these changes imply is a new mind-set about the connection between the environment and technological change, an enormous increase in environment and energy-related research, and significant movement toward new laws and incentives to attack climate change. Given these developments, the pessimistic tone with which the paper ends needs to be modified to some extent.

On the other hand, history is history, and thus, the thrust of the paper's narrative need not be re-thought. In addition, it is still true that the basic legislative framework of US environmental law, enacted for the most part during the 1970s, remains a highly regulatory one, in which the possibilities for technological change are inadequately addressed. At the moment, there is no legislative initiative in sight that would change this, nor is there any assurance that the climate legislation and international negotiations now in progress will create the kind of technological transformation that the paper believes is necessary.

Tomorrow's technology – viewed optimistically – holds the key to the amelioration of today's environmental problems. At the same time, one must realistically acknowledge that yesterday's technologies are in fact the cause of these problems. Consumer products designed with little thought for their environmental hazards or disposal costs; resource-intensive, highly polluting manufacturing processes; fossil-fuel

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energy and transportation systems – and these have left a grim legacy that shapes the agenda of current environmental policy.

This "double-edged sword" linking technology and the environment has long been recognized, at least by commentators (Heaton and Resosudarmo 2000). For their part, American policy-makers have often invoked the "technology-fix" option in preference to demands for behavioral change. Unfortunately, little serious attention has been paid in the US, either by scholars or policy-makers, to the problem of crafting a deliberate environmental technology policy for the long term.

An environmental technology policy can be defined as the collection of ways in which public policy influences the process of technological innovation to achieve environmental goals. Sometimes, such impacts are deliberate; at other times, they can be unintended, though just as large. This paper charts the history of environmental technology policy in the US over four distinct eras, starting with the first regulatory forays in the 1970s, and ending with the current moment. It will show the transformation of national public policy from an early aggressive stance by the national government to a relatively static posture on Washington's part today, with industry and local governments now the most progressive elements.

To the extent that the US has an environmental technology policy, it is hamstrung by an underlying mindset that over-emphasizes R&D as the key to innovation, and the regulated sector as the source of technological change. Scant use has been made of firms outside the regulated industry, who often can develop the most creative, new solutions. Nor have the technological revolutions that dominate the twenty-first century been much enlisted.

18.2 The 1970s

Modern environmental policy was born in the United States during the 1970s, a decade of stunning legislative and regulatory achievement. After the National Environmental Policy Act's (NEPA) mandate for environmental impact statements (EIS) was signed into law on January 1, 1970, other regulatory regimes followed in quick succession: the Clean Air Act (CAA – 1970 – dealing with air pollution), the Clean Water Act (CWA – 1972 – dealing with pollution into waterways), the Resource Conservation and Recovery Act (RCRA – 1976 – dealing with hazardous waste), and the Toxic Substances Control Act (TSCA – 1976 – dealing with toxic chemicals).[1] Each of these statutes – though highly disparate in their conceptions

[1] In fact, several other statutes, including those dealing with pesticides, hazardous consumer products, and endangered species, were passed during the 1970s. All of these constitute important elements of environmental policy. They are not included in the discussion here both for reasons of brevity and because technology does not figure nearly so explicitly in their structure as it does in the regulatory areas covered above.

and goals for technological change – has had an enormous impact on the trajectory of technology development in the US.

The Clean Air Act was by far the simplest and most aggressive of the statutory regimes. It attempted to "force" the development of new technology by mandating standards of pollution control – most notably for automobile emissions – that were known to be beyond the limits of then-available technology. The expectation was that it would be the corporate target of the regulations – e.g., the automobile companies – that would produce the needed technology.

In retrospect, the CAA's environmental technology policy exhibits at least three misconceptions: (1) that new technology can be mandated by legal fiat; (2) that timetables for compliance can ignore normal R&D cycles; and (3) that the regulated, polluting industry is the likely site from which radical new technology will arise. In fact, as it often turned out – again most notably in the automobile case – the technology that did eventually achieve compliance arose from the ranks of suppliers, small firms or new entrants – not the dominant companies. And it arose much more slowly and more incrementally than hoped.

The Clean Water Act took an entirely different approach, mandating the adoption of "best available technology (BAT)." BAT was defined as the environmentally most protective technology then in use by the leaders in a given sector. What this implied was a massive upgrade of the environmental standards of lagging firms (some of whom went out of business instead) – and no change in the position of leading firms, since what they were already doing became the regulatory standard.

The CWA was a boon to the existing water treatment industry, whose shares on Wall Street flourished during the 1980s. And it did lead to dramatically improved water quality. In retrospect, the problem was that the CWA created no incentive to go beyond the technology in existence. Indeed, many commentators have argued that the regulatory structure in fact established a competitive disadvantage to new technology, since it took so much effort for the proponent to convince regulators to give it a chance, much less ratify it as "best available" (Heaton 1992).

The Resource Conservation and Recovery Act (RCRA) established a strict "cradle to grave" monitoring and management system for hazardous wastes at the Federal level, while leaving solid waste problems largely under local control. Its "technical standards" for the handling and disposal of hazardous wastes were set by EPA in Washington, based on its judgments of best practice under the circumstances. Given the deplorable state of waste handling when the Act was passed, it is indisputable that there has been great improvement since.

Looking critically, what is most lacking in the RCRA experience is any realization of the power of "upstream" technological change; in this case, changes in manufacturing processes so as to lessen waste production. While RCRA's regulations improved waste treatment, they made no attempt at "source reduction." Waste treatment companies thus enjoyed dramatically higher profits for a decade or so – and a better-handled problem grew ever larger.

The Toxic Substance Control Act (TSCA) is the only one of the four regulatory regimes directed at product technologies – new and existing chemicals – as opposed to the by-products of industrial processes (air and water pollution, and waste).

One of TSCA's most dramatic and successful provisions was a ban on the sale of PCBs (polychlorinated biphenyls). As there was only one large producer of PCBs at the time, this mandate effectively broke up a monopoly and brought forth an impressive array of environmentally substitute technologies from a variety of firms.[2]

The more problematic aspect of TSCA's technology impact was its choice to impose environmental testing requirements on new, but not on existing, chemical products. While this was done so as not to unduly disrupt the market, it had the effect of imposing new costs directly on technological innovation. An unusual feature of TSCA's regulatory scheme was a provision directing that it not "unduly hamper" technological innovation, and mandating study to see if this was the case. While early studies of the initial impact showed that it fell hardest on small-volume chemicals and small companies, most people assume that at this point, more than 20 years later, that the innovative status quo in the chemical industry has been restored (Ashford and Heaton 1983).

18.3 The 1980s

With the election of President Reagan in 1980, a period of backlash against the environmental policies of the 1970s set in. Although Reagan's campaign had promised to "get the government off the backs of the American people," (i.e. dismantle regulation), it quickly became apparent that the American people did not want this. Nor would the Congress allow it. What emerged, therefore, was a movement toward "regulatory reform." Conservative think-tanks and economists dominated the debate, urging that "command and control" regulation (i.e. the 1970s format) be scrapped in favor of "market mechanisms" and "economic incentives." It was assumed that this would promote "economic efficiency" and technological innovation.

Given the widespread political support for environmental controls, regulatory reform turned out to be most active in other areas, notably the sectors where prices and entry had previously been controlled by the government: energy, transport, communications. Policies whose impacts are still being felt – the breakup of the AT&T monopoly, the de-regulation of airlines – trace their genesis to this period. It seems clear that they have created a revolutionary restructuring of industry and technology in many instances.

In the environmental arena, the legacy of the 1980s was a change in mind-set rather than a change in law. The statutory framework from the 1970s remained almost entirely unmodified, but those who administered it tried as best they could to graft economic incentives and flexibility onto its structure. To some extent, they

[2] It is also interesting to note that the dominant producer, Monsanto, went out of the business entirely, and began a long process of corporate reinvention.

succeeded. Part of the result was a quantum leap in the complexity of regulation and the analytical base on which each regulatory action rested.

Perhaps the most dramatic environmental initiative during the 1980s was the phase-out of chlorofluorocarbons (CFCs). This was accomplished globally thanks to the Montreal Protocol, where the US was a leading voice. By the time the controls came into place, industry in the US and elsewhere in the Organization for Economic Co-operation and Development (OECD) community had largely accommodated the new reality, with substitute technology that was widely available. Although the situation was different in the developing world, many American, European and Japanese multinational corporations made serious efforts to subsidize the diffusion of environmentally superior technology throughout their supply chains. This, coupled with public assistance to developing countries, made the CFC initiative the leading example of global technological change arising from environmental regulation. The fact that atmospheric conditions have responded so fast with the closing of the ozone hole makes this example one which can be widely praised (Heaton et al. 1991).

18.4 The 1990s

The mid-1990s were the only period during which the US seriously considered the creation of a deliberate environmental technology policy. This was due in large part to Vice President Al Gore, whose passions focused both on the environment and on science and technology, and who was given a free hand by President Clinton to fully manage national policy in both of these domains. Gore proposed the ETI – Environmental Technology Initiative – as a means to energize technological innovation for the environment. The legislative package included substantial funding for R&D, as well as new analytical capabilities in the Environmental Protection Agency (EPA) and the Department of Commerce, who were to lead an effort that would join the environmental and business communities. Clearly, Gore and the other leaders of this policy initiative understood the need to consciously craft a central role for new technology in environmental sustainability, and the critical place that emerging technological revolutions – information technology, biotech, new materials, nanotechnology – could play in moving forward (Heaton et al. 1992).

The ETI was destroyed by the highly partisan politics that dominated Washington in the mid-1990s. In 1994, the Republicans took over the Congress and set out to dismantle programs that they saw as too interfering in the market. The ETI – only a proposal, not law – was among the first casualties. Given the countervailing strength of the environmental community in national politics, the result was a policy gridlock in which no new initiatives could come to fruition. Behind the scenes, a movement for industry-government-community consensus appeared (again, a result of the Gore "Reinventing Government" initiative), but the discussion of the role of technological innovation in building sustainability was scrapped.

Outside of the spotlight of national politics, the 1990s were noteworthy for the flowering of two policy reforms from the 1980s, each of which has been a major force for technological innovation. In the area of air pollution, caps on SO_2 emissions, coupled with an emissions trading policy, had been authorized in the 1980s. By the late 1990s, it had become apparent that this market-oriented reform was in fact working: SO_2 pollution was on the decrease, and many companies were developing new technologies that they hoped would allow them to sell emissions credits to other firms. The success of this program is now routinely suggested as a model for CO_2 caps to combat global warming.

The power of information to prompt technological change is shown by the Toxic Release Inventory (TRI), which came into being in the 1990s. Under this program, for the first time, firms had to keep a comprehensive report of their toxic releases into the environment, whether from regulated or non-regulated substances. These reports, submitted to EPA, are now freely available on the web on a county-by-county (local government) basis. Once toxic releases began to be discussed in public, the corporate community responded dramatically with systematic efforts to reduce them. While no studies are available to show the extent to which new technologies have been elicited, it is clear that such continuous reporting constitutes one of the few examples in which an environmental policy has been crafted to exert a continuing motivation for technological change.

18.5 The Twenty-First Century

It seems fair to say that since the departure of the Clinton-Gore Administration in 2000, there has been little interest in the national government in forging an environmental technology policy. This is not to say, however, that the country as a whole is uninterested; on the contrary, the early twenty-first century is noteworthy for the extent to which state and local governments have adopted policy innovations, and leading firms have become vocal advocates for change.

Although local environmental problems have by no means disappeared, global climate change is by far the most visible and most-discussed issue at the present time. It also offers a good example of the evolving roles in the policy debate. While the Bush Administration has taken years to cautiously acknowledge the reality of global warming, other levels of government have acted boldly. Dozens of cities have adopted CO_2 reduction policies, and a coalition of states has sued the Federal government to force it to recognize CO_2 as a pollutant under the Clean Air Act.[3]

Faced with both scientific and political reality, President Bush has offered promises, in two State of the Union messages, to do something. One initiative that has received substantial support is the Freedom Car program, managed in the

[3] This suit, which enlists the northeast states and California, was recently argued in the Supreme Court. The Bush Administration argued that CO_2 was not the kind of pollutant envisioned in the CAA and that it cannot take action unless Congress directs it to do so.

