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Environmental Security

Renewable Energy in the Middle East

Enhancing Security through Regional Cooperation

Edited by
Michael Mason
Amit Mor

Springer

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Renewable Energy in the Middle East

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Series C: Environmental Security

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PART IV INSTITUTIONAL ASPECTS OF A REGIONAL AND GLOBAL ENERGY SYSTEM

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ABBREVIATIONS AND ACRONYMS

AMIS	African Mission in Sudan
AMISOL	Moroccan Association for Solar and Renewable Energy
ANNU	An-Najah National University
AUB	American University of Beirut
BCF	billion cubic feet
BCM	billion cubic metres
CDM	Clean Development Mechanism
CDR	Council for Development and Reconstruction (Lebanon)
CPI	consumer price index
CPV	concentrating photovoltaic
CSP	concentrating solar power
DESERTEC	Desert Technology Programme
DNA	Designated National Authority
DSWH	domestic solar water heaters
EC	European Commission
EDL	Électricité du Liban
EHI	Ein Harod Ihud (kibbutz)
EIB	European Investment Bank
ENERGAIA	International Renewable Energies Exhibition (Montpellier, December 2007)
ERC	Energy Research Centre
ESC	Energy Steering Committee (Lebanon)
ESCWA	United Nations Economic and Social Commission for Western Asia
EU	European Union
EWE	Energy, Water and Environment Community
GCC	Gulf Cooperation Council
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gases
g/L	grams/litre
GW	gigawatt
GWa	geothermal water
GWh	gigawatt-hour (1 million kilowatt-hour)

HDI	human development indicator
HFO	heavy fuel oil
HVDC	high voltage direct current
ICC	International Criminal Court
IDPs	internally displaced persons
IEC	Israel Electric Corporation
INDH	National Initiative for Human Development (Morocco)
IPCC	Intergovernmental Panel on Climate Change
IPP	Investment Planning Programme (Lebanon)
JBCO	Jordan Biogas Company
JD	Jordanian Dinar
JGTP	Jordan Gas Transmission Pipeline
JUST	Jordan University of Science and Technology
kJ	kilojoule
kV	kilovolt
kW	kilowatt
kWh	kilowatt hours
kWp	kilowatt peak
LCD	litres consumed per day
LCECP	Lebanese Centre for Energy Conservation Project
LPG	liquid petroleum gas
LSE	London School of Economics and Political Science
MAD	Moroccan Dirham
MD	membrane distillation
MED	multiple effect distillation
MEDITEP	Mediterranean Partnership for Sustainable Energy Development
MEMR	Ministry of Energy and Mineral Resources (Jordan)
MENA	Middle East and North Africa
MESS	multi-effect solar still
MEW	Ministry of Energy and Water (Lebanon)
MLP	multilevel perspective
Mm^3	million cubic metres
MNI	Ministry of National Infrastructures (Israel)
Mtoe	million tons of oil equivalent
MW	megawatt (1,000 kW)
MSF	Multiple Stage Flash Distillation
MSW	municipal solid waste
MV	megavolt
MWh	megawatt hours

NATO	North Atlantic Treaty Organization
NCSR	National Council for Scientific Research (Lebanon)
NERP	National Emergency and Reconstruction Programme (Lebanon)
NIS	New Israeli Shekel
O&M	operation and maintenance
OECD	Organisation for Economic Cooperation and Development
OMSW	organic municipal solid waste
ONE	Office National de l'Electricité (Morocco)
PA	Palestinian Authority
PCBS	Palestinian Central Bureau of Statistics
PEC	Palestinian Electricity Company
PSI	Palestine Standards Institute
PUA	Public Utilities Authority
PV	photovoltaic
RA	resource assessment
RE	renewable energy
RETs	renewable energy technologies
RO	reverse osmosis
RO-PV	reverse osmosis photovoltaic
SEFI	Sustainable Energy Finance Initiative
SELCO	Southern Electric Company (Palestine)
SNI	Samuel Neaman Institute
SPS	Science for Peace and Security
STEG	Société Tunisienne de l'Electricité et du Gaz (Tunisia)
SWH	solar water heater
TEMPUS	Trans-European mobility scheme for university students
TJ	terajoule (1 billion joules)
toe	tons of oil equivalent
Ttoe	thousand tons of oil equivalent
TREC	Trans-Mediterranean Renewable Energy Cooperation
TWh	terawatt hours
UN	United Nations
UNAMID	United Nations-African Union Mission in Darfur
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
VAC	volts alternating current
VDC	volts direct current
VLE	vapour liquid equilibrium

INTRODUCTION

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Abstract. Development of renewable energy resources in the Middle East and North Africa promises significant environmental and energy security gains. Regional scientific cooperation is necessary to identify such benefits and the modalities for realising them. A starting-point for any such work is to set out the security conceptions employed by state and non-state actors in the region, identifying sources of mutual understanding. Interpreting energy security in terms of human welfare and climate sustainability rather than (only) state access to energy resources increases the possibility of shared understanding on common security principles.

Keywords: NATO, Mediterranean Dialogue, Middle East, North Africa, renewable energy, environmental security, energy security, climate change.

1. Science for security and the NATO Mediterranean Dialogue

This volume arises out of, and develops, themes addressed at a NATO-funded Advanced Research Workshop – *Enhancing Security in the Middle East through Regional Collaboration on Renewable Energy* – that took place at the London School of Economics and Political Science (LSE), London, UK on January 16–18 2008. Co-convened by Dr. Michael Mason (LSE) and Dr. Amit Mor (CEO of Eco Energy Ltd.), the workshop examined the prospects for collaboration on renewable energy within the Middle East by bringing together scientific experts, economists and legal practitioners from the Middle East & North Africa (MENA) and Europe, as well as representatives from the NATO Environmental Security Panel and the World Bank.

Advanced Research Workshops are one of the key support mechanisms promoted by NATO's Science for Peace and Security (SPS) Programme, which fosters research collaboration between NATO countries and partner countries. A priority topic under the SPS Programme is environmental security, understood as environmental problems that can significantly affect security and/or socio-political stability. The unsustainable utilisation of fossil fuel energy resources is, in these terms, a leading source of environmental insecurity in the world. The initial premise for the LSE workshop was that the development of renewable energy resources in the Middle East promises significant gains – for energy security specifically, as well as regional state and environmental security more generally. Furthermore, it is an explicit aim of NATO Advanced Research Workshops that they contribute to shared problem-solving, and it was this ethos that informed the LSE meeting, highlighting for participants the need to identify potential modalities for regional cooperation on renewable energy.

While academically autonomous, the LSE workshop represented scientific cooperation under NATO's Mediterranean Dialogue, which seeks to contribute to regional security and stability with non-NATO countries in the Mediterranean. The workshop included participants from all but one (Mauritania) of the seven Mediterranean Dialogue partners – Algeria, Egypt, Israel, Jordan, Morocco and Tunisia. In addition, participants were invited from the Palestinian Territory and Lebanon, and their presentations are also included in this book. The geographical focus of the workshop was on the renewable energy capacity of the eastern Mediterranean countries (Israel, Jordan, Lebanon and Palestine), in line with the regional experience and expertise of the workshop convenors. Of course, this Mediterranean region also faces the greatest security challenges. However, the North African (Maghreb) countries have made progress in key areas of renewable energy expertise; e.g. Tunisian experiments with solar energy applied to water desalination, Moroccan development of wind energy and experience with renewable energy finance. It was thus in the spirit of the Mediterranean Dialogue that the Advanced Research Workshop facilitated mutual learning on renewable energy policies and practices between the North African participants and their eastern Mediterranean neighbours.

These scientific exchanges were interdisciplinary and independent of any official state positions on energy and security policy. Given the divergent backgrounds and expertise of the workshop attendees, it was encouraging that significant consensus was reached in workshop deliberations regarding renewable energy capacity-building in the southern and eastern Mediterranean states. It was agreed that there is a substantial untapped potential for the utilization of renewable energies in the region – notably solar power. This potential is not being realised, it was noted, due above all to regional insecurity, under-investment in clean energy research & technologies, and low political awareness of the benefits of renewable energy. The Conclusion to this volume sets out the ideas and proposals for regional collaboration on renewable energy. In order to clarify the thematic security context for these conclusions and the substantive chapters that inform them, we will now define the key concepts of environmental and energy security, followed by a brief summary of the structure of the book.

2. Environmental and energy security

As may be expected, there are diverse security perceptions and policies in the southern and eastern Mediterranean states. The long-running Israeli–Palestinian conflict continues to frame in 'hard security' terms the understandings of those countries most affected; that is, security is seen through a traditional state-centred lens as military protection from external threats (whether Arab or Israeli). This geopolitical interpretation is most evident in Israeli and Palestinian security commitments, and also shapes at least in part the perceptions of the Arab Maghreb and Mashreq (eastern Mediterranean) states. There are of course differences, from the more oppositional stance of Syria to the more cooperative moves of Egypt, Jordan and the Maghreb states. Nevertheless, the central geopolitical cleavage shaping regional 'securitisation' remains an Israeli state estranged from its regional Arab neighbours, whose own uneasy solidarity is founded largely on their shared support for Palestinian self-determination. These Arab states often must also contend with non-state actors – notably Islamist organisations – promoting more radical views on the Israeli–Palestinian situation.

At the same time, regional conceptualisations of security have become increasingly open to the idea of new security challenges, including environmental ones (Brauch et al. 2003). This has partly been prompted by external actors, such as the Environmental Security Initiative in the Middle East – a regional forum launched in 1997 under the sponsorship of the US Department of Energy and Environmental Protection Agency. It is not surprising, then, that some of this discourse reproduces influential North American notions of environmental security, whereby resource scarcity and environmental degradation are causally linked to political friction and conflict (Homer-Dixon 1999). For the Middle East, this has led to forecasts of potential 'water wars' as rising water demand and unsustainable extraction levels exacerbate, for example, Israeli–Syrian (Golan Heights) and Israeli–Palestinian (West Bank) tensions (e.g. Bitar 2005). Such claims are not new and, despite attracting heavy criticism from scholars (Zeitoun 2008), they routinely influence political and media representations of security issues in the Middle East.

Of course, the MENA region is the world's largest reservoir of fossil fuels and it is the chronic dependence of Western states – particularly the US – on oil that has made the stability of this area an enduring preoccupation for NATO countries. The 1973 Arab oil embargo was arguably the historical moment that highlighted the strategic importance of Persian Gulf oil to the world economy. Current global security anxieties over the impending onset of 'peak oil', supported by the forecast of the International Energy Agency that world oil demand will outstrip supply by 2012 (International Energy Agency 2008), are centred on the concerns of many countries that access to reliable and affordable energy supplies will become increasingly difficult. Yet these supplies are seen as vital to ensuring economic growth and domestic prosperity, and thus of 'national security' significance. This state-centred notion of energy security has been invoked to support military moves to protect and maintain strategic non-renewable energy sources (Russell and Moran 2008). As oil demand increases from China, India and other developing countries (including the MENA states), while key oil production decisions shift from private energy corporations to non-Western state oil companies, the prospects for geopolitical tension and conflict are argued to be substantial (Peters 2004; Klare 2006).

Recent comparative research has shown that the geopolitical perspective on energy security fails to capture the extent to which oil causes or exacerbates conflict. Rather than simply a manifestation of the struggle for control of fossil fuels between powerful states, 'oil wars' are more plausibly the result of a pervasive rent-seeking behaviour at different scales; that is 'intensive political competition aimed at gaining short-term access to oil revenues, as opposed to political competition over what policies might be in the long-term public interest' (Kaldor et al. 2007: 26). For states heavily dependent on oil production, the corrosive social and political effects of this rent-seeking have been observed not just in the Arab Middle East but also in Africa (Anglola, Nigeria), Central Asia (Nagorno-Karabakh) and South-east Asia (Indonesia, Malaysia) (Ross 2001; Kaldor et al. 2007). These consequences include the inhibition of civil society and democratic values, the militarisation of the state, and the heavy use of patronage to allocate resources. In MENA, these tendencies are all evident in the oil-rich Persian Gulf states, with the added security risk, according to Western governments, of some oil rents being diverted into transnational criminal and terrorist networks.

To be sure, the geographical focus of this volume is on MENA countries which are not Persian Gulf states. In the first place, aside from Algeria, Libya and Egypt, the Arab Mediterranean states and Israel have negligible fossil fuel endowments. In contrast to the oil-rich Persian Gulf states, these countries are net importers of fossil fuels, rendering them particularly vulnerable to volatile oil prices and potential supply disruptions. It is this shared energy insecurity that provides an incentive for regional collaboration on renewable energy. Secondly, while oil-related rent-seeking is not absent in the Mediterranean

Arab states (e.g. Jordan and Egypt earn large locational rents from their control of key transit routes for energy supplies [Ross 2001: 329]), their governmental structures are not reliant on substantial rents from a single natural resource. Indeed, their greater fiscal reliance on taxation creates a structural incentive to be seen to be responsive to the everyday energy needs of their populations. This political accountability is reinforced by constitutional moves, however slow and partial, towards greater democracy and more secure civil and political rights (e.g. Algeria, Egypt, Jordan, Morocco).