Department of Energy, which underwrites R&D for new engine types, higher fuel efficiency and low emissions. A much-cited Presidential promise to overcome the American "addiction to oil" through new technology has thus far been more rhetoric than reality, although very recently the Administration has offered support for new automotive fuel economy standards and alternative fuel production.

Given the Democratic takeover of the Congress in last November's mid-term elections, it has become inevitable that a policy to combat global warming will soon be legislatively mounted. While no one can predict how this will turn out, the political climate bears a number of resemblances to 1970, when Democratic politicians and a Republican President (Nixon) anxious to regain popularity worked together to craft a surprisingly vigorous Clean Air Act. With a well-organized and committed environmental community, plus many corporate supporters, a similar scenario is not unlikely.

Whatever turn the politics take, it is clear that much of the corporate community in the US has vocally adopted a new environmental ethos. Perhaps the most dramatic manifestation of this new attitude is the formation of the United States Climate Action Partnership, which enlists ten major firms and four major environmental groups in a clear program of legislative and corporate goals to reduce greenhouse gas emissions. As recently described in the New York Times,[4] this initiative "provides a hint that business wants to get ahead of the rising momentum for federal controls."

Less publicly but just as importantly, many leading firms have begun to recast their corporate strategies in terms that speak of long-term environmental sustainability. Some – like Dupont – have created management structures and goals openly directed at the development of more new, sustainable products. Others, like the financial and insurance industry, routinely weigh the long-term environmental risks as a critical element of their investment calculus.[5]

18.6 Conclusions

The 30-year record of US environmental technology policy – as much unintended as deliberate – exhibits a number of significant accomplishments in eliciting new technology. These include:

- A massive upgrading of best practice – i.e., technological diffusion – throughout industry in the areas of air pollution, water pollution and waste management.

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[4] January 19, 2007.

[5] The insurance industry in particular has for some time provided some of the best analysis of the economic risks of climate change, and has been most forceful in its advocacy for new national policies.

- The creation of a large cadre of technical professionals in the environmental field – engineers, analysts, managers, investors, lawyers – with huge potential to design and deploy new technologies.
- Replacement of several serious chemical hazards – PCBs, CFCs, asbestos – with much improved substitutes, and the accompanying creation of new industry structures.
- The implementation of a few regulatory regimes – e.g., TRI and SO_2 emissions trading – that constitute a continuing force for environmental improvement and technological innovation.
- A new ethos in leading industrial firms that commits them to environmental sustainability.

The US record is also disappointing, in that:

- No conscious, deliberate environmental technology policy has ever been adopted.
- What little analysis there has been of the relationship between environmental policy and technology change has largely been ignored.
- A mindset still exists that tends to equate investments in R&D with innovation, and to assume that the firms and sectors that are the site of environmental problems – e.g. energy and transportation – will also be the site of new technologies.
- National environmental policy has been gridlocked for close to 20 years, making new policies that face global problems of sustainability hard to enact.

It is a sad reality to admit that the country that pioneered environmental policy in the early 1970s has now become an environmental laggard. Certainly, this is true in terms of national policies toward global sustainability, where even such phrasing rarely if ever surfaces. As to the private sector, particularly the environmental industry, many believe that the US is no longer at the forefront of technology development (Banks and Heaton 1995). While there are hopeful signs that this myopia may be corrected, it is far from clear when or how this will occur.

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Chapter 19
The Development and Diffusion Processes of Sustainable Technologies and Implications for Public Policy: A Case Study in Japan

Kohta Juraku and Tatsujiro Suzuki

19.1 Introduction

There are numerous energy technologies that can contribute to a sustainable society. The market mechanism is an important process for developing and diffusing those technologies, but public policy can and should play important roles to facilitate such processes. In Japan, the national government has taken various initiatives in research and development (R&D) and in the introduction of renewable power technologies since the late 1970s. For example, solar power (PV) technology is often cited as a representative "successful" case initiated and strongly supported by the government.[1] This solar power case can be seen as a "success" due to the government-led R&D and diffusion of the sustainable technology. Another "successful" example is wind technology. The installed capacity of wind power technology quickly rose more than 100 MW – as much as the installed capacity of PV. Development funding had been curtailed from national project research in the mid-1980s; and as a result, almost all wind turbines are imported from foreign countries.[2] Still, such rapid developments were facilitated by various government measures, such as the Renewable Portfolio Standards (RPS) introduced in 2003. These are typical examples of government-led support for introduction and diffusion of sustainable energy technologies.

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[1]Kimura and Suzuki (2005) described the story of the PV development in detail.

[2]Matsumoto et al. (2005) and Matsumoto (2005) discussed the interesting consequences.

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Recently, "high-efficiency water heaters" have suddenly become popular in the Japanese residential market. Although these appliances are more expensive than ordinary water heaters, their sales record was much better than expected before they were even brought into the market. One new high-efficiency water heater is the CO_2 heat pump-based electric water heater that was developed toward the end of the 1990s and was introduced into the market during the early 2000s. Currently, it is being rapidly distributed in the household water heater market. It should be noted that this high-efficiency water heater is not the direct product of national governmental project research, and few experts predicted the rapid introduction and commercial success before it was introduced into the market. It is true, however, that public policy and funding played important roles in both research and diffusion of this technology. Therefore, it is important to review the role of the public sector and to learn from actual lessons of various energy technologies. The lessons from this case can be useful for analyzing the complex relationships between the public, industrial, and private sectors. In this chapter, we attempt to identify the factors that contributed to the "unexpectedly good" results of this high-efficiency water heater. Especially, we focus on the critical elements that were important to overcome: the so-called death valley and the rapid diffusion of the product. We examine the CO_2 heat pump-based electric water heater case in detail.

19.2 CO_2 Heat Pump-Based Electric Water Heater[3]

19.2.1 Brief Introduction of the Technology and Current Status of the Market in Japan

In May 2001, Tokyo Electric Power Corporation (TEPCO), which is the only regional electricity supplier in the Tokyo metropolitan area and the biggest electric power utility company in Japan, released a new type of electric water heater, named "Eco-Cute," to the water heater market. The heater was the product of a collaborative project among the following three parties: TEPCO; the Central Research Institute of Electric Power Industry (CRIEPI), which is the private nonprofit organization funded by the electric power utility companies; and Denso Corporation, which is an automobile component manufacturing company of the Toyota Motor group.

Before the introduction of Eco-Cute, electric water heaters were not popular in the Japanese household water heater market. Despite its high price of $6,000 (a typical regular gas hot water heater is $3,000–4,000), TEPCO was able to sell more than 6,000 Eco-Cute heaters during the first fiscal year. This was a surprising success for TEPCO.

[3] We conducted seven interviews with persons involved in this case (see Appendix A). We referred to the case description of the Editorial Department of OHM (2006), too. We also summarized the history of this case in Table 1 (see Appendix B).

Eco-Cute is the first CO_2 heat pump-based electric water heater for residential use in the world. Eco-Cute could achieve very high efficiency by using heat pump technology. The designed coefficient of performance (COP) of Eco-Cute was over 3.5 in the first model released in 2001. This means that the heater can transfer three times the heat it consumes. The performance was improved, and its COP ran up to 4.9 in the models released only 5 years later. This high efficiency contributed not only to reducing CO_2 emissions but also to reducing energy costs for consumers. According to the estimates by TEPCO, it can cut CO_2 emission about 65% and reduce the heating cost per month from about \$40 to \$8 for an average family of four persons.

Soon after its release, other regional electric utility companies commenced the sales of the Eco-Cute, and many electric appliance manufacturers and some conventional water heater manufacturers released their own Eco-Cute products to the market. By 2008, its cumulative number of shipments amounted to 1.5 million, and its price has decreased to around \$4,000 through mass production as well as tough competition among manufacturers. This price is sufficiently competitive with conventional gas or electric water heaters. Now the latest Japanese government policy sets the target installation number to 5.2 million by 2010.[4]

19.2.2 History of Eco-Cute Development

19.2.2.1 Basic Research and Development Phase

The origin of the Eco-Cute can be traced back to the national project called "Super Heat Pump Project" in 1984, which was part of a larger national project on energy efficiency improvement, called "Moon Light Project," developed by the Ministry of International Trade and Industry (MITI). The electric power industry sector took charge of this project research, and they established the cooperative research group including utility companies, manufacturers and CRIEPI. CRIEPI accepted the role of advising on and evaluating the research.

In 1985, CRIEPI commenced research on heat pump technology with only one researcher, Tetsu-shiro Iwatsubo. He was reassigned from the research team of fossil power technology because he was an expert on heat engineering. The following year, CRIEPI hired another researcher, Michiyuki Saikawa, who also majored in heat engineering. They began their own independent research on the heat pump-based electric water heater at CRIEPI in parallel with research funded by the government. Because the heat pump was widely used for air conditioners at that time, CRIEPI researchers selected a relatively new field – a heat pump for electric water heaters, an area dominated by gas heaters then – as their research topic. The gas industry apparently was not interested in improving energy efficiency of the gas

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[4] "The Plan for the Achievement of Kyoto Protocol" endorsed by the Cabinet in April 28, 2005.

water heater at that time. This was consistent with CRIEPI management policy, which typically encourages researchers to choose subjects not widely studied by conventional manufacturers and/or utilities' in-house research programs.

Several manufacturers had developed and released heat pump-based water heaters in response to the request of electric utilities during the 1980s, but their performance was not very good. Especially, the upper limit of the temperature of the boiled water was too low (<60°C) and the efficiency was not high (COP was still <3.0). Furthermore, the price of that system was too high for customers.

The CRIEPI team finished the preliminary survey, set the target performance, and developed the new mechanism, the "two-stage compression heat pump cycle." The new system's estimated COP was about 3.8. The production of a prototype water heater based on this concept was accomplished in 1998, and they developed the commercial heat pump water heater for household use by1992.

However, the commercialization project was canceled during the final phase of the process for several reasons: performance problems, high cost, and issue of the chlorofluorocarbon (CFC) regulation. Because of the cancellation, their project was given a stern judgment by their management.

Their next project was the development of the two-stage compression heat pump-based water heater for business use. They started the collaborative project with large construction companies ("general contractors") and manufacturers in 1992 and finished the development successfully in 1996. However, this project was also canceled during the final phase of the commercialization. The main reason was the CFC regulation again. Although they used a CFC substitute as a refrigerant in their product in response to the CFC regulation for ozone layer protection, experts had begun a discussion on the need for regulating CFC substitutes to respond to global warming issues. This sudden change of environmental regulations was the primary reason for the cancellation.

The heat pump research was strongly supported by one senior management member, Teru-hide Hamamatsu, who believed that the potential effectiveness of the heat pump technology could contribute to energy conservation. Defending the project from criticism inside the institution, he ordered the team to research the CO_2 heat pump technology, which was, again, a small research topic in Japan in 1993. According to the regulation of CFCs to protect the ozone hole since the beginning of 1990s, almost all Japanese electric appliance manufacturers adopted the CFC substitutes as the new refrigerant in their consumer products. In Europe, many experts considered the so-called natural refrigerants (including CO_2, water, atmospheric air, ammonia, butane, and so on) as better candidates as they are not greenhouse gases. However, natural refrigerants required more innovative and challenging research efforts than do conventional chemical CFC substitutes.

The CRIEPI team started the preliminary survey on natural refrigerants soon after approval of their manager, Hamamatsu, in 1993. They selected CO_2 as the most suitable refrigerant to develop the water heater and started the basic research in 1995. They installed an experimental CO_2 heat pump loop in 1996, and studied the characteristics of the CO_2 heat pump. They verified their hypothesis that CO_2 refrigerant was suitable for water heaters. They presented the research results and status in several international and domestic workshops and academic conferences beginning in 1997.

19.2.2.2 Development and Commercialization Phase

In 1997, the Kyoto Protocol on climate change was approved at the Third Conference of Parties (COP3) during the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto, Japan. In that international agreement, Japan promised to reduce the CO_2 emission 6% from the 1990 level between 2008 and 2012. The Japanese government implemented a series of policies in response to the Kyoto Protocol, one after another. Although Japan had improved the energy efficiency mainly in the industrial sector since the 1970s, civilian energy consumption had increased continuously, and no strong regulations existed. The government decided to establish policy for energy conservation in the residential field for the first time. They created guidelines for housing heat insulation and introduced the “top-runner mechanism” in the consumer electrical appliance field. However, whereas the improvement of energy efficiency in air conditioning and other machinery use was being promoted, the water heating field was not included in the regulation.

In addition, CFC substitutes were also regulated by the Kyoto Protocol and could not be used any longer as refrigerants in electrical appliances. Japanese manufacturers were obliged to develop an alternative refrigerant-based heat pump technology once again.

Under such circumstances, some members of the domestic electrification department of TEPCO visited CRIEPI. At first, they wanted to find some initial candidates that could contribute to changing the air conditioner refrigerant from CFCs to a natural refrigerant. Saikawa, who had taken the initiative in the research on the CO_2 heat pump, pointed out that the CO_2 heat pump was more suitable for a water heater than for an air conditioner.

Although most TEPCO staff were disappointed by the explanation of Saikawa, one staff member, Tomoaki Kobayakawa, was convinced that the CO_2 heat pump electric water heater was promising technology. He was aware that water heating was an important (about one-third of household energy consumption) but untouched area of energy efficiency in the household. Electric utilities had been selling electric water heaters since the 1960s, but it was primarily for load leveling, not for energy conservation. Furthermore, it was not popular because it was too expensive, too large, and not a user-friendly machine. Especially in TEPCO’s area, the average gas price was the lowest in Japan and the coldest (heavy snowfall) districts were not included, so the sales of the conventional electric water heaters of TEPCO was the worst of nine electric utility companies.

TEPCO was also aware of the effectiveness of heat pump technology and sold the heat pump-based multifunctional water heater system during the 1980s, but because of its poor performance and high cost the system was unable to compete with the gas water heater. Consequently, the “domestic electrification” section had shrunk in size drastically. In 1998, only seven persons belonged to the domestic electrification section of TEPCO, which had about 38,000 employees.

Kobayakawa thought that the CO_2 heat pump-based electric water heater could break through such a situation. He wrote the proposal documents on development of a household CO_2 heat pump-based electric water heater and submitted it to his boss, Momoki Katakura. Katakura was the director of the Center to Promote Demand Side Management (DSM) at that time. He understood the effectiveness and feasibility of a

CO_2 heat pump-based electric water heater in terms of the contribution to DSM and gave the approval to start the project. After this decision, Kazutoshi Kusakari, a rookie in the domestic electrification department, joined the project. He had a national license in architecture and had sufficient expertise on the housing market. He has had a central role in the development of Eco-Cute in the TEPCO team since then.

They started the project, but had very few members and no R&D function in-house. CRIEPI would provide expertise and advice and in fact collaborated with TEPCO; but they could not develop the consumer product alone. They had to find a manufacturer who would join the project. They contacted several major manufacturers that had developed and produced water heaters for corporate R&D, but all of them declined their request. According to stakeholders,[5] they could not afford to spend their resources on water heater development because they had to develop natural refrigerant-based air conditioners, refrigerators, and similar products as soon as possible. Another interviewee pointed out that they were concerned about profitability because TEPCO did not perform well in the conventional electric water heater business.

Therefore, Kobayakawa visited Saikawa at CRIEPI again and asked him about other possible manufacturers. Saikawa introduced him to an unfamiliar name of a company in the electric industry. It was Denso Company, a group company of the Toyota Motor Corporation that develops and produces electrical automobile components and supplies them to Toyota and other automobile companies. Denso had started its own CO_2 refrigerant research for automotive air conditioner development at the beginning of the 1990s, triggered by the request of the European automobile industry. It had presented its achievements at some international academic conferences, and Saikawa had exchanged information with its representatives. Though Denso had no experience in the housing appliance field, it had produced seven million automotive air conditioners per year, so it was an expert manufacturer in heat pump technology. Saikawa thought that it could play a significant role in their project.

Kobayakawa visited the headquarters building of Denso in Aichi Prefecture, which was a 2½-h trip from Tokyo, in July 1998. He invited them to join the CO_2 heat pump-based electric water heater development project. Masahiko Ito, who was the manager of the new business department and negotiated with TEPCO, worried about the sudden visit of an unfamiliar guest at first but slowly understood TEPCO's intention. At that time, Denso wanted to find new business to diversify their field outside the automotive one. The proposition from TEPCO was consistent with that strategy. They had accumulated know-how on the CO_2 heat pump for about 8 years but could not achieve commercialization. Ito agreed to join the cooperative development, and his appointment was approved by the board of directors.[6]

The project was officially started by three institutions in February 1999. TEPCO planned the specifications of the product and managed the process. Denso developed the technological elements and manufactured the prototype models. CRIEPI

[5] In our interviews. The Editorial Department of OHM (2006) also quoted similar comments.

[6] An interviewee pointed out that the credibility of the company name TEPCO was highly effective for convincing the executives.

verified the performance of the prototypes and gave technical advice to the other two partners. The project members consisted of only a few experts and kept the details secret from outsiders. Even inside their institutions, this project was carried out in secrecy. The "partners" gathered for a meeting once a week and had intensive discussions. TEPCO decided on the performance requirement; Denso then developed the parts; and CRIEPI verified it. This cycle was repeated again and again.

Kusakari of TEPCO had extensive experience on residential appliances; for example, he emphasized the importance of the size of the chassis. To keep the size of the chassis acceptable, they accumulated data of household demand of hot water in various situations and optimized the capacity of the hot water tank. He also argued to simplify the system to only the water heating function because of the lesson of the failure of the multifunctional heat pump system during the 1980s. He believed these points were essential to broaden the potential market and to decrease the cost in the future from the point of view of residential appliance specialists. The engineers from Denso had other opinions, but Kusakari did not concede on these points. On the contrary, Denso transferred their know-how on compressor technology and IC control technology in the automotive field effectively. They were able to respond to the high requirements of TEPCO and CRIEPI and had quickly improved the performance of the prototypes.

The project team installed prototype water heaters in many areas in Japan to verify the behavior and performance under different circumstances. They added a data-gathering system to each prototype machine by using the data communication function of the mobile phone so they could monitor the status remotely. The wife of an engineer accepted the role of a monitor. She checked the behavior of the machine carefully and recorded it in detail. With these data, they were able to improve and optimize the electronic control program of the water heater. They also modified the compressor and heat exchanger many times.

Finally, they were able to start manufacturing the final release candidate model in December 2000. It had 4.5 kW of boiling ability and achieved a COP of 3.5, which was well over the set target COP 3.0. The total amount of the development budgets were only several million dollars and the development period was less than 2½ years.

19.2.2.3 Introduction and Diffusion Phase

TEPCO named this brand-new electric water heater Eco-Cute by means of an in-house contest at the beginning of 2001. They decided to permit the use of this name not only for their own product but also to every CO_2 heat pump-based electric water heater released by other utilities or manufacturers. Eventually, several groups developed and prepared to release similar water heaters. "Eco" meant "ecological," of course, and "Cute" has double meanings of the English word "cute" and the Japanese word *"kyu-to"* which means "hot water supply." On January 31, 2001 they announced that the release date of Eco-Cute was scheduled for May 2001. During the first fiscal year, more than 6,000 Eco-Cute water heaters were shipped even though its price was still high (about $6,000). This number was much greater than the expectations of the stakeholders, and sales have been good up to now. Good sales have stimulated the competition between manufacturers and promoted improvement of the performance, bringing the cost down. Many electric appliance manufacturers have entered the market and released their own products. Consumers can choose the appropriate model depending on their needs from many variations of the Eco-Cute heaters, including special models for cold districts, design-conscious chassis models, and down-sized models for mansion residents. The retail prices also dropped to a level similar to that of conventional gas water heaters (around $3,500–4,000). By 2008, more than 1.5 million Eco-Cute heaters had been installed in Japan. According to several estimates,[7] it has been possible to produce 5.6 million fewer tons of CO_2 emissions and save 120,000 tons of crude oil equivalent of primary energy consumption by using 700,000 Eco-Cute water heaters.

During this introduction and diffusion process, the national government has provided a financial support scheme for customers. In 2000, the Agency for Natural Resources and Energy (ANRE) asked TEPCO if they had some new products that could contribute to alleviating global warming and address the energy-saving issue. TEPCO introduced and explained the Eco-Cute to them. ANRE showed interest and was pleased, but both TEPCO and ANRE were concerned about the high initial cost for customers; ANRE considered the possibility of providing a subsidy scheme. They requested much data and documents on Eco-Cute from TEPCO and began negotiations. Kusakari, the key person of the Eco-Cute project in TEPCO, believed that the subsidy scheme from the government was essential to introduce and diffuse their new water heater to the market. Based on his experience and the accepted theory in the housing industry, customers choose new technology that has low maintenance cost but high initial cost if they can recover the difference within 3 years. Although Eco-Cute can reduce the heating cost of an average family about $400 per year, the price difference was more than $3,000 at that time. Hence, Kusakari thought that this difference had to be made up in some way. He willingly provided the materials in response to the request of the agency. Finally, the government approved the financial support scheme to make up half the difference of the price between Eco-Cute and the conventional gas water heater to each customer. This financial support scheme was introduced in financial year (FY) 2002 and continued until FY2004.[8] In this scheme, the additional cost for customers was reduced

[7] CO_2 emission reduction was estimated by the Study Group for Promotion of CO_2 Heat Pump Based Water Heater (2005). It is a report created by the private working group to the director general of Agency for Natural Resources and Energy, the affiliated agency of METI (Ministry of Economy, Trade and Industry). Primary energy consumption reduction was calculated by the authors based on CRIEPI (2005).

[8] After FY2006, the financial support scheme was changed to fixed-amount support. The amount of support was about $500 in that year and has decreased gradually. However, the average street price of Eco-Cute has alsov dropped, and the sales of Eco-Cute have not slowed down significantly until now.

to about $1,500, and customers could recover it in about 3 years. Thus, Eco-Cute was competitive in the market because of this financial support, according to the accepted theory. The amount of subsidy has decreased in proportion to the price decrease of Eco-Cute year by year, but this scheme has played an effective role in the primary stage of the introduction and diffusion process of Eco-Cute.

TEPCO themselves have also carried out a series of promotional campaigns. They had started the "all-electrification" promotional campaign in 1999 with the conventional electric water heater and the IH (induction heating) cooking stove. In Japan, people usually use gas for cooking and water heating and electricity for lighting and electric consumer appliances; and the electric and gas utilities have maintained their own territory for many years. In response to the move toward deregulation of the electric power industry, however, TEPCO and other electric utilities began to break into the market that had been dominated by gas utilities since the end of the 1990s. The "all-electrification" campaign was part of this trend. The emergence of Eco-Cute was a good opportunity for them to promote their electrification campaign.

Under such circumstances, in 2000, a half year prior to the release of Eco-Cute, TEPCO introduced a new discounted special electricity fee rate called "Denka-Jozu" for so-called "all-electrified" houses. Before this change, the special rate for "all-electrified" houses was the two-time-zone rate. At night there was a discounted rate, but during daytime the premium rate was applied. TEPCO emphasized their estimation that the total heating cost would drop for almost all families, but consumers did not have a good impression of the "premium" rate time and tended to distrust the estimation. In "Denka-Jozu," TEPCO responded to this customer concern and adopted the three-time-zone rate. They changed the rate in the morning and evening from the premium rate to the standard rate. Generally speaking, household electricity demand is increased during these time zones because of household activities. This change could attract the attention of customers and increase the competitiveness of Eco-Cute.