This increased societal openness has created the possibility for alternative environmental and energy security framings. These concepts have been promoted by regional environmental groups (e.g. Arab Network for Environment and Development, Friends of the Earth Middle East, Green Line Association) and epistemic (expert) communities (e.g. International Development Research Centre [Cairo], Steering Committee for Regional Collaboration on Energy Efficiency and Renewable Energy Technologies: see Chapter 10). Their common focus, which mirrors the concerns of development and humanitarian agencies in the region, is on human welfare rather than state-centred 'national security'. For the Mediterranean region, this has recast environmental security to mean the protection of people from environmental hazards (Liotta 2003). More specifically, from this perspective there is a clear linkage between energy insecurity and human development: the lack of reliable and affordable energy is seen as a substantial barrier to the achievement of Millennium Development Goals in the southern and eastern Mediterranean states. Yet, this conceptualisation highlights at the same time the positive role of renewable energy resources in contributing to vital water production (e.g. solar desalination) and environmental protection (e.g. clean production) in the region. It also reinforces the message at the global level that international and civil society cooperation is essential to achieving common energy and environmental security (e.g. Müller-Kraenner 2008).

3. Energy security and climate policy

The major economic powers in the world have acknowledged that energy security decisions cannot be divorced from international obligations to address climate change mitigation and adaptation. At the Hokkaido Toyako G8 Summit in July 2008, the leaders of 16 states and the European Union issued a Declaration on Energy Security and Climate Change, which stressed the role of alternative energy technologies and implementation of energy conservation policies in meeting the dual global challenges of human-induced climate change and energy insecurity. A greater exploitation of renewable energy sources was equated with effective climate change mitigation (through a reduction in greenhouse gas emissions) and also improved energy security, as countries reduced their dependence on fossil fuel resources.

However, the relationship between global energy use and climate change is complex and contested. The Intergovernmental Panel on Climate Change (IPCC), which predicts that fossil fuels will remain dominant in the global energy mix to 2030 and beyond, has still attracted criticism for optimistic forecasts regarding the future uptake of energy efficiency measures and the growing energy intensity of the world economy (Pielke et al. 2008). In a recent study of energy security and climate policy in five European countries, the International Energy Agency noted worsening trends for both CO_2 emissions and (national) energy security by 2030 (International Energy Agency 2007). It is important to note that some national moves to enhance energy security may have no climate change benefits (e.g. contingency planning to cope with physical disruptions to supply) or even lead to more carbon emissions (e.g. the extraction of unconventional oil sources, such as the development of tar sands in Canada and Russia).

Furthermore, climate change is also perceived as a security risk independent of its interactions with energy governance. According to the emissions scenario employed, IPCC projections of global average surface warming this century range from 1.8°C to 4.0°C, and even at the lower end, this implies environmental changes with far-reaching social and economic consequences (IPCC 2007). These destabilising effects have security consequences, which have been recognised as such by governments – the UK Government being one of the first: in May 2007, Margaret Beckett, then UK Foreign Secretary, identified climate security as a foreign policy priority for the Government, citing approvingly a US report that climate change acts as a 'threat multiplier' in unstable regions in the world, intensifying problems such as state failure and social disorder (CNA 2007). Influential think tanks have shared this diagnosis. Without global cooperation, climate change is predicted to trigger national and international distributional conflicts, especially over water and food availability, the impacts of natural disasters, and environmentally-induced migration (Campbell et al. 2007; WBGU 2007).

For the Mediterranean Middle East and North Africa, regional climate predictions have to contend with a lack of scientific observations on atmospheric conditions and greenhouse gas emissions. There are also unresolved issues regarding the calibration of Atmosphere-Ocean General Circulation Models and Regional Climate Models in order to simulate conditions consistent with environmental processes of particular importance to the Mediterranean region, such as the incorporation of dust into the atmosphere and multiple sources of pollution (Mellouki and Ravishankara 2007). However, there are enough historic and current observations from the region to give credibility to IPCC projections. In its Fourth Assessment Report the IPCC predicts that, for the southern and eastern Mediterranean, warming over the twenty-first century will be larger than global annual mean warming – between 2.2–5.1°C according to an optimistic emissions scenario (A1B), in which rapid economic growth and technological change have reduced reliance on fossil-intensive energy sources. Annual precipitation is deemed likely to decrease in much of Mediterranean Africa and very likely to decrease in the eastern Mediterranean, with an increased risk of summer drought in the latter (Christensen et al. 2007).

There is increasing speculation on the potential security implications of these physical changes. According to the IPCC Fourth Assessment Report, even without climate change, many northern African countries will exceed the limits of their economically usable, land-based water resources before 2025 (Boko et al. 2007: 435). Climate change is predicted to aggravate this water stress and also heighten food insecurity in a region where high food prices have already caused riots (e.g. in Egypt during March 2008). Similarly, freshwater resources in the Middle East, already under significant pressure from rapid demographic growth and economic development, are predicted to become scarcer as regional climate change causes decreases in participation. Regional asymmetries and dependencies in water availability may exacerbate political tensions between countries. As noted above, though, water scarcity is not a robust predictor of conflict. For example, 'virtual water' (water imported in the form of food) can ease local water or food shortages, and therefore serves as one means by which countries in the region can adapt to climate change (El-Fadel and Maroun 2008).

Within the Middle East, the security implications of climate change have been registered in terms of strategic national interests, particularly in Israel, where a 'geopolitical global warming storm' has been forecast: Israel is represented as arguably the only country with the capacity to adapt effectively to the regional effects of climate change, but at the same time facing the prospects of renewed hostility from neighbouring countries potentially overwhelmed by the social and political costs of climate-induced stresses (Interdisciplinary Center for Technology Analysis and Forecasting 2007). In contrast to this geopolitical framing, regional environmentalist networks have highlighted an alternative, less pessimistic scenario of heightened cooperation over regional water and energy management policies (Friends of the Earth Middle East 2007). Here we can discern a shift in focus to the 'climate vulnerability' of individuals and communities, which finds intellectual support in notions of human security and environmental peacekeeping (Dalby 2008). It means a policy interest in the adaptive capacity of the most vulnerable – an understanding promoted by various aid delivery NGOs (e.g. CAFOD, Oxfam International) and development agencies operating in the region (e.g. French Development Agency, UNDP).

4. Summary of chapters

The chapters in this volume are revised versions of papers delivered at the Advanced Research Workshop, which have been revised on the basis of comments received at the workshop (discussants and other participants) and also sent out to anonymous academic reviewers. Given the interdisciplinary nature of the workshop, this meant that presenters were often questioned from other disciplinary perspectives, and all the authors exhibited the necessary patience and openness to ensure the effectiveness of this peer review process. It should be stressed that the chapters are independent assessments of the respective authors and should not be construed as representative in any official way of the policy positions of their respective countries.

Section I (Chapter 1) outlines the regional security situation as it currently stands in the Middle East (in its wider geographical sense). General (rtd) Mohammad K. Shiyyab, a leading security analyst from Jordan, identifies the key geopolitical challenges – from the Israeli–Palestinian conflict to nuclear proliferation in Iran – and highlights the necessary role for governance reform and economic development in promoting regional security cooperation. Alongside his candid recognition of the failure of Arab regimes to make political progress towards democratisation, Shiyyab also calls for the United States and Europe to be more consistent in their own democracy promotion efforts in the region.

In line with the geographical focus of the Advanced Research Workshop on the Arab Mashreq countries and Israel, Section II of the book features overviews of national energy policies and practices in the eastern Mediterranean. Israeli energy needs and strategies are discussed by Mor, Seroussi and Ainspan in Chapter 2: their in-depth knowledge of energy demand and supply trends informs realistic recommendations for developing renewable energy in Israel. In Chapter 3, Mason, Al-Muhtaseb and Al-Widyan identify significant energy supply challenges in Jordan, which are opening policy space for alternative energy sources. For Lebanon, as reported by Fadi Comair (Chapter 4), extreme dependence on fossil fuels for its energy needs has yet to induce any significant political commitment to renewable energy, such that there are major technical capacity-building challenges. Not surprisingly, the Palestinian energy situation is even more precarious. What Imad Ibrik calls an ‘energy tragedy’ in Chapter 5 is related to almost total dependence on outside energy sources, the absence of an autonomous energy infrastructure, and the physical fragmentation of Palestinian territory. It is notable that, despite variations in national circumstances, each of the energy use profiles in Section II agrees that there is a substantial case for renewable energy development in the eastern Mediterranean, particularly solar technologies.

Section III of the book then considers options for greening regional energy use in the southern and eastern Mediterranean. The availability of sufficient public and private financing is essential to developing renewable energy in the region. In Chapter 6, Hynd Bouhia summarises recent efforts of the Moroccan government to improve incentives for renewable energy investment. Drawing on first-hand experience of fiscal planning in Morocco, her proposed architecture for renewable energy investment funds is plausibly directed at both national and regional actors. Moving in Chapter 7 to environmental planning incentives, Ofira Ayalon addresses the linkages between waste management, clean energy and carbon emissions. While she draws mainly on Israeli research, she identifies a number of 'double dividends' potentially applicable across the region; for example, the role of photovoltaic solar systems in providing remote villages with secure and clean energy. Bourouni and Chaibi investigate further this rural potential for solar energy in Chapter 8. They discuss the results and policy implications of a Tunisian demonstration project, which investigates the scope for solar power to produce desalinated water. Given protracted water scarcity issues in the southern and eastern Mediterranean, this is arguably one of the most important benefits that can be provided by decentralised solar energy units. Of course, other renewable energy sources are also of interest to the region. Zejli and Bennouna review in Chapter 9 the role of wind energy in Morocco, offering wider conclusions on the portfolio of policy instruments deemed conducive to fostering the effective uptake of wind power technologies.

Section IV considers the institutional aspects of energy governance, both in the MENA region and also globally (in terms of energy-water linkages). In Chapter 10 Al-Widyan and Al-Muhtaseb sum up first the physical potential of renewable energy usage in the region, and then review a selection of actual and proposed energy projects that involve regional cooperation. They note that the issue of regional collaboration for renewable energy has already been discussed by academics – most recently in 2004–2005 at USAID-funded workshops which took place at the American University of Beirut (AUB) – but without any significant influence on the energy agenda of MENA countries. The NATO-funded Advanced Research Workshop at LSE in January 2008 included some of the participants from this earlier initiative, and participants endorsed the need to consolidate the epistemic community established by the AUB workshops, as well as reaffirm the institutional recommendations for regional energy collaboration set out by Al-Widyan and Al-Muhtaseb. The conditions for such cooperation are now more favourable – a window of opportunity has been created by high oil prices, new energy infrastructure investment opportunities, the interest of international development banks in renewable energy, and the UN climate change regime (notably the Clean Development Mechanism and international negotiations over the post-Kyoto commitments). Tony Allan addresses in Chapter 11 the wider context of energy governance, focusing on global energy-water resource challenges. This suggestive analysis pinpoints three 'resource weddings' – instances of integrated energy-water use generating mutually positive social and economic benefits – but also cautions about the possibility of two 'environmental resource funerals' arising from the consumptive demands of rich countries.

The Conclusion to this volume considers the immediate prospects for a renewable energy transition for the MENA region, discussing both the issues of regional cooperation capacity and the potential for clear energy investment. There is significant potential for an increase in the uptake of renewable energy technologies in the region, but it is clear that this requires particular political and economic support structures. External assistance is necessary but the interventions of foreign states, donor organisations and international NGOs need to be far more coordinated and strategic than in the past, sensitive always to local human development needs. Current discussion of a Mediterranean Solar Plan, endorsed at the Paris Summit in July 2008 that launched the Union for the Mediterranean, is generating expectation that there is a realistic vision for regional energy security that also simultaneously addresses European concerns over climate sustainability and MENA economic development aspirations. This initiative, as examined in the Conclusion, may cultivate a shared understanding of common security that, in tandem with a necessary settlement to the Palestinian issue, could help to erode long-standing suspicions of regional cooperation – both amongst Arab states and between Arab states and Israel.

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ENHANCING SECURITY IN THE MIDDLE EAST: THE CHALLENGES OF REGIONAL COOPERATION

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Abstract: The Middle East continues to face a number of serious security challenges – the Israeli Palestinian conflict, Syria, the Iraqi situation, nuclear proliferation in Iran, the conflict in Afghanistan, political instability in Lebanon, related events in Darfur, terrorism, and radical Islamists. Past US and European efforts to promote regime change have undermined the credibility of Western governments in the region. However, political and governance reforms in the direction of democracy, with the respectful support of Western governments, are a prerequisite for a stable and peaceful Middle East.