A government-affiliated award has played the role of public relations activity. The "Energy-Saving Grand Prize" is an annual award for excellent product and technology developed by Japanese institutions. This award is presented by the Energy Conservation Center, Japan (ECCJ), which is an affiliate foundation of ANRE and is strongly backed by the national government. Eco-Cute got the grand prize in 2001. This prize had a good influence on its introduction, as a guarantee of its effectiveness and reliability. Eco-Cute also received many prizes, including "EPA Climate Protection Award" from the U.S. Environmental Protection Agency (EPA).

As mentioned before, TEPCO permitted competitors and other regional power utilities to use Eco-Cute as their own CO_2 heat pump–based electric water heater product. The unified brand name was effective in establishing public acceptance. The basis of the CO_2 heat pump technology itself was not protected completely by patents, although each step of know-how was patented by TEPCO, Denso, and CRIEPI group or other institutions. Competitors were able to enter the Eco-Cute market easily and utilized their own accumulated technological knowledge to improve the performance and decrease the cost. Many Japanese electric appliance manufacturers have their original technology on compressors and heat exchangers. The competition based on the market mechanism has promoted the improvement of Eco-Cute products.

Furthermore, at the present time, the national guideline for residential energy efficiency is under consideration by the Ministry of Land, Infrastructure, and Transportation (MLIT). High-efficiency water heaters such as Eco-Cute will be included in this guideline as recommended appliances to reduce residential energy consumption.[9] The guideline will regulate the way to estimate and indicate the performance as well as reference specifications. Already some large cities, such as Metropolitan Tokyo and Yokohama, have similar guidelines of their own. These regulations involving residential policy will play an important role in the improvement of Eco-Cute.

These measures by the public sectors and utility companies themselves acted as incentives for customers and helped promote the introduction and diffusion of Eco-Cute.

19.2.3 Summary of the Eco-Cute Development Case

In its basic R&D phase, the most important point was that CRIEPI could continue research on heat pump technology for about 10 years despite the fact that they had twice failed to commercialize their own technology. They were able to continue their research with the support of one senior manager and accumulate the knowledge on heat pump technology with a limited budget. This experience had enabled the development of Eco-Cute.

During the commercializing development phase, changes in the external environment triggered commercial development efforts of Eco-Cute. Because of the growing social need for higher energy efficiency and non-CFCs technology, CO_2 heat pump technology found an application field in the household water heater market. The Japanese government, stimulated by the COP3 conference held in 1997 in Kyoto, made many efforts to initiate a series of measures in rapid succession in response to the agreements. It is notable that at first the residential water heater field was untouched by both the government and the gas utilities. This fact can be seen as the emergence of some kind of “niche” market. Global warming issues, the Kyoto conference, and related governmental policies, however, raised public awareness of high-efficiency appliances. Meanwhile, the electric utilities wanted to broaden their market to respond to the deregulation movement in the electric utility sector.

It is interesting to note that nonmainstream actors in the energy industry and outside companies – namely, the heat pump research team in CRIEPI, the domestic

[9] This guideline is being discussed under the initiative of the Institute for Building Environment and Energy Conservation (IBEC), which is an organization affiliated with MLIT.

electrification department of TEPCO, and Denso – collaborated and played key roles in the development of Eco-Cute. Both CRIEPI and TEPCO teams were non-mainstream divisions and were once considered failed teams in each organization. For these two institutions, the decision of Eco-Cute development was not made with a strong, unified intention of the whole organization. In that sense, the motivating factors mentioned above did not have much influence on the management of either CRIEPI or TEPCO.

Denso was a complete outsider of the electric utility industry sector, and they had no experience in household water heaters. The development team was also small in the company. Each, however, had the necessary expertise and abilities to develop the CO_2 heat pump-based electric water heater and played their own role well, complementing each other.

Finally, during the introduction and diffusion phase, Eco-Cute overcame the "Death Valley" mentality and was diffused rapidly with the support of the following series of incentive factors.

1. Governmental financial support scheme for consumers.
2. Strong promotion sales as a total electrification package by power utilities, including a special discount electricity rate.
3. Public relations campaign by the government, including the "Energy-Saving Grand Prize" award.
4. New energy efficiency regulations (consumer electronic appliances and housing) stimulated technological development and consumer interest.
5. Competition among manufacturers promoted cost and performance improvements.

These factors played important roles in the introduction and diffusion process. They functioned as incentive factors and attracted a wide array of customers. Especially, the governmental financial scheme was highly effective during the initial high-cost period. The cost and performance improvements achieved by open competition had beneficial effects on the diffusion phase.

19.3 Discussion

This case study of the development and highly successful introduction of sustainable technologies revealed that there are several points for further improvement of sustainable energy technology promotion.

In its basic R&D stage, we observed very complex and interesting processes that are quite different from the "linear process" of successful technology development. In the case study presented, these technologies can be considered unintended by-products of national research projects that, however, did trigger their R&D programs. CRIEPI did not directly transfer any results of the national heat pump research project to Eco-Cute development, but their basic R&D on heat pump technology was surely triggered by the national project. Their experience at least partially provided the necessary knowledge base for later commercialization of Eco-Cute.

Furthermore, it is interesting that the technologies involved were at that time not mainstream research subjects. In the case of CRIEPI, most of the R&D projects were on supply-side technologies; and even among demand-side technologies, the heat pump was a new field when CRIEPI participated in the national research project. Especially for the CRIEPI teams, the project was once judged a “failure,” but they were able to continue their programs thanks to the strong support of a senior manager.

A similar situation is observed in its development and commercializing phase. The domestic electrification section had become a minor section in the huge TEPCO utility company when they started the project. In fact, the electric water heater was considered a failed product for the company. The TEPCO team, though, utilized their know-how on residential appliances to respond to new market needs (i.e., residential high efficiency). It can be said that they took advantage of being a small section in the company to take flexible action. The Denso team was also not in the mainstream of the business field of that company.

Additionally, it is important that the outsiders (CRIEPI and Denso) played key roles in the technology development. Not only being a small part of their own institutions, these actors were outsiders in the water heater business field. Even though they were outsiders, they had the relevant expertise on new water heater technology.[10]

In sum, a series of marginal social factors played an essential roles in the R&D and commercialization process of this technology.

It should be noted that all of those factors could produce “successful” results under the particular circumstances of market needs. That there was a growing market need to respond to the global warming issue had great influence on the commercial success of this technology. Climate change policy motivated the market needs for higher efficiency of household appliances. Hosting the COP3 conference in Kyoto was an epoch-making event for Japan, which seemed to have created this strong pressure on both the public and private sectors. A series of policies were created not only by traditional energy policy institutions (METI) but also by the Ministry of Construction and local governments that were responsible for the energy efficiency regulations for housing. This suggests that although traditional energy policymakers are still important it is also important to expand the policy community for more comprehensive energy policy-making.

It is not surprising that teams in an electric utility company took the initiative in the collaborative R&D in response to these changes in the market, as they were more sensitive to market trends than manufacturers and research institutions. In

[10] Matsumoto et al. (2003, 2005) and Matsumoto (2005) proposed a concept “relevant outsiders” in such phenomenon. “Relevant outsiders” are the outsider actors of the traditional stakeholders, but they have some kind of knowledge or interest in the issue. They are relatively free from some common opinions, basic assumptions, or traditional beliefs of the established circle, so they can be more free-minded than traditional actors. They often make some breakthroughs or innovations. Juraku et al. (2007) proposed a similar concept, “relevant marginal actor,” in the local social decision-making process of nuclear power plant sites as an extension of Matsumoto’s concept.

addition, they were able to take a financial risk, and they were the major financial sponsors of the large public relation campaigns that facilitated spread of the new high-efficiency water heater technology.

During the introduction and diffusion phase, the traditional actors played an important role again. First, METI's financial subsidy schemes played an important role in the introduction phase of the technology. It is important to note that METI carefully designed the subsidy scheme so it would not treat any particular technology unfairly. The energy conservation public campaign promoted by the government also increased public awareness of the importance of the issue. Second, the utility companies provided various promotional campaigns as one industry. Especially, discount fee rates and intensive promotional advertisements in the mass media attracted the attention of customers.

Finally, open competition in the market created a favorable environment for rapid technological improvement. The new water heater technology was not the product of radical "innovation" but of a combination of technological elements and their successive improvement. In the Eco-Cute case, various electric appliance makers joined the market after the initial success of Denso (outsider), and technological improvements over the first generation were substantial. This was possible because TEPCO and others did not patent the basic concept of the Eco-Cute product.[11] Hence, it was not difficult for the competitors to enter the market. They brought their own heat pump technologies on air conditioner and refrigerator development to improve the performance of Eco-Cute. An interviewee pointed out that the culture of "performance improvement in the competitive market" was brought to the Eco-Cute market by the electric appliance manufacturers. This open competition has facilitated rapid technological improvements, and it has boosted growth of the market. Currently, about 10 manufacturers produce Eco-Cute based on their own technologies with different prices.

19.4 Policy Implications

The process of the "successful" commercializing of a technology was complicated and included many unexpected events. The process was not the result of careful planning or policies but, rather, a result of a combination of factors. The fact that the technology was developed by nonmainstream actors is also interesting. This case study is very different from the mission-oriented project research style.

As mentioned earlier, the Japanese government had been conducting large national research projects on the development of sustainable energy technologies

[11]Of course, they patented several dozen of the technological elements that they invented. These patent rights are shared by TEPCO, CRIEPI, and Denso. However, they did not patent the basic concept of "Eco-Cute." The heat pump technology itself has existed since the beginning of the 20th century, and the idea of a CO_2 heat pump is not a new invention.

since the 1970s. Up to now, the total investment has been about $50 billion. PV, wind, and geothermal technologies are examples of mainstream R&D projects. However, part of the governmental funding went to a variety of small-scale, unnoticed projects, which triggered the development of Eco-Cute technology. Although it was not the intended result of the national projects, government R&D funding has been essential for initiating and/or continuing small-scale research activities. It is also important to note that CRIEPI, a nonprofit organization, provided invaluable funding to keep the project moving despite repeated failures in the early stages.

To retain the flexibility of our sustainable policy, we need as many technological options as possible. The diversity of technology development is essential to prepare many technological options. From this standpoint, this case study is highly instructive. It is important that our R&D policy includes different technological development processes. Because it is almost impossible to "predict" the winner among technology options, it is vital that the many kinds of technology in the basic research phase are continued to retain the flexibility of a sustainable technology strategy. National research projects could support this flexibility of research through funding of diverse technology options.

During the introduction and diffusion phase, the lessons from this case study show that understanding market dynamics is critically important for a product's success. In this case, the government set the tone of the market by pushing environmental policies and new regulations. It was a big player in assisting and facilitating the diffusion process of "energy-efficient technologies" through various incentive measures. As is well known, new technology has to overcome the "Death Valley" attitude to be commercialized successfully. The case study showed that with appropriate governmental support and a good market design the technologies could overcome the "Death Valley" syndrome by themselves through continuous improvements to meet market demands. It is important that the combination of public policy and private actors create such conditions of success. Unfortunately, though, it is not easy to "predict" and "plan" such development processes beforehand.