Keywords: Middle East security, Israel–Palestinian conflict, Syria, Iraq, Iran, Afghanistan, Lebanon, Sudan, terrorism, Islam, good governance, regional cooperation

1. Introduction

In the post-Cold War era, the predicted and hoped for degree of global security and stability has not been achieved. The only apparent certainty is the fact of uncertainty and its direction is very difficult to forecast.

I come from a region – the Middle East – that is amongst the least safe in the world, and marked by more insecurity than most. Since the late 1980s, commentators have noted political and economic trends favouring regionalism, including the realignment of security alliance systems and the emergence of new economic trading blocs (Rostow 1990; Fawcett and Hurrell 1995). If the Middle East has not yet emerged as a coherent economic region, its regional geopolitical identity of contestation and conflict is certainly impacting on the rest of the world. Spillovers are one characteristic of this new regionalism; the negative spillovers of geopolitical instability in the Middle East have created a variety of new challenges and risks. These include: a new conventional arms race; the proliferation of nuclear, biological, and chemical weapons, and

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their delivery systems; substantial economic disparities leading to poverty, unemployment and corruption; high foreign debt; involuntary population movements, including new streams of refugees; high rates of illiteracy, the unsustainability of energy and water resources; ethnic conflicts, radical Islamist parties and movements; ethnic and religious rivalries; the resurgence of nationalism; and state and non-state-sponsored terrorism.

Despite this long list of challenges, however, we must continue onward in pursuit of peace and stability throughout the region. Below I will discuss some of these key issues, and I will also provide some insight on the potential for future cooperation and eventual resolution of these issues.

2. The Israeli–Palestinian conflict

Politically, our most important concern in the Middle East is to build upon the peace that Egypt and Jordan have made with Israel. More than 17 years have already elapsed since the Madrid Conference. What has been achieved so far is still a fragile prospect and the Arab–Israeli negotiation process is not entirely out of the woods of reversibility. Without concluding an Israeli–Palestinian peace, "the peace process and peace-building operations will be in relative jeopardy" (Hassan Bin Talal 1996) and the only option left would be more violence.

The chances for any progress emerging from the Annapolis conference and recent visits by Bush and Condoleezza Rice seem at best limited. Middle East peace treaties in the past were forged by strong statesmen – Menachem Begin of Israel and Anwar Sadat of Egypt, Israel's Yitzhak Rabin and Jordan's King Hussein. But Mr. Olmert and Mr. Abbas are two of the region's weakest leaders, unpopular among their own people and discredited by charges of corruption. Additionally, President Bush's refusal to engage in direct mediation in the manner of Jimmy Carter and Bill Clinton, and his insistence that comprehensive talks be broken down into bilateral and multilateral tracks, further diminishes any hope for a breakthrough.

As it stands, the Israelis will only be negotiating with one part of the Palestinian political system. Ignoring Hamas completely is irresponsible; expecting Hamas members to merely go along with a peace process from which they have been excluded, but which will affect them as Palestinians, is simply unrealistic. This dramatically increases the incentive for Hamas to thwart the process, should something positive appear to be resulting from Annapolis and its aftermath.

For some analysts, ignoring Hamas might appear to be sound policy; in theory, it encourages moderates and isolates extremists. However, it might create numerous pitfalls for the peace initiative. First and foremost, Hamas is being completely excluded from the process by Israel and the United States. Although their popularity has diminished since the 2006 elections, which saw them win a majority, Hamas still represents a substantial part of the Palestinian population and currently governs over 1.5 million Palestinians in the Gaza Strip.

We simply cannot neglect the risks of the present situation in Palestine and its spillover effects. In this respect, each party must take each other's paranoia more seriously. Confidence and security building measures are essential to change the state of mind of all parties. In the wake of the recent Israeli military assault on Gaza, President Obama has an opportunity to exercise US independence and leadership in the region rather than the failed approaches of the past. Achieving positive developments and progress during Israeli–Palestinian negotiations is highly likely to facilitate and expedite peace with Syria and unlock peace with Lebanon. This would certainly have a positive impact on regional stability as a whole.

3. Syria: The way ahead

Future cooperative initiatives from external parties need to recognize the shortcomings of previous efforts that have undermined the regional credibility of Western tactics. The US has to stop all activities that were part of the former strategy of regime change, issue a formal statement that a stable Syria is in the best interests of the region, and focus more on diplomatic foreign policy tactics to affect the desired change.

To enact policies with the objective of further isolating Syria will most probably result in Syria strengthening its ties with Iran and looking east for future economic and political alliances.

In this regard, pursuing the following suggestions would be highly desirable: restart EU–Syrian negotiations on the Association Agreement; work with Turkey to determine what role it can play in furthering economic engagement, particularly given Syrian suspicions of the United States; expand support for multilateral people-to-people initiatives that enable Syrians to travel to and study in democratic countries, including those outside Europe and the United States; offer technical assistance to both the private and public sectors on methods to combat corruption with the objective of helping Syria move to a transparent fiscal governance system; encourage the private sector, such as international consulting firms, to offer education programs to Syria's private sector and citizens on topics such as business management and intellectual property rights protection; and assist Syria in its bid to join the World Trade Organization.

4. The Iraqi situation

In Iraq, and even with the increased of numbers of soldiers provided under the US 'surge' strategy of 2007, it seems that the military solution has enjoyed limited success. However, the problem remains: a weak Iraqi government, a weak army and the lack of American public support to the war. The Iraqi government remains a government in name only and its security forces remain ineffective against militia forces. In sum, the military solution might not be the best option and search for a more viable solution is badly needed.

In this context, Dr. Hubertus Hoffmann, President and Founder of the World Security Network, has commented: "The Bush Administration has forgotten the main lessons of great strategists like Carl von Clausewitz, who wrote in his famous work *On War* in 1832 that war is a continuation of politics by other means" (Hoffmann 2007a). This approach has been turned upside down by an American 'power ideology' with a pure security focus supporting military measures without addressing the global and local political forces underlying major sources of insecurity. Ultimately, war in Afghanistan and Iraq and US-led anti-terror activities have become geopolitical aims in themselves, intellectually separated from a historical-political analysis. In this anti-Clausewitzian style lies the seed of U.S. problems in these important wars.

Recent opinion polls show that ending the Iraq war is one of the main demands of American voters from their choice of presidential candidates. However, the declaration of Mr. Bush – on his January 2008 visit to Kuwait – that the presence of US troops in Iraq was not a short-range venture, signalled that the US military presence in Iraq will continue during the next US presidency and may well extend more than a decade. This led some political analysts to believe that the US is pursuing aims that are much more bigger than peace in Iraq.

The US is keen on making Iraq its main military base in the Middle East. Controlling strategic oil resources of the Middle East region, supporting Israel, facilitating weapons exports to the region, and shaping the access of its European and Asian rivals to regional energy resources all belong to the US agenda for prolonging its presence in Iraq.

It is clear that Iraq needs more support to sustain its peace and reconciliation process. All Iraqi parties must be included in the process, which should focus on the core issues of federalism, the constitution, power sharing, the distribution of oil wealth, incorporation of ex-Ba'athists (a measure to allow former officials from the Ba'ath party to apply for goverment jobs came belatedly after much US pressure), militia disarmament, and the status of Kirkuk.

A greater role for the United Nations (UN) in Iraq appears inevitable even though chances for success are quite low. The UN is uniquely situated to broker a political compromise in Iraq because "it is the only body that approximates neutrality and can claim all the relevant state actors within its membership. Only the UN can offer itself as a neutral convening ground for the contending factions and the neighbors, with their conflicting interests" (Traub 2007). The UN should attempt to broker a political settlement among the Iraqi parties, though only if it gains the compliance of key actors.

The United States must not only explicitly back the process, but press its own allies in Iraq – above all, the Kurds – to make meaningful concessions. Harder still, the US must accept that decisions about troop deployments and other fundamental concerns could be shaped by the domestic and regional negotiations over Iraq. The negotiation process must incorporate all the regional players who have leverage over the various Iraqi factions.

5. Iran and nuclear proliferation

Iran is just one of a number of countries in which huge increases in energy demand is anticipated. The countries of the Gulf Cooperation Council, Jordan, Turkey, Egypt and others in the region, have expressed an interest in developing nuclear technology to meet their future energy demands. Between the need for energy security and the fear of having nuclear capable neighbours, the stage is set for the rapid proliferation of nuclear facilities. The safety and security of such facilities is of vital importance in the future.

The year 2007 was packed with dreadful news regarding US–Iran relations; it ended with a glimpse of hope with the release of the US National Intelligence Estimate (NIE) report on 3 December 2007. The NIE "judged with high confidence that in fall 2003, Tehran halted its nuclear weapons program." Before that news was public, a U.S. or Israeli military strike against Iran's uranium enrichment facilities was considered a possibility. An attack on Iran would have dangerous consequences for our already fragile region. Such an attack may bring about change, but who guarantees that it will be the kind of change that is needed for stability in the region?

The NIE report revealed that Iran does not have an active nuclear weapons programme and eased international pressure for sanctions. Furthermore, it has invigorated the Islamic Republic's hard-liners. This comes as the Arab World has been trying to counter Iranian President Mahmoud Ahmadinejad's rhetoric and his government's influence over the presidential turmoil in Lebanon, the politics in Syria and the Israeli–Palestinian peace process. Within 2 weeks following the publication of the NIE report, China signed a major contract on energy development and supply with Iran, and Russia quickly dispatched two shipments of nuclear fuel for the Bushehr nuclear reactor.

In addition, Ahmadinejad became the first Iranian president to attend a summit of the Gulf Cooperation Council. The meeting in Doha, Qatar, was hailed by many as a symbolic milestone to defuse decades of tension between Shiite-dominated Iran and other oil-producing, mostly Sunni nations of the region. The Iranian leader, however, said little at the meeting to calm nerves about his country's regional geopolitical ambitions (Nasr and Takeyh 2007).

Suspicion that Iran seeks to dominate the Gulf region has prompted some Middle Eastern states — including Saudi Arabia, which the US regards as the leading Arab voice, to increase military spending. According to Christian Koch, Research Director for International Studies at the Gulf Research Center in Dubai, United Arab Emirates:

> There's no trust on the Arab side about Iran's intentions. There are concerns of Iran's nuclear program for military purposes. There are concerns about Iran' influence in Iraq, over the unsettled political situation in Lebanon and over the dispute regarding three Gulf islands in Iran's control that are claimed by the United Arab Emirates. (Fleishman 2007)

The March 2008 Iranian Parliamentary elections, in which conservative allies of President Ahmadinejad, seem to have given him momentum going into the presidential elections in 2009. However, conservative critics unhappy with his media grandstanding also gained ground, with reformists making gains in the major cities on the back of growing unemployment. Popular discontent with his administration has continued to grow. In January 2008, former president Mohammad Khatami publicly criticised Ahmadinejad at Tehran University, where students protested against the current president in September 2007.

Mr. Bush took a hard line on Iran over its nuclear programme, stating forcefully that "Iran remains a threat to world peace and all options are on the table" to guard against military provocations like Iranian threats to American ships in the Straight of Hormoz (Myers 2008). Regime change in Iran has been an open aim of the US administration. Late in 2007 the US Congress agreed a request from the President to fund a major escalation of covert activities in Iran, including support of minority groups (e.g. Ahwazi Arabs) and dissident organisations (Hersh 2008). Some observers, however, argue that engaging Iran politically would be a better approach, which is in line with European diplomatic intentions and President Obama's commitment to direct negotiations with Iran.

6. U.S.-led invasion of Afghanistan

In Afghanistan, the stated purpose of the US-led invasion was to capture Osama bin Laden, destroy al-Qaeda, and remove the Taliban, a regime which had provided support and safe harbor to al-Qaeda. 2008, though, was the deadliest since the beginning of the invasion in 2001. More than 6,500 people were killed in insurgency-related violence, according to an Associated Press tally of figures from Western and Afghan officials (Associated Press, December 8, 2008).

The initial attack successfully removed the Taliban from power; however, there has been an ongoing resurgence of Taliban forces (Kaplan and Bruno 2008). With respect to the goal of restricting al-Qaeda's movement, the war has been even less successful. Since 2006, Afghanistan has seen threats to its stability from increased Taliban-led insurgent activity, growing illegal drug production, and a fragile government with limited control outside of Kabul.

Due to these same issues, the UN Security Council warned in November 2006 that Afghanistan may become a failed state. In the same year, Afghanistan was rated 10th on the failed states index, up from 11th in 2005. Furthermore, from 2005 to 2006 the number of suicide attacks, direct fire attacks, and attacks using improvised explosive devices all increased. Declassified intelligence documents show that Al Qaeda, Taliban, Haqqani Network and Hezb-i-Islami sanctuaries increased fourfold in Afghanistan over this period (Rothstein 2006). The campaign in Afghanistan successfully unseated the Taliban from power, but has been significantly less successful at achieving the primary policy goal of ensuring that Al-Qaeda can no longer operate in Afghanistan. The Taliban is becoming more popular due to many casualties among civilians and more recruits, particularly from Pakistani extremists on the southern borders of Afghanistan (UN News Centre 2006). Not surprisingly, most of the suicide bombers come from this border region.