Appendix 19.1: List of Interviews

<Eco-Cute Case>

Mr. Kazutoshi Kusakari, a member of TEPCO Eco-Cute team (January 17, 2007)
Dr. Michiyuki Saikawa, a member of CRIEPI Eco-Cute team (January 25, 2007)
Mr. Shizuo Tsuchiya, a member of Denso Eco-Cute team (January 30, 2007)
Mr. Koji Takakura, Chofu Seisakusho Co., Ltd. (March 6, 2007)
Mr. Yutaka Takeuchi & Mr. Kazutoshi Kusakari, TEPCO (May 24, 2007)
Mr. Kiichiro Sato, Research Institute of Economy, Trade and Industry (RIETI), Former METI Officer (September 18, 2008)
Mr. Masaki Hirano, Denki Hoan Kyokai Zenkoku Renraku Kaigi, Former METI Ofiicer (September 25, 2008)

Appendix 19.2: History of Eco-Cute Development

1960s	Power utilities started the sales of conventional electric water heater (to promote load stabilization)
1985	CRIEPI joined the "Super Heat Pump" national R&D project They also started an independent R&D project on heat pump technology
Late 1980s	TEPCO introduce the multifunctional heat pump water heater for domestic market (but not good sales due to high price and insufficient performance)
1988	CRIEPI started the R&D of "two-stage compressing heat pump cycle" water heater
1990	Denso started the CO_2 heat pump technology (targeted to the European automobile air conditioner market)
1992	CRIEPI canceled the commercialization of their "two-stage compressing heat pump cycle" water heater owing to high price and CFC regulation They changed the target market to business use (adopting CFC substitutes in response to CFC regulation)
1993	CRIEPI started the basic R&D of natural refrigerants (including CO_2)
1995	CRIEPI concluded that CO_2 is the best natural refrigerant for water heater use
1996	CRIEPI installed an experimental CO_2 heat pump loop
1997	COP3 conference in Kyoto – Kyoto Protocol was approved Regulation for CFC substitutes was also decided: CRIEPI canceled the commercialization of their water heater for business use
1998	Japanese government started to introduce various measures in response to the Kyoto Protocol, but no special action in the domestic water heater field
1998.3	TEPCO people visited CRIEPI Dr. Saikawa introduced CO_2 heat pump water heater technology
1998.4	TEPCO decided to develop the CO_2 heat pump water heater for household use market CRIEPI introduced Denso to TEPCO as a collaborator
1999.2	TEPCO, CRIEPI, and Denso began the joint development
1999	TEPCO began the "all-electrification" promotion campaign
2000.7	TEPCO introduced the "Denka-Jozu" new electricity rate system
2000.8	METI inquired about a new energy conservation product for TEPCO TEPCO introduced the CO_2 heat pump water heater (which was under development at that time) METI began the consideration on the financial support scheme for TEPCO's new water heater (TEPCO submitted the data on their water heater; METI negotiated with MOF)
2000.12	Final release candidate model of CO_2 heat pump water heater was accomplished
2001.1	TEPCO named the new water heater Eco-Cute They announced the release of Eco-Cute in May 2001
2001.5	First Eco-Cute product was released
2001.6	Mitsubishi Electric entered the Eco-Cute business The phrase "high-efficiency household water heaters" appeared for the first time in an official government document
2001.10	Matsushita Electric, Matsushita Electric Works, Daikin Industries, and Sanyo Electric entered the Eco-Cute business
2001	Eco-Cute received the "Energy-Saving Grand Prize" from ECCJ
2002	More than 6,000 Eco-Cute products were shipped during the first fiscal yearGovernment financial support scheme was introduced

(continued)

Appendix 19.2 (continued)

2002.10	Chofu Seisakusyo entered the Eco-Cute business
2004	TEPCO's "Switch!" promotion campaign
2004.10	Hitachi Home & Life Solution entered the Eco-Cute business
2005.10	Sanden entered the Eco-Cute business
2005.11	Hitachi Housetec entered the Eco-Cute business
2006	There were more than 700,000 Eco-Cute cumulative shipments
2007.10	There were more than one million Eco-Cute cumulative shipments
2008.10	There were more than 1.5 million Eco-Cute cumulative shipments

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Chapter 20
Democratic Turn of Resource Governance in Japan: Prewar and Postwar Efforts for Integration in Resource Policy

Jin Sato

20.1 Introduction

The subject of natural resources is a suitable focus for debate among natural and social scientists and how the division of scientific labor can be practiced. Although the subject has often been categorized as an area of interest to natural scientists (e.g., forestry and hydrology), the history of resource policy reveals that the very concept of "resource" is social, reflecting the needs and political conditions of the time. This chapter outlines the changing role that resources have played in the history of modern Japan with a specific focus on their political pretext. It further argues the need for revitalizing resource studies as a uniting academic field in an otherwise fragmented subject.

The idea of natural resource has a uniting force. First, it forces us to take water, land, forest, and minerals, among other products, together in a common framework. Otherwise, we would not need the term "resource." Second, defining what constitutes a resource among the possibilities in nature is a social intervention that opens up a common working space for both natural and social scientists. Transforming certain aspects of nature as a resource is a reflection of human evaluation. Subsequently, technical knowledge becomes essential to transform resources into goods and services that then satisfy human wants. The sequence could be the other way around, where technical development allows certain entities to become resources.

I pointed out that the resource idea has a uniting force; but perhaps the right word is "reuniting" instead of uniting because the way we divide up nature into segments as convenient targets for manipulation is only a product of state-led

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modernization after the nineteenth century (Scott 1998). This point was clearly brought to my mind when I was doing anthropological fieldwork in a remote village of Thailand in the late 1990s. In a community located close to a rich forest, I was trying to visualize how local villages use various resources that surround them. One day I asked the village headman to plot some arrows on the map to indicate where he would go for various types of resources (e.g., wild pig, fuel wood, wild vegetables, bamboo, timber). I was expecting a neatly drawn resource map that shows distinct locations for specific types of resource. To my surprise, he drew arrows going in almost all directions from his home.

This was when I realized my own academic habit of dividing up resources into categories of goods. Villagers, on the other hand, go anywhere anytime to collect whatever they need whenever it is available. Also, the villagers were once shifting cultivators who habitually moved around despite government efforts to settle them in one place. For these villagers, resources are naturally perceived as one but not fixed in one particular location.

In contrast to this local perception, modernization encourages segmentation and bureaucratic control of individual resources and development of scientific disciplines that concentrate on a particular resource such as forests or soil without addressing their interconnections. Resources, however, comprise a social concept that identifies potential use of nature and the environment. They are different from raw material that has been extracted and processed in that they are embedded in nature.

There are two characteristics of resources that make the governance issue prominent as well as challenging. First, because natural resources are offered by nature and not created or inherited by some individual or groups of people, they do not originally belong to anybody; this makes their ownership debatable. Second, when society identifies parts of nature as resources to be utilized, those resources are not neatly distributed on earth according to the institutional boundaries and capacity of those who are to govern them. They could easily go beyond manmade institutional boundaries.

This is where democracy becomes relevant. For example, how should we govern resources that are locally utilized while at the same time important to nation states either for their security, economy, or ecological reasons? To what extent can we overwrite laws and policies based on the present concern for the environment that were originally made to promote growth and development instead of conservation?

These questions have complex twists in developing countries that formerly experienced complete centralization of resource control under colonial rule and now are experiencing a radical change by their governments taking the resources back after gaining independence. The Japanese case is an unusual one where extreme centralization was enforced by the militaristic government but after the defeat in World War II (WWII) was forced to make a radical turn toward democratic resource governance under the influence of the American occupation forces. It is because of this unusual experience of Japan that I wish to further explore this topic.

This chapter, therefore, deals with this unique democratic turn and explores what lessons we can extract from the experience. Among the lessons, I particularly highlight the way we conduct holistic studies, which attempt to integrate natural and social sciences. The Resources Committee (hereafter referred to as RC) that was created in December 1947 after WWII prepared an important forum for intense debate among natural and social scientists. They debated how resources should serve the 80 million people, many of whom were on the verge of starvation. The lesson should also extend to the redefinition of resources in Japan, a country long perceived by itself as members of the world's "have-nots."

20.2 Awareness of "Finiteness"

How did the resource concept emerge in Japan? The term "resource" came into the vocabulary of policymakers in Japan only around 1915. Before that, there were terms such as "raw materials" or "natural wealth," which placed emphasis on the material aspect and did not exactly capture the nuance conveyed by the word "resource" (Sato 2007).

There were two lines of thinking that brought about this new concept. The first came from the elite sections of the army that keenly observed the development of WWI in Europe to find that what is crucial in modern war is not only the military capacity for combat in the frontlines but also the supply of raw materials to back them up. This awareness led to the move, first, toward nationwide "research" on production capacities of private factories that manufactured potentially useful goods for supporting the military. Second, it led to an establishment of laws that justified the government confiscation of goods and production facilities in case of a national emergency.

An alternative line of thinking came, also around 1915, from scholars and observers of the rapidly degrading landscape in rural Japan, which was clearly the consequence of infrastructure development that gave little consideration to the surrounding environment. The "preservation of resources" first became a topic of discussion in the House of Peers in 1919, when Takio Izawa and Kyoshiro Inoue questioned Prime Minister Kei Hara regarding the national policies concerning preservation of resources. This was first occasion where the term "resource" appeared in a national level policy discussion. Hara replied by denying the need to preserve since human ingenuity will always find technical alternatives even when certain resources are physically exhausted.

It is understandable that as Japan tried to catch up with the European nations and the United States, the government placed heavy emphasis on present production rather than preservation for future. However, inferiority in influence should not be the reason to dismiss the existence of such an idea. The preservation of a finite landscape became a topic of continuing interest to private individuals and scholars, if not the policymakers.

20.3 Centralized Control and Outward Orientation

With an increasing awareness of material scarcity to carry out the "total war" and the increasing knowledge of mobilization systems that were being institutionalized in European nations, bureaucrats and politicians in Japan started to discuss how resources can be put under state control. In 1927, the "Resources Bureau (*Shigenkyoku*)" was created under the cabinet to meet this objective. The person who named and led this bureau was an elite bureaucrat, Haruo Matsui.

It is important to understand why Matsui was attracted to the resource concept and, in fact, invented it in Japan. He recalled his first encounter with the resource concept back during the 1910s when he read an article in the *London Times* on U.S. President Theodore Roosevelt's conservation policy. In his book *Resource Policy* (*Shigen Seisaku*) in 1938, he argued that the most pressing issue of his time was "differentiation." By this he meant segmentation and lack of coordination, particularly among the government agencies that had expanded enormously and were performing overlapping mandates. He viewed "resource" as a uniting concept that gives an integrated perspective of various means (both human and nonhuman) together in one. Resource was a particularly suitable concept for Japan as it emphasized potential rather than existing raw materials that were considered quite scarce at the time. Matsui placed high hopes on human resources and emphasized the importance of science, technology, and human ingenuity, which could substitute for the scarcity of material in the country. He wrote in his memoir:

> Around 1923 or so, I read Richard Ely's small book which summarized what resource policy is all about…. Theodore Roosevelt was the one who translated this kind of idea into action. I found this movement quite interesting and told this to the then chief of the Cabinet Legislation Bureau, Mr. Yamagata … to initiate resource conservation movement in Japan (Matsui 1975, p. 35).

Matsui's contribution did not end there. He introduced the idea of *hoiku* (保育, nurturing) as his own translation of the English term "conservation." Matsui claimed that "in a resource-rich country like the US, sustaining what they already have through conservation may be enough, but in Japan, a country with scarce natural resources, there is a need for some element of resource development in addition to conservation. This is why I prefer to use the term *hoiku*" (Matsui 1975, p. 36). Unfortunately, his idea was faded and overwhelmed by the general mobilization movement led by the army that began during the 1930s that propelled the whole nation toward WWII.[1]

The "shock" of WWI made the military become aware of the need not only to mobilize the existing forces at hand but also the "potential" forces including the spirit of the public who are to willingly contribute to the total war. At that moment,

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[1] Japanese interest in resources continued to rise until WWII. One of the standard explanations about the causes of war was Japan's demand for resources. However, Yasuba argued with evidence that a "lack" of resources and the necessity of external acquisition was more of a fiction created by the military who needed good reasons to invade China and Southeast Asia (Yasuba 1996).

the traditional separation of military and the rest of the economy became vague, with the increasing extraction of the latter by the former. "Resource" was a convenient term that would help neutralize the militaristic nuances of the mobilization movement while at the same time successfully included the "human" aspect in the resource definition.

20.4 Importation of "Democratic Governance" After WWII

The defeat in WWII and the subsequent establishment of the General Headquarters of the Allied Forces (GHQ) had an important influence on Japan's postwar resource policy. The Natural Resources Section of the GHQ, which was headed by Stanford professor Hurbert Schenck, invited then Harvard geography professor Edward Ackerman as a technical advisor. Ackerman introduced the idea of integrated planning and the experience of Tennessee Valley Authority (TVA) to Japanese bureaucrats who were eager to learn the democratic way of resource governance. Ackerman also advised creation of the Japanese version of the Resources Committee, in which its American predecessor played an important role translating the idea of "resources as one" into actual policy. Ackerman noted that the Japanese campaign that portrayed themselves as "have-nots" was a half-fiction that did not reflect the real potential of the country. As he stated:

> One of the most repeated and most effective instruments used in the psychological warfare was the "have not" campaign conducted by the Fascist powers before and during the last war. Japan, like Germany, presented itself as a poor but deserving nation intent only upon getting enough to keep its growing population alive (Ackerman 1948, p. 32).

Of course, the introduction of resources planning was not an objective of the American occupation. Rather, the main mission of the GHQ was to democratize Japan so the ultra-right and ulrta-left would never again dominate as political forces. In reviewing the reports and minutes of the meetings pertaining to resources planning, however, one can seldom find the word "democracy" in a direct way. This is related to two factors behind the establishment of the RC. One was the lesson from the American version of the National Resources Committee that Ackerman helped to establish in Japan. Because of the ideological battle that overwhelmed the work of the committee, the original mission of technical judgment lost its way to political manipulation. This was one reason why the RC in Japan defined its mission tactically as purely technical and scientific. The second factor was bureaucratic turf. There were already line ministries and committees related to national planning. To justify its existence, the committee carefully limited its mandates to scientific research and technical advice on issues that were cross-bordering the line ministries; it decided not to venture into politics.

Appeals to science and technology inherently accompany the risk of compartmentalization of work that is suitable for each available technology. Therefore, the question is how the committee performed in implanting an integrated approach to resource governance. This first important attempt of the committee was to establish, in addition to the overarching group where reports from subcommittees were gathered, a regional planning committee that focused on "applying" the product on the ground by taking a case study approach. Many social scientists were brought especially into this application step.

The RC consisted of no more than 20 committee members from resource-related agencies and representatives from academia. The committee was supported by roughly 700 specialized committee members who provided expert knowledge tailored to the issue at hand. The RC, under its 20-member overarching committee had subcommittees focusing on land, water, food, fibers, and energy issues. Subcommittees on hygiene, regional planning, and socioeconomic areas were soon added; and as the number of committees increased, the RC gradually became more comprehensive in its coverage.

The main function of the RC was to provide recommendations to the Prime Minister – and later to the Minister of Science and Technology Agency – that ultimately materialized in actual government policies. Thus, one way to examine the RC's achievements is to examine these advisory statements and determine what impact they had on actual policy.

The RC issued 16 recommendations and 24 reports before the establishment of the Science and Technology Agency (1956). Topics ranged from flood prevention (1948) and prevention of water pollution (1951) to railway electrification (1949) and distribution of salt rations (1955). Many of these recommendations were implemented – although not always completely – to enhance coordination among related agencies and enhance policy effectiveness. The recommendation on water pollution prevention in 1951 was among the most advanced of the time, appearing much earlier than the arrival of environmental movements during the 1970s when pollution was recognized as a nationwide issue. The recommendation included the establishment of interdisciplinary monitoring teams at the center and in eight regions of Japan with the authority to enforce pollution standards. The recommendation also contained precise scientific standards depending on the types of water and a proposal to establish a national institute on water quality science to respond to the request by the public in measuring the level of pollution in each region.

The RC soon evolved into the Resources Council (*Shigen Chosa Kai*), which became an interesting center for the holistic approach. One example is the inclusion of pollution and degraded resources in the mandate of the committee's target for research. This is perhaps in contrast to the U.S. resource policy where emphasis was more on production. Japan was not able to afford the luxury of solely increasing the production capacity of what was already available and also had to focus on what was increasingly becoming unavailable, such as degraded rice fields, improperly functioning reservoirs, and leaking canals. By including these negative aspects into its research agenda, the Resource Research Council was able to place disaster research and resource policy in a unified perspective.

How successful was the democratization of Japanese resource governance via the Resources Committee/Council? We must say that it was not very successful. First, as the size of the Resource Research Council swelled, the influence of subcommittees that were working on specific resource issues became dominant.

The council, which originally assumed the function to prioritize and coordinate various resource questions in a cross-sectoral manner, soon became a simple clearing house for reports from the subcommittees. Second, Japan was not ready to implement American-style democratic resource governance, although the idea itself had great appeal to many of the leading policymakers at that time. The self-restriction to "science and technology" that the founders insisted on as a strategic instrument soon became intrinsic mandates for many researchers working for the council. As the first generation of bureaucrats influenced by Ackerman retired, the connection between resource governance and democracy faded away.

20.5 Conclusions

Looking back at the history of modern Japan, it can be said that interest in resources was most intense when Japan was materially impoverished. With the arrival of high economic growth during the 1960s, natural resource issues gradually receded from the national agenda; and after the 1980s there were almost no groups of people who addressed the question of resources from an integrated viewpoint. For example, few courses on natural resources are taught at universities. Nevertheless, Japan's economic growth has been supported by a stable supply of raw materials, and the structure of the economy has not changed much for the past few decades. It is just that sites of resource development have moved far beyond its national boundaries to more distant countries abroad. This is even a greater reason for us to study the meaning of resources and raise political questions about their control.

Let us summarize the main argument and draw some lessons from the history of resource study in Japan. Again, the resource policy arena is one of the most interdisciplinary policy-oriented fields of discussion in modern Japan, although few seem to appreciate that fact. It was also a very international field where ideas about resources were influenced by countries such as Germany and the United States.

The key lesson after Japan made its democratic turn in 1945 was that integration required a strong centripetal force, such as a practical need to satisfy the hungry population. Integration was attempted out of necessity and not out of an academic ideal or romantic pursuit of a holist approach. Simply, there was no other choice. The basic setup for this orientation was strongly promoted by the government in the case of the RC.

The function of the RC was not necessarily to develop an integrated field of resource science as such, but it served as a thermometer to measure the temperature of various resource problems and tried to prioritize among them so as to direct technology in areas that were in heavy need. In other words, instead of constructing an almighty ship to navigate the sea of unexpected challenges, they carried on interdisciplinary discussions to read the currents. This seems to fit well with the definition of resource. In the second edition of the Oxford English Dictionary, "resource" is defined as "a stock or reserve upon which one can draw when necessary."

I wish to highlight the word “when necessary” here. It implies that there are times we see certain resources as unnecessary, or we may even dismiss things that can become a resource. Goods and services that produce direct utility to people can mostly be provided by the state and by markets. But who would provide resources that would be called upon only when necessary? Or who would define necessity – and for whom? This leads us to the question that may arise after reading this chapter: Having become one of the wealthiest countries in the world, do we need to remind ourselves of the legacy of the RC or even to revitalize it in the context of globalization?

I think we do, particularly at a time when market forces have become the key distribution mechanism for goods and services that directly appeal to our desires. Resources that do not necessarily produce utility but serve as a foundation of economic life require systematic and long-term attention. Of course, the question is whether we have enough centripetal force to bring our knowledge together and avoid unnecessary sectionalism at the same time. The key lies in mainstreaming the environment to accommodate other areas of immediate human concern such as heath, poverty, and inequality, among others. That is, we should not consider environment and resource issues separately from other issues. This is precisely why invoking the RC experience becomes relevant today.

Despite the radical contrast in orientations, prewar and postwar resource studies share commonality in the sense that they were both promoted and supported by the government. The largest task ahead is to revitalize the resource study that is derived truly from the viewpoint of people. This is exactly what Japan has failed so far to do and what the village headman in Thailand taught me when he treated all resources as one.

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Chapter 21
Considering the "Social Adaptation" of an Infrastructure and the Consequence of Its Impact on Sustainability

Takayuki Minato

21.1 Introduction

Every structure or facility has a particular purpose and reason for existence, and they can be categorized according to the purpose. One important category of structures is world heritage sites, including temples and churches, palaces, parks, gardens, castles, fortresses, land and valleys, bridges, railways, steelworks, public baths, and even tombs. Many of these sites are now tourist attractions, granting benefits to the host country. According to our brief survey of such heritage sites, there are several interesting examples of the purpose that these structures serve outside of the commercial function. Before entering into the details, we briefly survey these examples.

Matera, Italy is famous for the Sassi,[1] or its ancient quarters of rock-hewn homes (Sassi Web 1998; UNESCO 2009a). This was already a residential area during the Old Stone Age, and then monks moved in between the eighth and thirteenth centuries. The Albanian and the Serbian monks are believed to have migrated here to escape from the Ottoman Turks around the fifteenth century. After the nineteenth century, the area declined; and only tenant farmers lived there, resulting in the Sassi symbolizing the poor. Remaining residents were evicted from the area by the government after World War II (WWII).

Another interesting heritage site is The Defense Line of Amsterdam (UNESCO 2009b; MHAF 2009), The Netherlands. The structure was initially constructed as a fortification based on the principle of controlling waters during the sixteenth century. By this time, the people of this area had expert knowledge of hydraulic engineering. During the seventeenth century, the structure began to be used for

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[1] Sassi means rock wall in Italian.

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defense purposes when the war of independence took place against Spain. In fact, it is said that the "Goode Holland Waterline," originally built to control water, was found to be effective against enemy invasion. During the nineteenth century, the structure was extended 135 km around the city, with a network of 45 armed forts, to defend the city.

Modern tourists are highly interested in world heritage sites, leading many of these structures to play the new role of tourist attraction. However, it remains important to observe how people utilized these properties over time in accordance with their needs and purposes.

The Matera and the Defense Line examples demonstrate that an individual structure can be used for different purposes, and an infrastructure can represent a value different from that derived from its primary functions. These structures have had a long life cycle, and different groups of people have used it for different needs over time. Sassi was the "symbol" of the poor. This type of symbolic role for an infrastructure persists today. For example, subway systems are technically a means of effective transportation, but they also often represent national pride because the subway implies that the city is big or modernized, thus showing the engineering and economic power of the country. This view is extraordinary in the sense that the value of an infrastructure is not limited to its primary purposes as justified by typical engineering criteria. The structure can also be a medium that represents peoples' power, culture, pride, and even history.

In general, the construction of infrastructure needs resources, and the use of resources is dependent on certain design criteria when they are transformed into artifacts. The decision as to how the infrastructure is designed depends on a particular group of people, usually some combination of engineers (technocrats) and government officials (bureaucrats). This means that output is controlled by not only the design criteria but also their knowledge, preferences, and so on, thus resulting in different possible locations, materials used, shapes, and so on. On the other hand, upon utilization, the users of the infrastructure may find that is has different values than intended. In other words, the actual functions and value of infrastructures depend on users' preferences or the way they use the structure.

It is the capacity of an infrastructure that is meaningful. Its function sometimes goes beyond what is expected. The role of an infrastructure as it adapts to meet society's needs should be examined, particularly in accordance with how people want to use a structure. The story of Moses' bridge in Long Island, New York is a famous example that can shed light on this thought. According to Winner (1987), Moses was thought to have designed and built bridges of low height so that buses, typically used by poor black people at the time, could not pass under them. Winner's argument concerns aspects of technological politics with regard to who governs (the achievement of political power through the use of technology) and what governs (the generation of a new social order by technology itself). This claim may be further scrutinized as "who governs who and what" and "what governs who and what" when considering the social adaptation and its impacts on society (Fig. 21.1).