The crux of the problem between the West and Afghanistan is characterised by the inability of the former to follow through on its previous good intentions and promises. British Prime Minister Gordon Brown, on a visit to Afghanistan in November 2007, made more pledges of increased aid and a programme of re-construction. The Afghans need security and decent infrastructure replete with roads, hospitals and schools; they also need substantial support in revitalising their moribund economy and some hope of light at the end of the tunnel, however long that tunnel may be (Lancaster 2008).

7. The Lebanese crisis

In Lebanon, each community, group and individual has its own agenda, objectives and ties within and outside the Arab World. Lebanese problems ceased to be only theirs decades ago. Since Syria was given the green light to take over the country, Lebanon's problems became regional and international.

State institutions in Lebanon are virtually paralysed: the government barely governs; the economic crisis is deepening; mediation efforts have failed (including the latest initiative put forward by the Arab League); political murders continue; and militias, anticipating possible renewed conflict, are re-arming. Still, fearful of the consequences of their own actions, leaders of virtually every shade have taken a welcome step back from civil war.

At almost every social level, Shiite support for Hizbollah has solidified, which is a result of both the movement's longstanding efforts to consolidate its hold over the community and a highly polarised post-war environment since the Israeli attacks in summer 2006. Further, the movement has demonstrated its mobilisation capacity and enjoys support from an important segment of the Christian community (International Crisis Group Report 2007a).

Meanwhile, Sunnis and many Christians remain alarmed at Hizbollah's strength and ability to unilaterally trigger a devastating confrontation, both domestically and in terms of the tense relationship with Israel. Both groups increasingly see Hizbollah not as a national movement, but rather as a Shiite movement aimed at advancing an Iranian or Syrian agenda. In short, while the movement sought to exploit the 2006 conflict for domestic political gains, the street battles quickly morphed into confessional ones, forcing Hizbollah into a sectarian straitjacket and threatening to distract it from its primary political objectives.

Hizbollah faces other dilemmas. Deployment of the army and of a reinforced United Nations Interim Force in Lebanon (UNIFIL) at the Israeli border has significantly reduced its military margin of manoeuvre, although both the Lebanese Government and UNIFIL have refused to disarm Hizbollah. The movement's Shiite social base also is exhausted and war-weary, a result of Israel's intensive campaign. Sectarian tensions restrict the Shiites' capacity to take refuge among other communities in the event of renewed confrontation with Israel. Hizbollah has thus been forced into a defensive mode, prepared for conflict but far from eager for such confrontation.

Lebanon's political system – based on power sharing between sectarian factions – inevitably encourages cyclic crises, governmental deadlock, unaccountability and sectarianism. More importantly, the country's future is closely tied to the regional confrontation that plunged it into armed conflict with Israel, paralysed its politics and brought it to the brink of renewed civil war. There can be no sustainable solution for Lebanon without a solution that addresses those issues as well – beginning with relations between the US, Israel, Syria, and Iran.

The US, France, Syria, Saudi Arabia and Iran should seek a way out of the Lebanese political crisis by negotiating, or encouraging negotiation of a package deal. Such a deal should include the adoption of a ministerial declaration that meets all sides' core interests, the acceptance of the principle of resistance as a transitional phase leading to the implementation of a proper national defence strategy, the reintroduction of diplomacy as a method to resolve the question of the disputed Shebaa Farms area, and support for the international tribunal dealing with the assassination of Rafik Hariri in 2005.

Syria needs to address Lebanese concerns by making clear its willingness to normalise relations. This must be done by exchanging embassies, demarcating the boundary between the two countries, and avoiding direct political or military interference in Lebanese affairs. On the other hand, Israel should agree to turn the Shebaa Farms over to UN custody as a temporary measure and avoid intrusions into Lebanese airspace and other provocative acts (International Crisis Group Report 2007a).

8. Sudan and the situation in Darfur

Regarding Sudan, we need to apply effective pressure on all sides to abandon attempts to achieve a military victory. We also must support the African Union–United Nations mediation as the sole international forum for pursuing a peaceful Darfur settlement and develop consensus for a political strategy. Such a strategy must include monitoring of violations and the application of punitive measures against those responsible (International Crisis Group Report 2007b). There is a need to bring in all constituencies for continued discussions on core issues such as land tenure, grazing rights, the Native Administration and cessation of hostilities. The aim is to identify individuals to represent the interests of those constituencies at these discussions.

In addition, a declaration should be made to respect an immediate cessation of hostilities and cease arms distributions to Internally Displaced Persons (IDPs). Full cooperation and protection to humanitarian operations in their respective areas – particularly from the actions of the Sudan People's Liberation Movement (SPLM) – is vital to create a common platform among the disparate domestic movements (Thomas-Jensen and Ismail 2007).

The Governments of Chad, Libya, Egypt and Eritrea should facilitate and support peacemaking efforts. They must ensure that the African Mission in Sudan (AMIS) is reinforced as quickly as possible via light and heavy support packages, and prioritise also the rapid deployment of the United Nations African Mission in Darfur (UNAMID). The UN Security Council should monitor and apply punitive measures, including authorised sanctions, to any party obstructing the negotiations, UNAMID deployment or the work of the International Criminal Court (ICC), or violating the arms embargo or international humanitarian law. Together with states party to the Rome Statute of the ICC and others, full and effective support to the Court is necessary to continue its investigations and prosecutions in Darfur and increase pressure on Sudan to cooperate with the Court. With the current consideration of the ICC Pre-Trial Chamber of a request from its Prosecutor to issue an arrest warrant against Sudan's President, Omar Hassan Ahmed al-Bashir, the international stakes are now higher regarding moves to seek accountability for crimes against humanity and how these play out against considerations among leading global powers of the need for geopolitical stability in the region.

Those are some of the key political issues which need to be addressed to enhance regional cooperation. Now, I shall highlight some other significant impediments, namely terrorism and governance, as they also have a direct impact on regional cooperation and stability in the Middle East.

9. Terrorism and understanding Islam

Terrorism attacks the values that lie at the heart of the Charter of the United Nations. Terrorists flourish in environments of despair, humiliation, poverty, political oppression, extremism and human rights abuse; they also flourish in contexts of regional conflict and foreign occupation, and they profit from weak state capacity to maintain law and order (Hassan Bin Talal 2007).

The 'new technology theory' emphasises the risk of new forms of terrorism, particularly attacks on complex information systems and the use of weapons of mass destruction. It is believed that Al-Qai'da will continue to try to acquire and employ chemical, biological, radiological, or nuclear material in attacks and would not hesitate to use them if it develops what it deems is sufficient capability.

In pursuance of an effective counter-terrorism strategy in the Middle East and beyond, there must be a coordinated bilateral, regional and international effort to safeguard and enhance the security of states. Exchange of information regarding motives, plans and activities of terrorist groups is vital. There must be a mechanism to abort terrorist actions and to thwart all forms of support which terrorist organisations receive, including safe-havens, training, arming, propaganda and funding.

Terrorism is by nature indiscriminate and thrives on destruction; its very existence depends upon the perpetuation of fear. Jews, Christians and Muslims have a common shared history. The divisive politics of the Middle East must not be allowed to destroy the natural capacity that people of faith have to live and work together. Fostering reconciliation and understanding based on the various historical, legal and religious traditions can contribute much to undermining the fundamentalisms from which terrorism draws ideological support. Much depends also on our willingness to look at the broader causes of terrorism, discourage state terrorism and failed regimes, and avoid becoming committed to the wrong regimes and wrong causes.

Transnational terrorism, which increased in the aftermath of 9/11, plays a decisive role in almost all worldwide conflicts. However, it is not fair to connect terrorism with Islam. Islam has existed for 1,400 years, so we have to ask why we now are facing this type of terror from radical Islamists, and seek to address the political, social economic causes which supply them with willing converts.

Whereas the threat to freedom from radical Islamists has never been so high, there is not much talk today about ‘Progressive Muslims’, ‘Liberal Muslims’, ’Secular Muslims’, and the like. In the USA, such movements aimed at reconsidering the positive values of the Islamic culture have recently emerged, largely as a result of both 9/11 and general concerns about the Muslim community’s future. Yet, in the Arab and Islamic world, these trends have been in existence for more than a century and could do much to identify the type of cross-cultural dialogue that Western countries like the UK and France are promoting, as they seem to reach out to disaffected and radicalised segments of their Muslim communities.

Islam calls on Muslims to demonstrate tolerance and delight in human life; it opposes extremism, exaggeration, and intransigence. These phenomena are veils against right thinking – they conceal the repercussions of one’s actions, and encourage a reckless disregard for religion, reason, and civilised behavior. Indeed, Islam rejects extremism as a deviation from true faith and a form of injustice. Furthermore, it is not a trait that characterises a particular nation; it is an aberration that has been experienced by all nations, races, and religions. We denounce extremism today, just as our forefathers relentlessly did throughout Islamic history. Time after time, they insisted on the importance of one clear truth: the ends do not justify the means. The foundation of relations between Muslims and others is peace.

Today, we in the Middle East call on the international community to work seriously on implementing international law and ensuring respect for UN conventions and resolutions, ensuring that there are no double standards, that injustice is uprooted and that people’s rights are respected and realised. Achieving this will contribute to displacing the causes of violence, exaggeration, extremism and terrorism.

10. The importance of good governance

Last but not least, bad governance is a major impediment to progress and cooperation in the Middle East. Political reforms are a prerequisite for good governance. Despite some initial steps toward public administration and civil service reforms, governance remains a challenge, and the participation of civil society, including parliamentarians, remains weak. Job creation in the private sector is increasing, but large differences exist across the region, with unemployment declining in some countries and rising in others. Women and youth continue to be over-represented among the unemployed and their meaningful political and social participation is highly desired and badly needed.

Good governance in which public institutions function responsibly, transparently, efficiently and accountably is essential to stimulating economic growth. On the other hand, weak governance means slower growth, inefficient public services, and less-than-desired human development because of the limited participation of citizens in shaping their future (World Bank 2003).

While recognising that improving governance is no simple matter, the main challenge in our region is to formulate and act on national programmes that would enhance and improve governance. More importantly, we need to do so in an open, participatory process. Such programmes could build on the debate and progress positively across the region, and lead to a strategy for better governance that can simultaneously encourage growth and development and meet the needs and aspirations of the region's people in the decades ahead.

This would mean the introduction and promotion of the democratisation process, mutual security, pluralism, respect for human rights, economic development, a free market economy, social progress, the maintenance of environmental sustainability, cultural dialogue, contacts between civilisations and upholding the rule of law.

In this context, some Arab states are less than enthusiastic about these projects because their regimes have difficulty with the application of democracy, pluralism, openness, and human rights. Such concepts are in their view, politically explosive and must be avoided by all means. Even a dialogue over these matters will be embarrassing to certain regimes. Meanwhile, other Arab states which respect these ideals must be encouraged and rewarded.

The necessary condition for success, however, is an intensive dialogue based on reciprocal respect and mutual trust. "Dialogue might not solve all problems, but no problem can be resolved without dialogue". New thinking is badly needed. When Albert Einstein said "the significant problems we face cannot be solved at the same level of thinking we were at when we created them" and "imagination is more important than knowledge" (as cited by Hoffman 2007b) he was pointing to the necessity of a fresh look and a new approach –something we need in critical foreign affairs situations and particularly in our situation in the Middle East.

11. Conclusion: Prospects for regional cooperation

To cope with these challenges, we call upon our partners in the United States and Europe to enhance the effectiveness of existing regional peace and human development initiatives and launch new ones, which would reflect the realisation that the security and stability of both Europe and the US are closely linked to events in the Middle East. Leaders in the region must be encouraged to embrace the tenets of democratic governance and promote regional cooperation in pursuit of a stable and peaceful Middle East.

Despite passing considerable economic and social reforms, Arab regimes continue to avoid substantive political reforms that would jeopardise their own power. In a recent Carnegie publication it is argued that democratic reform is a politically charged issue in the Middle East. Governments admit that change is necessary, but do not want to surrender power. Opposition groups want democracy, but cannot generate sufficient momentum. The Bush Adminis tration's 'freedom agenda' has brought the issue into focus but blurred the distinction between democracy promotion and forceful regime change (Carothers and Ottaway 2005).

The Middle East should emerge as a peaceful, multi-national and multi-cultural region where people respect each other's separate identity yet cherish their common heritage – a region that is dominated by rationalism and sanity, free from religious and nationalistic fanaticism.

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ELECTRICITY AND RENEWABLE ENERGY – ISRAEL PROFILE[1]

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Abstract: Israel's electricity sector faces the dual challenge of rapid economic growth – relative to most Western countries – and generation capacity that is barely sufficient to meet current needs. Israel has been at the forefront of renewable energy development for over 50 years, but, with the sole exception of solar water heating, has been unable to use these technological developments to develop its own renewable electricity generation sector. Since 2002, however, the Government of Israel has taken steps toward incentivising renewables development by the private sector, in order to reduce its heavy reliance on imported fuels and to meet its international obligations under the Kyoto Protocol. However, these steps have not stimulated renewables sector growth. Recently published feed-in tariffs for solar thermal and photovoltaic installations and tenders for large-scale commercial solar thermal and photovoltaic systems in the Negev, combined with other proposed incentives discussed in the final section of this chapter, may provide the incentives needed to develop a significant renewable energy sector in the country.

Nevertheless, the burden of proof remains on the Government of Israel to ensure that this progress continues during the next several years, despite the major economic and geopolitical challenges facing the country during this period.

Keywords: Israel, electricity, renewable energy

1. Introduction: Israel's energy situation as an opportunity for renewables

Israel's current energy situation reflects its unique combination of European living standards with the rapid growth in fossil-based energy demand typical

[1] This chapter draws from a paper of the authors titled "Energy Efficiency and Renewable Energy: Israel National Study" presented at the Plan Blue Workshop, *Mediterranean and National Strategies for Sustainable Development*, Monaco, 29–30 March 2007.

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of developing countries. The State of Israel has undergone rapid economic development during the past 10–15 years, and has attained the standard of living typical of many countries in western and southern Europe. Israel's overall gross domestic product (GDP) is approximately $150 billion, and its GDP per-capita is approximately $21,000, similar to that of Spain and Greece (World Bank 2008). Israel's population density and its location at the edge of the desert make it especially vulnerable to climate change; 60% of the population of 7 million resides along the narrow coastal strip along the Mediterranean. In contrast to many European counties, Israel has become more dependent on imported fossil fuels over time, and its energy intensity has not decreased. Moreover, although Israel's electricity demand has been steadily increasing, Israel has no electrical interconnections with neighbouring countries, and must depend on its extremely low reserves to meet demand during peak hours.[2]

An additional consideration for Israel's energy situation is its being in the advanced stages of OECD membership, and the environmental mandates associated with that membership, including a 30% reduction in greenhouse gas emissions by 2020. According to Israel's Ministry of Environmental Protection, Israel will increase its greenhouse gas (GHG) emissions by 54% if it does nothing, resulting in an 84% deficit with regard to its GHG obligations as an OECD member. The Ministry has proposed a set of new standards for electricity generation to ensure Israel’s compliance with these OECD obligations.

Given this combination of rapid energy demand growth and energy dependency, Israel should be at the forefront of renewable energy (RE). Nevertheless, while Israel continues to be a leader in RE technology development, it lags significantly behind most developed European countries in adopting these technologies for domestic usage. This review will demonstrate the historical and projected policies and strategies in these fields.

2. Current and forecasted energy demand and its implications for the development of renewable energy

While experiencing relatively high economic growth rates, Israel has not followed the trend toward declining energy intensity and greater energy efficiency characterising most of Europe. For example, Israel's per-capita energy usage increased by 44% since 1990, while the European Union average increased by only 15%. Table 2.1 below indicates the final consumption by energy product for Israel from 2004 through 2006.

Figure 2.1 illustrates Israel's historical and projected demands for electricity.

[2] This may change during the next several years, especially with regard to interconnections with Jordan's electrical system.

TABLE 2.1. Final consumption of energy products for 2004–2006.

	Final consumption of energy products			
	2004 Mtoe	2005 Mtoe	2006 Mtoe	Percentage of change: 2004–2006
Electricity	3,679	3,779	3,924	6.7
Petroleum products	8,609	8,607	8,692	1.0
Primary products	752	765	27	(96.5)
Total final consumption	13,040	13,151	12,622	(3.3)

Source: Israel Central Bureau of Statistics (2007)

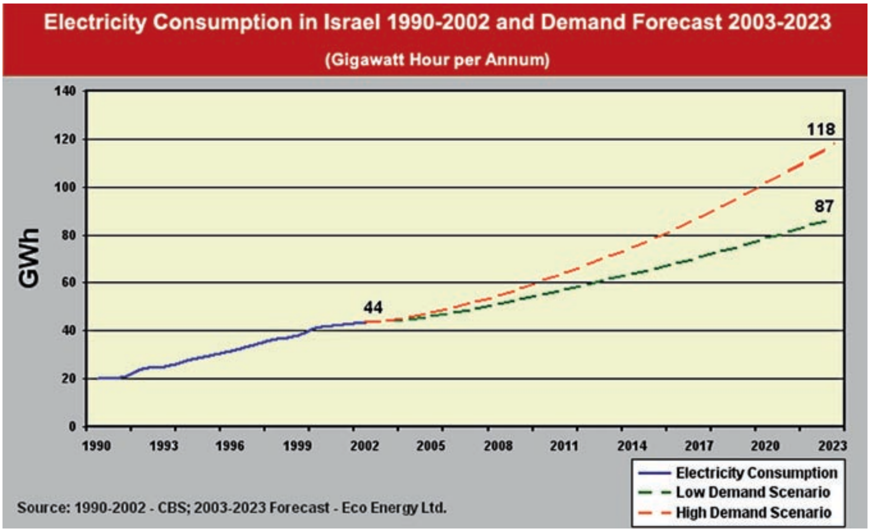

Figure 2.1. Electricity consumption in Israel.

As this figure indicates, Israel's electricity consumption has doubled during the past 10 years, and is expected to nearly double by 2028 – even in the low-demand scenario (rising to 87 GWh). Due to low technical generation reserves and given the long lead times required for constructing new electricity generation in Israel, it is very possible that there will be frequent supply shortages within the next few decades.

2.1. CURRENT AND FORECASTED ENERGY SUPPLY

Israel's energy ratio (primary energy supply per dollar of GDP including taxes) increased by 13% from 1990 to 2006, while the EU average declined by over

10%. Despite the relative slowdown in Israel's economy since the mid-1990s and the projected moderate rate of long-term economic growth, primary energy supply is expected to reach 48 million tons of oil equivalent (Mtoe) by 2025 (from 21 Mtoe in 2006). Table 2.2 indicates Israel's primary energy supply versus its GDP from 1990 to 2006.

Israel's energy sector is based almost entirely on imported fossil fuels. Primary energy consumption in 2006 amounted to 20.7 Mtoe, approximately 89% of which was supplied by imported fuels – 53% (11.1 Mtoe) of which was petroleum products, and 37% (7.7 Mtoe) was coal used primarily for power generation. The remaining 11% (2.1 Mtoe) of primary energy production consists mostly of natural gas, using Israel's recently discovered offshore natural gas reserves (Israel Central Bureau of Statistics 2008). In fact, Israel's energy dependency is among the highest in the world, with energy production totaling only about 0.7 Mtoe annually and net imports approaching 19 Mtoe. To address this high energy dependency, Israel is utilising its own offshore natural gas reserves (~35 billion cubic metres), the vast majority

TABLE 2.2. Energy intensity: 1990–2006.

Year	Base energy intensity: 1995 = 100	Intensity	Base GDP 1995 = 100	NIS (billion)	Base: 1995 = 100	Mtoe
1990	95.4	55.3	70.5	199.6	70.9	11,036.0
1991	90.9	52.7	74.8	211.8	71.7	11,159.6
1992	96.4	55.9	80.2	226.9	81.5	12,689.6
1993	98.8	57.3	83.2	235.5	86.7	13,490.8
1994	98.6	57.2	89.0	252.0	92.7	14,423.3
1995	100.0	52.2	100.0	283.0	100.0	15,564.3
1996	99.4	51.9	116.0	328.2	105.0	16,342.2
1997	98.9	51.6	129.0	365.1	107.4	16,713.6
1998	102.5	53.5	144.0	407.4	115.9	18,038.4
1999	102.8	53.6	157.5	445.8	119.7	18,626.6
2000	99.0	51.7	174.2	492.9	125.3	19,499.2
2001	99.3	51.8	176.7	500.1	124.9	19,435.2
2002	103.4	53.9	183.0	518.0	128.8	20,039.8
2003	101.7	53.1	186.2	527.0	128.6	20,015.2
2004	100.5	52.4	195.8	554.1	133.2	20,728.2
2005	96.8	50.5	208.1	589.0	135.0	21,004.9
2006	97.1	50.7	223.7	633.1	132.8	20,674.6

Source: Israel Central Bureau of Statistics (2007) of which are under contract with the Israel Electric Corporation (IEC) for its natural gas-fired generating stations. To meet the growing demand for natural gas for the power and industrial sectors it will be necessary to import natural import gas from other sources, primarily from Egypt, thereby increasing Israel's energy dependence.

Electricity generation capacity is primarily coal-fired, with approximately 4,800 MW producing approximately 35 million megawatt-hour annually, or approximately 70% of Israel's electricity generation. Overall, 11.2 Mtoe of primary energy was used to produce 50 billion kilowatt-hours of electricity in 2006, mainly in three steam turbines power stations located on the Mediterranean coast (two coal power plants and one dual-fuel capable – heavy fuel oil and natural gas). Israel Electric Corporation has been actively retrofitting its oil-fired generators to use natural gas, and most of its new electricity generation for the next several years will use natural gas as its primary fuel. Nevertheless, IEC's multiyear development plan, as approved by the Ministry of National Infrastructures, includes an additional large coal-fired power plant. This inconsistency in government policy regarding the environmental footprint of Israel's electricity generation has been a major factor hindering the growth of Israel's renewables sector. Table 2.3 summarises the fuels used for electricity generation since 1995.

Table 2.4 indicates historical trends for Israel's total primary energy supply from 1980 to 2006.

Tables 2.5 and 2.6 show the annual electricity consumption by rate sector and the annual average price per kilowatt-hour for each rate sector, respectively, expressed in US cents per kilowatt-hour (at year-end US dollar–shekel exchange rates). When combined with the consumption data above, it is apparent that overall electricity demand is not very responsive to price. In fact, customers who recently switched to Time-of-Use tariffs display the only clear evidence of price elasticity; these customers have shifted portions of their consumption to non-peak hours. This relative price inelasticity, combined with increasing environmental awareness, may bode well for incentive mechanisms for renewable energy, such as technology-specific feed-in tariffs that are likely to increase rates in the short- and intermediate runs.

Figure 2.2 presents the trend of per-capita energy supply since 1970. Note that per-capita supply has stabilised since 1998. However, energy supply requirements are growing due to rapid demographic growth.

Tables 2.7 and 2.8 illustrate the composition of Israel's energy supply and growth in energy demand. Of note is the distinct lack of renewable energy in the energy portfolio and the forecasted growth in energy consumption, implying greater dependence on imported fossil fuels in a “do-nothing” scenario.

TABLE 2.3. Primary fuels used for electricity generation: 1996–2006 (thousand tons).

Power Plant	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Fuel oil											
Haifa	448	439	421	494	488	441	402	431	369	344	418
Reading	579	539	592	646	571	477	371	448	407	392	112
Eshkol	996	1,035	1,173	1,199	1,257	1,047	888	882	309	116	117
Orot Rabin	–	–	–	–	–	–	–	–	–	–	10
Rutenberg	–	–	–	–	–	–	–	–	–	–	4
Private gen.	–	–	9	24	29	19	24	21	22	23	24
Total	2,023	2,013	2,195	2,359	2,345	1,984	1,685	1,782	1,108	875	686
Coal											
Orot Rabin	5,332	6,316	6,758	6,996	6,944	6,684	6,611	6,814	6,815	6,857	7,082
Rutenberg	2,476	2,324	2,525	2,267	3,353	4,882	5,591	5,796	5,902	5,837	5,583
Total	7,808	8,640	9,284	9,263	10,307	11,566	12,202	12,610	12,717	12,694	12,665
Gas											
Reading	–	–	–	–	–	–	–	–	–	–	244
Eshkol	–	–	–	–	–	–	–	–	823	1,127	943
Comb. cycle	–	–	–	–	–	–	–	–	–	–	355
Total	–	–	–	–	–	–	–	–	823	1,127	1,541
Gas oil											
Jet engines	10	6	13	6	7	5	15	6	3	14	5
Heavy duty	120	113	212	457	379	149	307	114	88	257	231
Comb. cycle	–	–	–	–	181	81	82	299	294	316	377
Total	130	119	225	463	567	235	404	413	325	587	613

Source: Israel Electric Corporation 2006 Statistical Report

TABLE 2.4. Historical trends for Israel's total primary energy supply: 1980–2006.