Infrastructures are the most important resources sustaining society. The common view regards infrastructure as a means to provide people with needs for living,

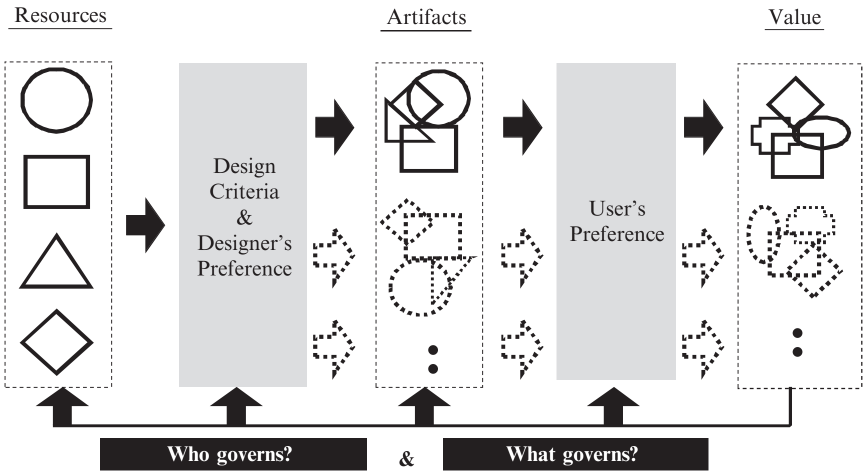


Fig. 21.1 Process of social adaptation

transportation, utilization of resources, protection against disasters, and so on. In this view, emphasis is put on the "physical function" of the structure. For example, a highway is designed and constructed to reduce travel time, and a power plant is expected to generate efficient energy. As a result, the value of the structure is evaluated based on both cost and functional capacity.

Note that the life cycle of an infrastructure consists of four phases: planning, designing, constructing, utilizing. If the traditional view is taken, more emphasis is put on the first three phases. In addition, the value of the structure is evaluated on the basis of conformance to the initially justified functional needs.

Although the primary role of an infrastructure is to provide functional benefits for people, it is also important to consider the changing roles of an infrastructure over time after its original utilization. In this chapter, this change is termed "social adaptation." In addition to simply looking at an infrastructure from the perspective of whether the structure is functioning as originally intended, social adaptation refers to the influences of an infrastructure on the social order that relates to individuals' choices as well as to social concerns such as poverty, the environment, and culture.

Social adaptation occurs during utilization. If studies focus on the first three stages of the infrastructure life cycle, the latent value resulting from changes during utilization will simply be overlooked. Structures are initially designed and built according to the logic of the initial purpose. However, the value also depends on how people use, renovate, transform, or even do away with the infrastructure. In other words, the value of an infrastructure should be examined based on the effect its existence has on social order.

With the above supposition in mind, infrastructures can be classified into the following five categories: (1) used for different purposes; (2) expanded or reduced; (3) renewed or restored; (4) removed or being removed; and (5) abandoned. This examination of infrastructures is completely different from the traditional view, which focuses on “making” infrastructures in conformance to predetermined benefits. Instead, the author scrutinizes the postconstruction social value of structures from the social adaptation point of view.

The main objective is to discuss what social effects infrastructures have and how those effects relate to sustainability. Sustainability is viewed or defined in at least two ways: effect and process (Sutheerawatthana and Minato 2009). It is not within the scope of this chapter to define sustainability further; instead, the discussion highlights the relevance of infrastructures to some issues of sustainability such as the environment, human rights, and culture.

These issues are discussed based on case studies of some actual projects. The first four classifications are discussed through the following case studies: Mt. Merapi Dam Project (Indonesia); Bang Pakong Diversion Dam Project (Thailand); Cheoung Gye Cheon (CGC) River Restoration Project (Korea); Arase Dam Removal Project (Japan).

21.2 Case Studies

21.2.1 Used for Different Purposes

As already noted, most world heritage sites belong to the category “used for different purposes.” The distinctive example of the Sabo[2] dams at Mt. Merapi is presented here, and the technological aspects of this structure that resulted in environmental damage are described (Fig. 21.2).

Mt. Merapi is one of the most famous active volcanoes in the world. It is located 30 km north of the city of Yogyakarta, in the Central Java province of Indonesia. The volcano has caused several types of disaster, of which two are of major concern. One disaster is caused by direct volcanic eruptions (*nuee ardente*), which take place every few years. Since 1548, there have been around 68 major eruptions. The other disaster is flowing volcanic debris (*lahar*) and flooding with sediment (*banjir*). This is caused by unstable debris that accumulate on the upper slopes of the mountain during the rainy season, and people suffered damage, including the loss of both property and lives.

Subsequently, Sabo dams were constructed in three phases between 1985 and 2001. There are now 14 check dams, 29 consolidation dams, and two training dikes. There were also two major operational requirements put into practice: a maintenance road network and sand-mining licensing. The network of maintenance roads was constructed to give engineers access to the dam sites to repair the deterioration of dam structures over time. In addition, licensing was employed to remove the accumulated debris behind dams that would reduce future dam capacity.

[2]Sabo means control of soil erosion in Japanese.

It is interesting to note that these two maintenance requirements provided additional functions to society. Again, Winner (1977) argued that attention should be given to the conditions or requirements necessary to keep technology operating well. The initial purpose of the dams was to reduce the severity of volcanic disaster. However, after completion of the construction, the dams began causing problems associated with the operational requirements.

The sediment in volcanic debris consists of sand and gravel, which have good market value as construction materials. Other than agriculture, these materials were the only source of income for the local people. Before the dams were constructed, it was only possible for the local population to take the materials downstream of the rivers. However, after construction of the dams, sand became trapped behind the dams, making the dam sites resource-rich locations. Sand removal was also necessary to maintain dam capacity. Soon, the local government decided to use a license system for sand quarrying. At the time, licenses were issued to large sand-mining corporations with modern machines, rather than to the general public.

Although the local people did not receive licenses, they took advantage of the maintenance road network to bring trucks with heavy digging equipment to the upper parts of the dam site area where they had not been able to go before. Therefore, the road network, which was originally constructed to allow engineers to maintain the dam facilities, gave access to local people for massive sand quarrying, allowing them to extend their activities deep into the forests and rivers at the upper parts of Mt. Merapi. As a result, there was damage to the forests and disordered extraction of natural resources. More important than the destruction of the environment, it led to conflict between the traditional local miners and private mining companies.

As seen in this Merapi case, infrastructure has secondary effects on society. In particular, it is important to realize that technological logic itself is not neutral, in the sense that engineering criteria such as shapes, length, strength, and durability, as well as operational systems, affect how people use the structure. As shown in this example, these consequences sometimes give rise to serious setbacks for sustainability.

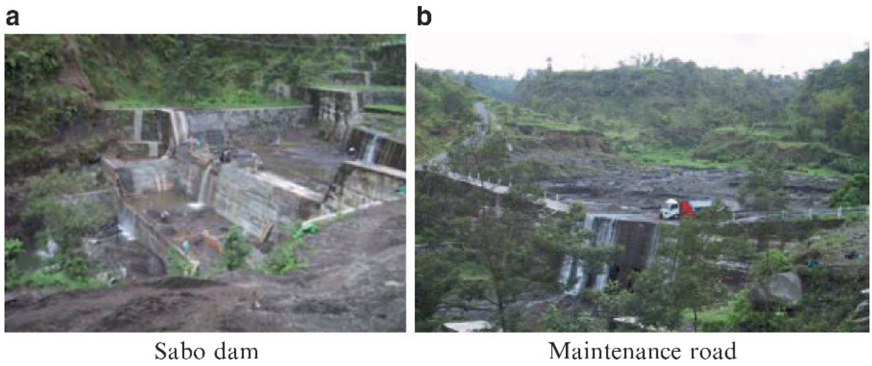


Fig. 21.2 Sabo dam and maintenance road at a Sabo dam site on Mt. Merapi (JBIC 2003)

Infrastructures play a number of roles by themselves; and more importantly, they have consequences beyond the scope of traditional engineering and economic views.

21.2.2 Expanded or Reduced

This section considers infrastructures that remain in use but whose use has been adjusted. This discussion considers why and how the problems presented by infrastructures could increase once they are found to be problematic.

The Bang Pakong Diversion Dam, planned as part of the agricultural water development projects in the Bang Pakong River Basin, was constructed in the Chachoengsao Province of Thailand (Fig. 21.3). The objectives of the project were to supply local communities and industries with irrigation for rice paddies and dry crops during the dry season (an area of 92,000 rai, or 14,720 ha). As there was inflow of seawater into the area, a diversion dam was constructed. The 166 m long dam was constructed in a diversion canal, located about 70 km from the Gulf of Thailand.

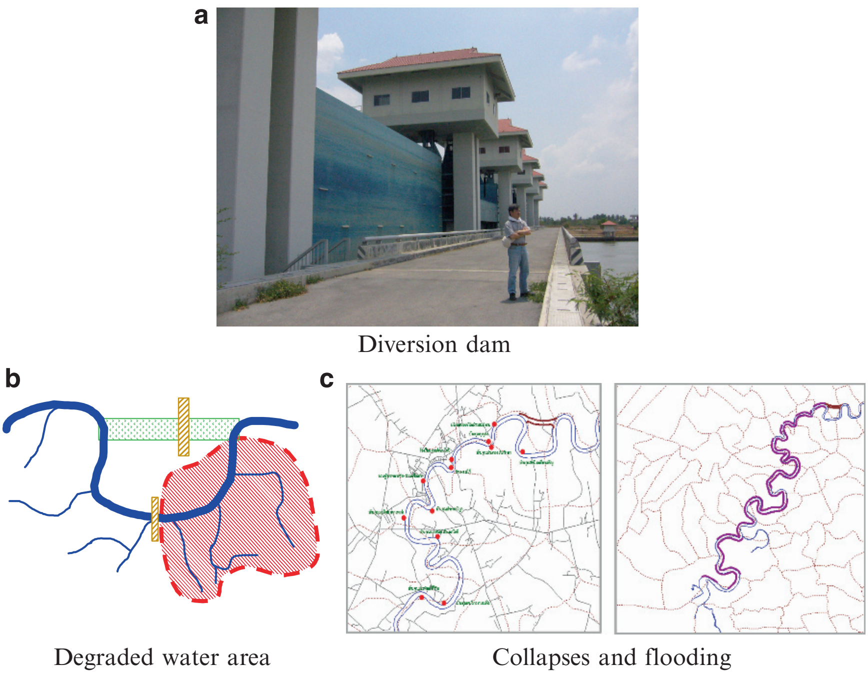


Fig. 21.3 Bang Pakong Diversion Dam and degraded water area

After completion of the construction, the full expected benefits of the diversion dam were not being achieved for two reasons. First, the operation of the dam caused degradation of water quality at the upstream side of the river and natural canals. Second, a series of sudden riverbank collapses took place at 12 locations downstream, and there was severe saltwater flooding along the riverbank totaling 79.85 km in length. As a result, remedies were taken to achieve the original intended functions of the dam. However, these modifications led to a chain of events that caused societal disorder.

First, new operating rules were adopted to resolve the collapses and flooding. These adjustments included the release of 130 million m^3 of stored water from two upstream dams to maintain average water levels. Although this adjustment seemed to work successfully to avoid collapses and flooding, the amount of water in the two upstream dams turned out to be insufficient. The plan to construct a new dam upstream was then accelerated. Second, to resolve the water degradation, three new floodgates were constructed, and water treatment was installed for more than 218 pig farms in the area. In addition, other facilities such as water-pump stations and hydrological stations were installed, costing approximately 100 million baht (US$ 2.8 million).

The influences of this type of remedy sometimes give rise to opportunities for particular stakeholders. For example, some politicians and engineers may insist that further construction is necessary. In that case, allocation of the budget may be changed so more construction is possible. Some citizen groups, on the other hand, may argue that the project should be undone. In many countries, it is argued that public projects are in the hands of these stakeholders. It is not this study's intention to blame particular groups of people, it is important to remember that an infrastructure project can be used as a device for a particular stakeholder to obtain value for himself rather than for society, thus strengthening cyclical development of a particular social order.