Period	Total primary energy	Transformation to secondary energy	Primary energy supply grand total
1980	5,427.3	2,478.6	7,905.9
1985	5,619.2	2,875.2	8,494.3
1990	7,236.0	3,800.0	11,036.0
1995	10,608.6	4,955.4	15,564.3
2000	12,808.2	6,690.8	19,499.2
2002	13,039.0	7,000.7	20,039.8
2003	13,217.6	6,797.8	20,015.2
2004	13,039.7	7,688.5	20,728.2
2005	13,151.1	7,853.6	21,004.9
2006	12,977.9	7,665.0	20,674.6

Source: Israel Central Bureau of Statistics 2005 Energy Report and 2007 Statistical Bulletin

2.2. GREENHOUSE GAS (GHG) EMISSIONS: CURRENT AND FORECASTED

Israel's overall CO_2 emissions approach 67 million tons annually, amounting to 9.7 t per person (Israel Central Bureau of Statistics 2008). Although this figure has declined by about 1% per year, Israel's population continues to increase by about 2% annually (higher than nearly any other developed country), and its total greenhouse gas emissions level has been increasing by about 1% annually since 1990. At current trends, annual CO_2 emissions will reach nearly 83 million tons by 2025, as illustrated in Table 2.9. Therefore, Israel faces significant challenges in lowering its CO_2 emissions, while meeting the energy needs of a growing population in a rapidly developing country. Greenhouse gas emissions in Israel currently exceed 80 million tons per year, with 60% of the emissions generated by the energy sector. The electricity sector alone is responsible for over 35 million tons of GHG emissions.

3. The current state of renewable energy in Israel

The lack of renewables in Israel's energy portfolio is noteworthy; Israel's entire electricity generation mix in 2006 consisted of coal (71%) and natural gas (18%), with the remainder consisting of heavy fuel oil and gasoil (11%). Moreover, Israel's statistics on primary energy supply include no mention of renewables, indicating that renewables' share of primary energy supply is less than 0.1%, far less than the 2% to which the Government has committed since 2003. Israel Ministry of National Infrastructures (2007).

TABLE 2.5. Annual electricity consumption by sector: 2002–2006.

	Million kilowatt-hour					Percent				
Tariff groups	2002	2003	2004	2005	2006	2002	2003	2004	2005	2006
Residential	12,734.7	13,347.7	13,482.5	13,637.3	14,198.1	31.9	32.0	31.4	30.8	30.7
Public and Commercial	3,324.3	3,331.1	3,295.9	2,969.1	2,838.6	8.3	8.0	7.7	6.7	6.1
Agricultural	120.3	115.2	105.5	90.7	84.1	0.3	0.3	0.2	0.2	0.2
Industrial	461.3	432.8	387.4	354.0	348.4	1.2	1.0	0.9	0.8	0.8
Water pumping	100.4	82.8	73.1	59.7	49.6	0.3	0.2	0.2	0.1	0.1
E. Jerusalem & Pal. Auth	2,300.1	2,455.0	2,598.5	2,862.8	1,870.0	5.8	5.9	6.1	6.5	4.0
T.O.U Tariff	20,878.8	21,956.0	22,989.8	24,336.0	26,785.8	52.2	52.6	53.5	54.9	58.1
Total	39,919.9	41,720.6	43,932.6	44,308.8	46,174.7	100.0	100.0	100.0	100.0	100.0

Source: Israel Electric Corporation 2006 Statistical Report

TABLE 2.6. Annual average electricity price (in US cents per kWh).

Year	Resid ential	Public and commercial	Agricultural	Industrial	Water pumping	Bulk	Total con- sumption
1995	8.5	8.2	7.0	6.8	6.1	6.5	7.6
1996	8.4	8.0	6.9	6.8	5.9	6.4	7.5
1997	8.3	8.1	7.1	6.8	6.1	6.5	7.5
1998	7.1	6.9	6.1	5.8	5.6	5.6	6.4
1999	7.6	7.3	6.4	6.2	5.9	5.9	6.9
2000	8.0	7.8	6.9	6.5	6.3	6.3	7.3
2001	7.3	7.0	6.1	5.9	5.7	5.7	6.6
2002	7.8	7.5	6.5	6.2	5.9	5.9	7.1
2003	9.1	8.6	7.4	6.9	6.7	6.7	8.1
2004	9.8	9.3	7.9	7.5	7.3	7.3	8.7
2005	9.8	9.3	8.1	7.7	7.4	7.4	8.8
2006	10.4	9.9	8.7	8.3	7.1	8.0	9.3

Source: Israel Electric Corporation 2006 Statistical Report

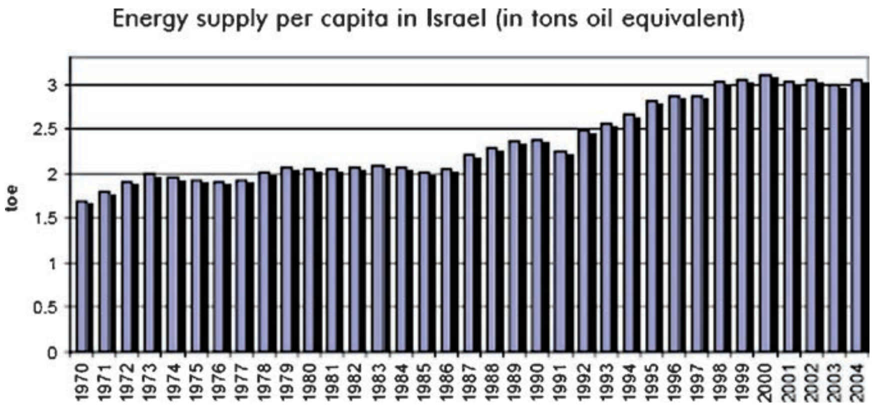

Figure 2.2. Energy supply per capita 1970–2004

Since its pioneering efforts to develop rooftop solar water heating, Israel has done little to develop a renewable energy industry that can substantially reduce that energy dependency. Like most of its eastern Mediterranean neighbours, Israel has among the highest solar radiation rates in the world, yet its solar industry has largely consisted of developing technologies, rather than manufactured goods, for export. Besides solar, Israel's renewables potential is limited. Biomass potential is about 8.6 Mtoe, primarily from

TABLE 2.7. Israel's primary energy supply 2006 (thousands of toe).

	Coal	Oil shales	Crude oil	Refinery feedstock	Petroleum products	Natural gas	Hydro and solar energy	Electricity
Indigenous production	–	31.7	1.5	–	–	2,091.1	–	–
Imports	7,721.8		10,318.0	–	4,203.0	–	–	–
Thereof: refinery feed stocks	–	–	–	1,611.8	−1,611.8	–	–	–
Exports (a)	–	–	–	–	−3,660.9	–	–	−158.4
Marine bunkers	–	–	–	–	−254.8	–	–	–
Stock changes (b)	−152.8	–	251.2	–	167.7	–	–	–
Statistical differences (c)	36.0	–	−294.8	−18.0	346.9	−0.2	0.0	−14.4
Primary energy supply	7,665.0	31.7	10,275.9	1,614.9	−819.0	2,090.0	0.0	−172.8

Source: Israel Ministry for Environmental Protection (2006).

TABLE 2.8. Primary energy supply and final energy consumption: 1970–2025.

Year	Primary energy supply per capita (toe)	Final energy consumption per capita (toe)	Primary energy supply (Mtoe)	Final energy consumption (Mtoe)
1970	1.7	1.2	5,033	3,495
1975	1.9	1.3	6,635	4,579
1980	2.0	1.4	7,906	5,427
1985	2.0	1.3	8,494	5,619
1990	2.4	1.6	11,036	7,236
1995	2.8	1.9	15,564	10,609
2000	3.1	2.0	19,499	12,808
2005	3.0	1.9	21,005	13,151
Projections through 2025				
2010	3.0	1.8	22,445	13,723
2015	3.0	1.8	23,983	14,319
2020	2.9	1.7	25,627	14,941
2025	2.9	1.7	27,384	15,590

Source: Israel Central Bureau of Statistics

TABLE 2.9. Total emissions: 2000–2005 with projections through 2025.

Year	Total emissions (in thousands of tons)	CO_2 emissions (in thousands of tons)	Population (in thousands)	CO_2 emissions per capita (t)
2000	2,010,088	64,104	6,289	10.19
2001	1,892,822	64,353	6,439	10.00
2002	1,785,661	65,652	6,570	10.00
2003	1,772,015	66,352	6,690	9.92
2004	1,685,900	66,901	6,809	9.83
2005 (est.)	1,613,419	67,458	6,929	9.74
Projections through 2025				
2010		70,988	7,634	9.30
2015		74,702	8,410	8.88
2020		78,611	9,266	8.48
2025		82,724	10,209	8.10

Source: Israel Central Bureau of Statistics

municipal waste. Israel's wind potential is also rather low, with maximum capacity around 600 MW (or about 1.75 billion kilowatt-hours), and faces the additional difficulties of location and grid interconnection.[3]

[3] Presentation by Dan Raviv of MST (Israeli renewable energy company) and Israel Ministry of the Environment (2000).

In order to develop Israel's renewables potential, the Ministry of National Infrastructures (MNI) published a set of policies and rules in 2004. Based on this work, the Israel Public Utilities Authority – Electricity (PUA) has since developed tariffs, licensing procedures, and codes of conduct for renewable electricity generators, covering solar, wind, biomass, and all hydroelectric facilities except for pumped storage (Israel Public Utilities Authority 2007). As of April 2008, renewable developers' response to these government initiatives has been slow, and less than 100 MW of renewable generators have received conditional licenses.

Despite Israel's relative progress in the solar sector, resulting in over 1.3 million solar water heaters producing the equivalent of over 4% of the country's electricity consumption – due to mandatory solar water heating installations – Israel has less than 1,000 kW of photovoltaic installations. In fact MNI estimates that, without significant government involvement, solar penetration overall will continue to lag behind most European countries through 2025. However, without the initial government incentives, it is unlikely that either photovoltaic or solar thermal systems will reach the necessary scale in Israel to be competitive with fossil fuels.

3.1. BARRIERS TO RENEWABLE ENERGY DEVELOPMENT

There are a number of reasons that RE has not made more inroads into Israel's energy sector, including the following:

(a) The Ministry of National Infrastructures, which has primary responsibility for energy policy, has not developed comprehensive implementation plans for RE. It has also not taken opportunities to coordinate RE with other governmental ministries that have mandates to promote RE. For example, for much of 2008, MNI was unable to develop an effective tender process for developing solar thermal and PV facilities in the Negev jointly with the Ministry of Finance, thereby maintaining the deadlock in efforts to revive Israel's leadership role in developing the solar sector. This inaction has impeded progress in establishing the necessary governmental coordination and budgeting for sustainable energy policy.

(b) The Israel Electric Corporation, due to its dominant role in electricity supply and fuel acquisition, has a strong bias toward maintaining and increasing dependence on traditional labour-intensive generation sources, especially coal. Despite recent initiatives to use cleaner coal and the notable shift to natural gas, IEC's fuel choices have increased risks to the environment and raised Israel's level of energy dependency. Moreover, IEC has stymied PV growth by creating formidable procedural roadblocks for PV to obtain the required authorisations to interconnect with IEC's grid; these procedural roadblocks have been reflected in the Public Utilities Authority's (PUA) rigid eligibility requirements for the solar feed-in tariffs.

(c) Low renewable tariff incentives that reflect only marginal environmental externality costs, as opposed to incentives in other countries that compensate renewables for portions of their fixed costs as well. The proposed tariff for solar facilities is somewhat higher, reaching nearly $0.52 per kWh for PV facilities, but this is relatively low by world standards, and has much stricter eligibility requirements as mentioned in (b) above.

(d) The extremely low levels of public investment in research and development on RE. Much of the research and training in RE is funded by universities such as Ben-Gurion University in Beersheba and the Weizmann Institute in Rechovot. Most remaining R&D has been self-financed (for firms who have been successful abroad) or partially financed through small financing ventures through the Infrastructure and Environment Ministries. Although there have been efforts by private-sector investors to finance proven technologies, these investors have largely bypassed the basic R&D investment usually funded by the public sector.

(e) The lack of public awareness of climate change issues in Israel, which lags behind that of most European countries. Although opinion polls of Israelis indicate that an overwhelming majority believe that the Government does not do enough to address the environment (89%), and that nearly two thirds identify global warming as a serious environmental issue (65%), actual practice indicates that less than 50% of Israelis have taken steps to reduce their energy consumption,[4] believing that the Government should take the initiative in developing the necessary action plans. Initiatives by organizations such as the Israel Union for Environmental Defence (IUED) and Greenpeace, as well as increased focus by the mainstream press on RE, have only begun to address this issue.

These factors explain why Israel has long ceased to be a leader in RE domestically. They may also explain why, despite Israel's proven capability in RE research and development, RE technology exports have been in the tens of millions of dollars, a small share of Israel's overall annual exports in

[4] Pratt Survey of Environmental Sensitivity in Israel – survey for the Heschel Institute.

excess of $20 billion (Israel Ministry of Foreign Affairs 2002; Israel Export Institute 2006a). Many promising RE developments have remained at the research stage because of the lack of resources and policy coordination necessary simply to make the initial assessment of their commercial viability. Therefore, it is critical that Israel improves its policymaking with regard to RE, despite an array of barriers including slow progress on policy, strong vested interest groups, and lack of public awareness. Such improvements must be reflected in an improved feed-in tariff mechanism for renewables development, clear, consistent, and quickly expedited licensing processes, and clear delineation of responsibilities among the governmental bodies, including the Ministries of National Infrastructures, Finance, and Environmental Protection, as well as the Israel Public Utilities Authority. The question for Israel is whether the small steps taken thus far will be sufficient to create an environmentally responsible, efficient, independent energy economy, while at the same time addressing growth rates that exceed those of Europe and North America.

4. Renewable energy policies and tools

4.1. BACKGROUND

The starting points for RE policy in Israel are the UN Framework Convention on Climate Change and the Kyoto Protocol. Israel ratified the UN Framework Convention on Climate Change in September 1996, and set the groundwork for its activities following its signing of the Kyoto Protocol. Through its Interministerial Committee on Climate Change, Israel prepared a national inventory of emissions and removal of GHGs, and has reported regularly on mitigation options and action plans to the United Nations, the most notable being the integration of natural gas into its energy supply policy that should reduce Israel's CO_2 emissions by 11.5 million tons annually by 2015.

The Kyoto Protocol has been the main compliance standard for Israeli regulation and compliance since 1998, when Israel became a signatory. In February 2001, the Government issued an official decision – Government of Israel Decision 2913(13) – setting GHG targets and funding mechanisms pursuant to its Kyoto obligations. Israel ratified the Kyoto Protocol in February 2004, to become effective in February 2005, and is classified as a non-Annex I country under the Climate Change Convention. To date, Israel has not adopted a position regarding post-Kyoto environmental standards to become effective in 2012, although the Ministry of Environmental Protection has recently issued tenders for assistance in addressing this post-Kyoto period, including assessing the merits of continuing Israel's Kyoto status as a "developing country" rather than a developed one.

Soon after ratification, Israel created a Designated National Authority (DNA) to determine whether its Clean Development Mechanism (CDM) initiative, developed in response to Kyoto ratification, complied with Kyoto's sustainable development criteria. The DNA consists of a variety of members, including Government ministries, the Israel Electric Corporation (IEC) and non-governmental organisations.

In May 2003, the Government of Israel announced a strategic plan for sustainable development consistent with the Plan of Implementation accepted at the World Summit on Sustainable Development in 2002. Each ministry is required to draft its own plan that sets forth tasks, action plans, measurable goals, and target dates for achieving those goals within a predetermined budget. The overall strategic plan relates to the period from 2003 to 2020, and is updated every 3 years. While the Ministry of National Infrastructures has the greatest responsibility for RE development under the strategic plan, other ministries assume major roles in developing energy policy standards and legislation, and marketing RE. To date, the ministries have largely met their obligations under the strategic plan, including updating their sustainable development strategies under the strategic plan, in 2004 and 2006 (Israel Ministry for Environmental Protection 2006). MNI is a glaring exception, however, having failed to meet obligations stipulated in the Strategic Plan, including: (a) to integrate solar energy in new construction, to have 2% of electricity production from renewable energy sources by 2007; and (b) to stimulate the research and development necessary to meet future RE targets.

4.2. RENEWABLE ENERGY DEVELOPMENT OPPORTUNITIES – GENERAL

In 2002, the Government of Israel set a target of at least 2% of all electricity to be supplied by renewable energy by 2007; this target rises to 5% by 2016 and 10% by 2020. Reaching this target requires the construction of large solar and wind plants, as well as a mixture of small hydro, biomass, and PV systems. Currently, although there are individual programs aimed at promoting RE, there is no overarching national strategy to achieve the Government-set RE targets.

The Energy Master Plan commissioned by MNI analyses alternatives for RE, and makes recommendations for strategies to achieve specific RE objectives. However, rather than developing strategies, the Government has initiated individual programmes with a few goals in mind. Some examples of programmes include: incentive mechanisms for renewable electricity generation and co-generation that are consistent with broadly defined goals such as improving Israel's balance of payments, improving public health, and promoting domestic achievements in renewables development.

The Government's RE priority is solar energy, and the MNI has set an initial goal for solar thermal energy of 250 MW at an estimated cost of $700 million, as an initial project that should grow over time. Despite this emphasis on solar development as a policy matter, however, the Government has budgeted little for solar R&D; PV-related R&D spending was only NIS 688,000 in 2004 with an additional NIS 200,000 from non-governmental public funding (International Energy Agency 2005).[5]

In 2004, Israel, through the Environment Ministry, established a Designated National Authority (DNA) for the Clean Development Mechanism. In May 2006, the Government and companies specialising in CDM projects sponsored a conference on the CDM and emissions trading as means of financing greenhouse gas reduction projects. Since Israel is classified as a non-Annex I developing country under the Kyoto Protocol, entrepreneurs who implement emissions reduction projects in Israel may sell their carbon emissions credits to developed countries.

The Ministry of Environmental Protection has promoted Israel's unique advantages of being a developing country with the expertise in clean technologies and professional investment community of a developed country; this expertise is essential for developing and identifying projects to offset emissions in Kyoto-classified developed countries.

The PUA has developed initiatives for incentivising RE, through rate-making and licensing procedures. Tariffs during the next decade are expected to cover over $1.5 billion in environmental investments by IEC alone, comprised of $1.4 billion in pollution reduction, and $0.1 billion in addressing hazardous waste cleanup at generator sites. In addition, the PUA is seeking to work with the Environment Ministry to set principles for long-term reduction of generator-caused pollution, including developing incentives for oil-fired generators that take steps to reduce pollution. The PUA has also tried to promote net metering for renewables, but has faced objections to this initiative for a variety of tax-related and operations-related reasons. In January 2007, the PUA issued draft licenses for small renewable generators selling directly to the IEC grid, setting forth the mutual obligations of the generator and IEC in its role as the single buyer and system operator.

The main economic incentive measures for RE are the renewables premium developed by the Israel Public Utilities Authority for non-IEC renewable electricity generator sales (except for some biogas) to the Israel Electric Corporation

[5] National Survey Report of PV Power Applications in Israel 2004, May 2005 (report for the International Energy Agency under contract from the MNI).

and the related feed-in tariff and licensing arrangements for solar thermal generation. In 2004, the PUA developed renewables premia to generation license holders producing electricity using renewable resources. The renewables premia reflect the costs of the avoided CO_2, NOx, SO_2 and particulate emissions due to the renewable generator's replacing fossil-fuel generators during each time-of-use period. A premium is based on the level of emissions in grams per kilowatt-hours as determined periodically by the Ministry for Environmental Protection, and is adjusted over time in response to Ministry revisions of emissions data and CPI indexation. These premia are added to the PUA-recognized production costs paid by IEC to IPPs, and vary with the time-of-use blocks, reflecting the avoided emissions associated with fuels that would have been used for electricity generation but for their displacement by the renewable fuel. Therefore, the costs of acquiring the renewable energy are costs recognized in IEC rates. The approved premia are in effect for the lesser of:

1. Fifteen years from the renewable generator's construction date and
2. The duration of the renewable generator's license

Although the premia are relatively small, ranging from 1.70 cents per kWh during shoulder hours to 2.69 cents per kWh during off-peak hours (due to the predominance of coal generation), the renewables premia have been an integral factor in obtaining financing for small renewables such as wind, small hydro, and biomass. Renewable generation owned by IEC is ineligible for the renewables premium, since the PUA already reflects these costs in designing IEC's tariffs (PUA Session 145, Decision 3 of July 13, 2004). Currently, the PUA is offering this premium to seven non-solar generators, with total installed capacity of 13 MW, comprised of 6 MW of wind, 6 MW of hydro, and 1 MW of biogas. However, this amount is expected to rise quickly, if larger-scale wind generation proposed for northern Israel is developed.

Israel-based venture funds have begun to finance renewables technologies that have a sustainable business concept. These funds have tended to be in the \$10−25 million range, and financed mainly by US investors who have experience with bringing early-stage startups to market in general, and have become more comfortable with the specific risks associated with such startups in the energy sector.

The Israel Electric Corporation, although not integrating RE into its fuel mix, has reduced its environmental footprint over the past 10 years through the substitution of fossil fuels with lower emissions. SO2 emissions per kilowatt-hour dropped from 5.7 g per kWh in 1995 to 2.6 in 2004, mainly due to the substitution of 0.5% and 1.0% sulphur coal replacing coal with higher sulphur content, but also due to the substitution of natural gas for crude oil. Similarly, NOx emissions declined from 3.0 g per kWh in 1995 to 2.0 in 2004, and particulates dropped from 0.28 g per kWh to 0.09, mainly due to improved fuel burning technology and the introduction of natural gas.

In addition to solar (to be profiled separately in this section), there is some potential for up to 600 MW of wind energy in Israel, although only 150−200 MW are included in the MNI-approved electricity plan. Currently, both IEC and private producers are either planning over 80 MW of wind facilities, exclusively in northern Israel. Although wind facilities developers have encountered few of the objections to wind power encountered by their counterparts in the US and Europe, there are few areas in Israel with the combination of topography and wind speed to make wind a viable option, despite its per-kilowatt-hour cost being less than half of the cost of solar thermal and its being ideally suited to the PUA's renewables premium mechanism. The most prominent wind facility to date has been the 6-MW Golan Heights wind farm, producing approximately 12,000 MWh per year (Baruch and Ben-Dov 2002). In addition, the PUA has issued conditional licenses to other non-IEC wind facilities intending to sell their electricity to the IEC grid.

4.3. RENEWABLE ENERGY DEVELOPMENT POLICIES – THE CASE OF SOLAR

The potential effect of solar energy development on Israel's economy is substantial. In a recent study conducted by Eco Energy, assuming 2,000 MW and 500 MW of PV phased in by the year 2025, solar-generated electricity would reduce greenhouse gas emissions by nearly 4 million tons by 2025, and would increase steady-state (i.e., post construction) employment by nearly 3,200 per year. The overall benefits through 2025, taking into account benefits from developing Israel's solar sector include energy security, environmental improvement and increased economic opportunity employment, environment, avoided T&D infrastructure, avoided pollutants, and balance of payment improvements is between $1.8 and $2.7 billion, with ongoing post-construction benefits of some $200 million per year (Eco Energy 2006).

Israel continues to develop leading-edge solar technology in companies such as Solel and Millennium Electric, and at university settings including the Blaustein Institute on the Sde Boker campus of Ben-Gurion University and the Weizmann Institute. The most prominent developments at these centers have been the Weizmann Institute's solar tower for concentrating solar energy, and the solar dish facility at the Blaustein Institute. The Institute's main research emphasis has been on improving solar thermal and PV efficiency for commercial purposes while the Weizmann Institute in Rechovot has focused on solar technology as a base for other currently research-oriented processes such as hydrogen fuel storage and transportation. The Blaustein Institute is presently developing concentrating PV systems that may be able to reduce the cost of PV to $800 per kilowatt peak (kWp) due to their energy-collection efficiency and scale economies due to their multiple commercial applications (Israel Export Institute 2006b). It should be noted, however, that the total funding for photovoltaics from the MNI in 2004 (as noted above) was only NIS 688,000 ($160,000).

Nevertheless, since 80% of Israel's households use their solar water heating system (the largest such penetration in the world), the prospects for PV adoption are positive should prices decline sufficiently. As mentioned earlier, most PV systems in Israel, with module prices averaging $5.50 per peak-watt and marketed through a few specialty stores, are not cost-effective without the Government incentives needed for PV to achieve the necessary scale economies.

A promising area for solar energy development, especially for regional development, is solar/desalination integration, by which solar energy produces electricity used by desalination facilities. Since the solar facility's operations are limited to daytime hours while the desalination system operates continuously, such integration requires either large heat storage capacity or fossil-fuel backup – both of which significantly reduce these facilities' economic viability. For facilities requiring electricity generation, the issue of fossil-fuel backup is significant, particularly with regard to future natural gas availability.

Solar/desalination integration in Israel has become a promising area of renewables development as well, although it has faced two significant obstacles: (1) a lack of sufficient inexpensive land along the Mediterranean coastline and (2) a lengthy licensing processes. The most prominent example of this integration is the cogeneration and desalination plant in Ashkelon, which is one of the largest in the world, and which is projected to produce over 100 million cubic metres of water annually. The power plant's capacity will be approximately 80 MW, 56 MW of which will be used to power the desalination plant. This facility has become a model of compliance with high environmental standards, setting a benchmark for future facilities throughout the Mediterranean region (Einav and Lokiec 2003).