21.2.3 Renewed or Restored

This section examines the case study of the CGC River Restoration Project (Fig. 21.4) to determine the meaning of restoration and its impact on society. The CGC River was originally a natural stream flowing west to east into downtown Seoul (Seoul 2009; CRP 2009). Around the sixteenth century, during the era of the Joseon Dynasty, there were no dedicated drainage systems, and the river had the capacity for people to dispose trash and wastewater. However, after the Japanese invasion during the seventeenth century, the amount of wastewater increased owing to a rapid increase in population, overwhelming the river's capacity. During this period, the stream was partially covered. After the Korean War ended in 1953, the situation worsened as people from North Korea swarmed into the area, thus causing environmental problems. To solve the problem, the river was completely covered

Fig. 21.4 Restored Cheoung Gye Cheon River

with concrete so poisonous gas could not be released. In addition, a 5.6-km elevated highway was constructed over the stream to meet increasing transportation needs.

Note that highway construction during the 1960s was regarded as a milestone for successful industrialization and modernization. At the same time, the area became a symbol of poverty and negligence due to environmental issues such as waste, stench, and gas. Around the 1990s, highway construction also came to be recognized as a source of traffic congestion, and the safety of the highway became a concern because of deterioration of the highway structure. The CGC restoration project began in 2003 and was completed within 3 years, prior to the inauguration of Mayor Lee Myung-bak.

The project consisted of restoration of a historically and culturally important heritage site and the improvement of peoples' quality of life. Alongside the river, there is also urban planning associated with business development. Another impact was stabilization of traffic flow, including a shift of transportation to subway use. The air pollution and noise around the area have also been reported to decrease since the restoration. In addition, various stakeholders, such as experts, citizen groups, and nonprofit organizations (NPOs) came together to create the plan, which included more than 4,000 discussion meetings. Public involvement was encouraged through the project, which enhanced peoples' awareness of the environment.

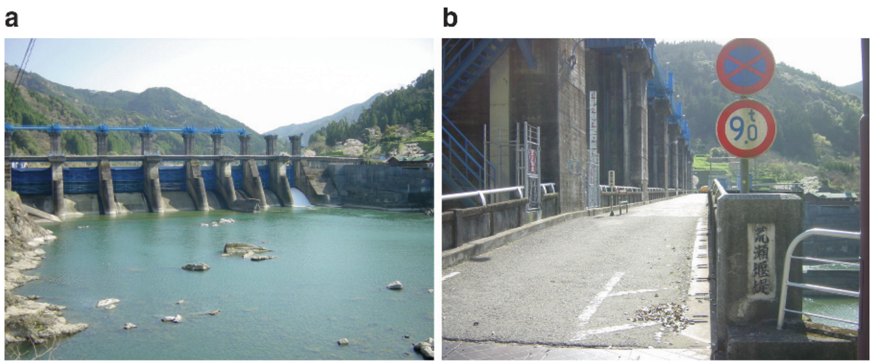
On the other hand, there seem to be several unknowns with regard to the social adaptation of the project. First, this huge project was completed within 3 years. This means that the scope of the project may not have been well defined. The consequent problems also may not have been examined carefully within the short time frame. Therefore, there is a possibility that the original agenda did not fully incorporate the needs of various stakeholders, including dissatisfaction with the design for the concrete riverbed and wall. Other sources of discontent include the evacuation of merchants who hade open-air trades along the river and the possible increase in rental and land prices after the demolition of old buildings. Future development needs to incorporate several additional adjustments; hence, the final outcome of this "restoration" is not yet known.

21.2.4 Removed

In general, an infrastructure is sometimes considered to be a permanent landscape fixture. However, some infrastructures are beginning to be removed. For example, more than 450 dams have been removed in the United States since 1912. Most of these dams were small and were removed because (1) they no longer performed the functions for which they were built, (2) they posed environmental or safety concerns, and/or (3) the cost of retaining a dam became greater than the perceived benefits. Previous infrastructure removals did not attract attention in the past. However, environmental, economic, and safety concerns may drive the assessment of retention or removal as more infrastructures age. This section discusses some of the decision-making issues concerning removal of infrastructure through the example of dams.

Dams serve a wide range of purposes, such as hydroelectric power, flood control, water supply and irrigation, and recreation. On the other hand, dams have serious impacts on the environment as they alter the biological process of the river, change temperature, and produce sediment behind the dam.

The Arase Dam, located in Kuma River, Kumamoto Prefecture, was constructed as a hydroelectric power dam measuring 335 m (Fig. 21.5). The spillway itself



Downstream from the dam — Upper deck road

Fig. 21.5 Arase Dam

stands 25 m high. This will be the first dam in Japan to be fully removed after expiration of ownership by the prefecture.

Discussions concerning removal of this dam gained popularity as the cost of retaining the dam exceeded its benefits. In fact, the decision seemed to be driven by the uncertainty of the economic benefits of the dam under the liberalization of electricity in the market. However, removal of the dam reveals a complexity of issues and interests. For example, discussions about the future include public safety against disasters, sediment issues for the downstream area, influence on property values, and compensation for those suffering damage from the removal and redevelopment of the community. This includes restoration of the dam road that connects the two sides of the river.

The difficulty in removing an infrastructure is that the structure has taken on an identity as a viable social component. Whether an infrastructure should be removed is a question that communities and government agencies will face in regard to the reconstruction of communities, fairness among those who will gain or lose monetarily, and the infrastructure's economic and environmental value.

21.3 Sustaining Infrastructure Value

One of the important considerations illustrated by the examples above is that the value of infrastructures varies over time. In other words, it is necessary to consider the flexibility of a structure to later modifications in response to the social needs of the future. Traditional engineering and economic approaches make implicit assumptions concerning an expected scenario and presume commitment to certain static functions and scopes of utilization. Therefore, in practice, various viable options, such as reinvesting and postponing, need to be incorporated in the planning. Moreover, infrastructures need to be maintained to sustain them as a valuable component of society (Fig. 21.6). The consideration of those options becomes particularly important in countries where the structures are aging. In addition, the issue of funding is a challenge for the future.

The other, far more significant insight gained during this study relates to the concept of technological politics, as shown in the first section. As seen in the Mt. Merapi case, an infrastructure has secondary effects on society. Social effects of an infrastructure become tangible only after the structure is implemented in society, and it is sometimes difficult to foresee these effects. However, if we pay attention to the process by which natural resources are transformed to artifacts via social decisions, the effects begin before the artifact is provided in society. It is important to realize the "power" of technology as a medium to serve not only physical functions but also functions within a social context (Fig. 21.7). Goods and services are outputs of decisions, but critical influences are sometimes predetermined by the use of certain technologies. Note that the development of such technology will be the condition for the next decision that shapes our society in certain directions, thus affecting the continuity of people's decisions.

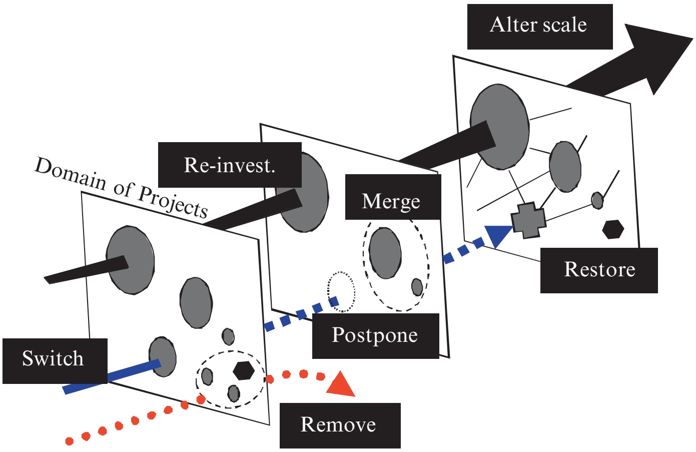


Fig. 21.6 Options for sustaining infrastructure

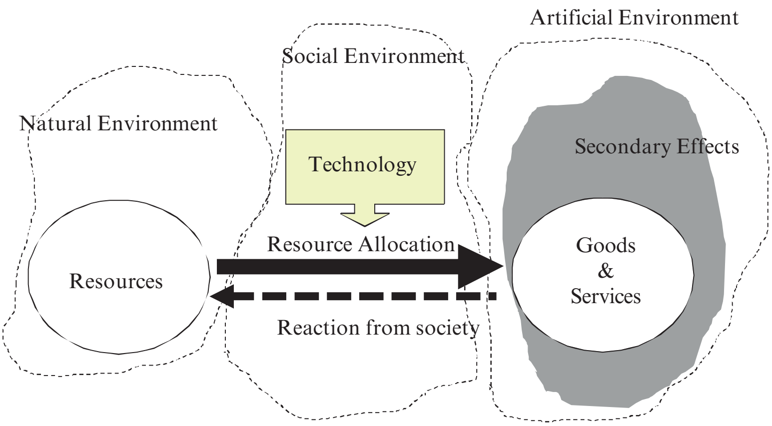


Fig. 21.7 Technology as a medium

21.4 Conclusions

This chapter discussed the social aspects of infrastructures within which their role relates to the development of social order. It began by drawing attention to the changing roles of specific world heritage sites, Matera and the Defense Line of Amsterdam, as they adapted to society over time. The roles of these structures should not be limited to their primary purposes associated with physical functions, such as living, transportation, and utilizing resources. Furthermore, the value of an infrastructure should be examined in accordance with how people used the structure. This is because the consequences sometimes have serious influences on peoples' choice, thus functioning as a means for a particular group of people to adjust, transform, and strengthen their interests and beliefs in public decision making.

The discussion has focused on the utilization phase of an infrastructure's life cycle rather than the planning, design, and construction phases. This view is different from that of traditional engineering or economics, which focus on the "making" of infrastructures. Although the primary purposes of implemented infrastructures are to serve people with physical functions, it is taken for granted that the utilization phase is most important when examining how infrastructures are used. In particular, infrastructures were classified into the following five categories: (1) used for different purposes; (2) expanded or reduced; (3) renewed or restored; (4) removed or being removed; and (5) abandoned. Some case studies were introduced to develop discussions concerning the social values and functions of infrastructures.

The discussion included the following observations and implications. The Mt. Merapi case study presented an example of people using the disaster protection dams differently than was intended, leading led to environmental damage. The example verified that prejustified technological logic is not always neutral because people interpret engineering criteria, such as shapes as well-operational requirements, to take advantage of the structure for their own purposes. This advantage-taking behavior was also demonstrated in the case of Bang Pakong Dam in Thailand. Successive remedies were carried out owing to the failure of an initial implemented structure. Such remedies included an adjustment of operational rules and new dam construction. The case demonstrated the aspect of an infrastructure by which particular groups of people utilize it as a means to embed their values into the society. This implies that such practices could be cyclical, thus strengthening the social order in a certain direction.

The other two cases, the CGC River Restoration and the Arase Dam removal, may lead to different perspectives. Those projects are not yet "finished" because unexpected additional consequences may be observed in the future. The renewal, restoration, or removal of infrastructures will be of more concern as the number of aged infrastructures increases in the future. Under the circumstances discussed here, economic viability and socioenvironmental issues will be of concern among stakeholders.

Although this was not addressed here, abandoned infrastructures should be given more attention with regard to completion of development. It is assumed that an infrastructure could sometimes be the source of decline as it is abandoned, thus representing a sunk cost. For example, the bankruptcy of the City of Yubari, which used to be a prosperous coal-mining region, gives rise to the question, "What is final development?"

This chapter tried to raise some of the new views with regard to the social value of infrastructures and developed interesting discussions. This viewpoint should be interesting to both natural and social scientists and should be incorporated into education, policy development, and even common knowledge, contributing to a sustainable society.

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