The Government of Israel is aware of the possibilities for regional development of solar energy projects, especially between Egypt's Sinai Peninsula, the Jordanian deserts, and Israel, thereby taking advantage of scale economies and information sharing, both of which are critical for solar development. This regional cooperation could occur through tax breaks and subsidised loans for companies – and universities – that are willing to engage in this regional development.

In August 2006, the PUA developed tariffs for solar thermal generators of 100 MW or greater (with and without fossil-fuel backup) and generators with installed capacities between 20 and 100 MW. These tariffs reflect the normative (representative) costs of a solar thermal facility similar to those located in Southern California manufactured by Israel-based Luz (the predecessor of Solel Solar Systems Inc.), and do not include the renewables premium for which other renewable electricity generators are eligible.

These normative costs are recognized in IEC's tariffs, since IEC is obligated to purchase the entire output of these generators. These tariffs do not assume any project financing support from outside sources, even from government agencies. Nevertheless, the tariffs reflect normative values to be representative for the first 20 years of a solar thermal plant's operations, and lower values for later years, reflecting both efficiency improvements over time and complete repayment of long-term debt obligations. The tariff for units with less than 100 MW capacity and units with at least 100 MW capacity are currently 20.7 and 16.5 cents per kWh, respectively. The PUA expects that at least 200 MW of additional solar thermal capacity will be developed during the coming years. The current tariffs for solar thermal facilities have been in place since September 2006, but it is uncertain when the facilities themselves will be fully operational, due to substantial delays in the land acquisition and licensing processes (PUA Decision No. 177, August 16, 2006 decision).

In 2008, the PUA and the Ministries of Finance and National Infrastructures took significant steps toward accelerating commercial solar development in Israel. The PUA published tariffs and codes of conduct between distributed PV facility owners and the IEC distribution company, including the first steps toward net metering for renewable generation. This net metering tariff addresses residential PV installations up to 15 kW and non-residential installations up to 50 kW and will be in effect for 20 years, after which the distribution company will pay only for generation provided to the grid. The base tariff for electricity sold to the distribution company will be NIS 2.01 per kWh ($0.52 per kWh at the base exchange rate of NIS 3.8933: US$1). This tariff will be adjusted annually through 2014 according to a formula reflecting exchange rate changes with respect to the US dollar and the Euro, as well as a 4% annual rate decrease from 2011 to 2014 reflecting projected technological improvements.

In March 2008, the MNI published a tender for two solar thermal generators of 80−125 MW each, and a second tender for a PV facility up to 15 MW. All facilities will be located in Ashalim, a location in the Negev desert with one of the highest insolation rates in Israel. The solar thermal facilities may have fossil fuel backup, but this amount is capped in accordance with the tender requirements and the relevant PUA tariff. The tender conditions are intended to provide a hedging mechanism for managing “macro” financial risks (i.e., inflation, exchange rates and interest rates) similar to that provided in previous PFI/BOT tenders issued by the Government of Israel, while requiring substantial evidence of general financial viability. To date, the tender has attracted some interest from non-Israeli companies with substantial experience in developing solar facilities as suppliers and contractors, in addition to the Israeli companies whose commercial activities have been limited previously to opportunities abroad.

In March 2009, the Ministry of National Infrastructures joined with the PUA to issue conditional licenses for a 100-kW solar thermal and a 4.9 MW photovoltaic facility. These licenses are the first to be issued for solar electricity generation facilities in Israel.

The momentum created since 2008 for expanding Israel's solar energy sector will require the Government of Israel's continuing support. Although, as mentioned above, the Government has committed itself to a schedule for expanding solar and other renewables generation, the burden of proof remains on the Government to ensure that the current economic and geopolitical challenges facing Israel do not impede progress toward that schedule's targets.

4.4. RECOMMENDATIONS FOR DEVELOPING RENEWABLE ENERGY IN ISRAEL

The following are recommended actions for developing RE in Israel, most of which require much more active government involvement:

1. A "carrot-and-stick" approach to developing RE, consisting of a combination of improved feed-in tariffs and enforceable emissions standards, such as Emissions Performance Standards. Although the current premia for renewable energy reflect the marginal external cost of the non-renewable energy displaced, they do not allow the renewable generator a sufficient return on its fixed investment and O&M costs. In contrast, the solar thermal tariffs for large-scale commercial solar thermal and PV facilities more closely follow the model of the successful feed-in tariff programmes in Europe, which have been responsible for rapid adoption of renewable generation and for R&D investment in new technologies. Such feed-in tariffs would also signal to the investment community abroad that Israel believes in the level of its domestically developed RE technology.
2. A non-bypassable public benefits charge on all electricity sales, in order to ensure adequate funding for R&D in renewable energy.
3. Regular updates of environmental costs that are reflected in the PUA tariff to account for worldwide changes in emissions values as emissions markets become larger and more liquid.
4. Development of net metering, beyond the initial tariffs issued in mid-2008 for small residential and commercial facilities.

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THE ENERGY SECTOR IN JORDAN – CURRENT TRENDS AND THE POTENTIAL FOR RENEWABLE ENERGY

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Abstract: Jordan has a substantial dependence on foreign energy sources with 96% of its needs served by imports of oil products, natural gas and electricity. The US-led invasion of Iraq in 2003 exposed the oil supply vulnerability of Jordan and provoked official efforts to diversify energy imports and develop domestic energy resources. Political support for investment in renewable energy in Jordan was boosted by the 2007 findings of a Royal Committee on the National Energy Strategy, and there is a government target that renewable sources meet 10% of national energy needs by 2020. The positive environmental outcomes of this commitment to clean energy are diluted by a plan also to invest significantly in the extraction and processing of Jordan's large oil shale reserves.

Keywords: Renewable energy, oil (petroleum), electricity generation, oil shale, Jordan.

1. Introduction

The Hashemite Kingdom of Jordan is a small Arab country with no conventional oil resources. It has a substantial dependence on foreign energy sources with 96% of its needs served by imports of oil products, natural gas and electricity. Jordan is still in the early stages of industrialisation, and has relied heavily on international assistance (IMF and World Bank) and US support (foreign aid and preferential trading terms) since a severe balance of payments crisis at the end of the 1990s. IMF conditions on economic liberalisation and privatisation

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have directly shaped economic reforms in the country, including the restructuring of the energy sector. On the throne since 1999, King Abdullah II has embraced this programme of economic reforms, although political liberalisation has proceeded more slowly.

In this chapter, we outline first the major characteristics of the Jordanian energy sector during the past 2 decades, noting a growing dependence on fossil fuel imports, which, in the midst of the high oil prices, finally provoked government efforts to develop domestic energy resources. More strategic energy planning in Jordan since the 1990s has seen extensive regulatory reforms and targeted commitments to increase and modernise power generation and transmission capacity. After setting out the main goals of the National Energy Sector Strategy, we discuss the potential for utilising renewable energy in Jordan, focusing on wind energy, solar energy and bioenergy. Finally we discuss recent regulatory initiatives designed to increase the incentives for businesses to invest in renewable energy production.

2. The Jordanian energy sector in the period between 1990 and 2007

2.1. INCREASING AND UNQUESTIONED OIL DEPENDENCE: 1990–2002

In the period between 1990 and 2002, the Jordanian energy sector was distinguished by a growing import reliance on crude oil and refined products (notably fuel oil, diesel and kerosene) for domestic energy needs. There were two major reasons for this.

In the first place, Jordan depended on Iraq to cover all its requirements for crude oil and oil derivatives, benefiting both from free transfers of oil and from a low negotiated price for the rest of the oil imports (Khresat 2008). These favourable terms encouraged Jordan to increase its imports of crude petroleum without consideration of the implications for its increased energy dependence. Thus, whereas in 1990 the total imported of crude petroleum and its products was 3,471 thousand tons of oil equivalent (Ttoe), in 2000 this had risen to 4,815 Ttoe, further increasing slightly in 2002 to 4,954 Ttoe (MEMR 2003). This oil import reliance was reinforced by the low price of crude petroleum in the international market (at less than US$37 per barrel in the early 1990s) plus the low price for Jordan of imported energy, notably the electric energy supplied by Egypt and Syria.

Secondly, during this period, the unquestioned and growing dependency on oil imports was reinforced by negligible research and development in renewable energy resources, as well as the absence of a national energy audit. At this time there was no dedicated energy centre or institute in any Jordanian university, while there was also very little governmental awareness-raising or public education on energy efficiency or renewable energy.

2.2. THE ONSET OF ENERGY INSECURITY: 2003–2007

In this period, the volatile impacts on world energy markets resulting from the US-led invasion of Iraq (starting March 2003) were particularly significant for the Jordanian energy sector. No longer able to secure oil from Iraq on favourable terms, Jordan began to depend on Saudi crude oil and international oil derivatives. For the first time in recent history, Jordan was substantially exposed to the unpredictability of world oil markets and, more importantly, a period of rising oil prices. During 2004 the price of oil arriving at Jordan's single oil refinery at Zarqa was US$37.24 per barrel. In 2006 it had almost doubled to US$65.8 per barrel, and in 2007 it became US$74.3 per barrel. In the middle of 2008, the price had spiked at US$140 per barrel with uncertainty as to its whether this presaged a new era of peak oil (Jordan Oil Refinery Company 2008).

Not surprisingly, this substantial increase of the price of oil and its derivatives was fully felt in Jordanian expenditures on oil. During the year 2004, the national invoice for energy (including the electric energy from Egypt) was 1,153 million Jordanian Dinars (JD) for 5,236 Ttoe. In 2006, the energy invoice was 1,913 million JD for 5,048 Ttoe, and by 2007 it was 2,280 million JD for 4,910 Ttoe (Jordan Oil Refinery Company 2008).The last figure shows even with a decrease in total oil demand, increases in oil prices led to a jump in the national expenditure on oil. In fact the amount of oil in 2007 imported was less than that in 1995 but with about seven times increase in expenditure (above the 330 million JD expenditure in 1995).

In this period, the demand of primary energy and electricity in Jordan increased for various reasons, including industrialisation, urbanisation and population growth. A substantial and direct impact of the Iraq War on energy demand can be linked to the large numbers of Iraqis who fled to Jordan to escape the conflict. Indeed, it has been estimated that as many as 750,000 Iraqi refugees were living in Jordan by 2007. While accurate information on these refugees is limited, the large increases in Jordanian primary energy demand in 2004 and 2005, as shown in Table 3.1 (below), can at least be partly attributed to this major population influx.

2.3. MEETING INCREASED ENERGY DEMANDS: THE MOVE TO NATURAL GAS AND OIL SHALE

In response to rising energy demands and dependency, the Jordanian Government has made efforts this century to develop local fossil fuel resources and diversify energy imports. This development rests on attracting substantial private investment, as it has been estimated that US$2.5 billion is needed to expand supply capacity to meet forecasted demand in 2015 (Jaber et al. 2004: 176).

Table 3.1. Increasing demand for primary energy and electricity in Jordan, 2004–2007.

Primary energy	2004	2005	2006	2007
Crude oil and its products + neutral gas (Ttoe)	6,208	6,706	6,952	7,267
Imported electricity + renewable energy (Ttoe)	281	321	235	171
Total (Ttoe)	6,489	7,028	7,187	7,438
Percentage of increase	12.38	8.31	2.26	3.49
Electric energy				
Peak load (MW)	1,555	1,751	1,901	2,160
Percentage of increase	8.89	12.6	8.57	13.62
Generated electricity generated in Jordan (JWHr)	8,967	9,654	11,120	13,001
Percentage of increase	12.17	7.66	15.19	16.92

Source: National Electric Power Company (2008)

Indeed, since the early 1990s, all aspects of the energy sector – from oil and gas exploration and production to electricity generation, transmission and distribution – have undergone commercial restructuring in order to attract private sector investment.

Since 2002, domestic oil and gas production has in Jordan has remained modest. By 2006 only 1,200 t of crude oil was being produced, with 8.9 billion cubic feet (BCF) of natural gas: their combined contribution to overall energy consumption in the country was 3.8% (MEMR 2007: 20). The Ministry of Energy and Mineral Resources (MEMR) has now concluded agreements with companies from the US, Croatia, Holland and Ireland for oil and gas prospecting in the country. It is estimated that the country has 230 BCF of natural gas, with immediate outside interest (from the US company Anadarco) in intensifying extraction from the one developed gas field at Risha in the north-east corner of Jordan.

More significant to Jordanian energy needs has been the import of natural gas from Egypt since 2003. This involves a pipeline stretching from El-Arish in the Egyptian Sinai to Aqaba in southern Jordan and then extending to the north of the country, supplying the Aqaba, Rehab, and Al-Samra power plants with natural gas (see Chapter 10). The pipeline is transporting 318 million cubic feet per day. While the it cost US$500 million, the progressive conversion of these plants to run on natural gas rather than oil has led to substantial savings in energy expenditure for the government.

Jordan's rich oil shale reserves – the third largest in the world – have become increasingly important in planning for future energy demand: it is estimated that the 40 billion tons of oil shale reserves contain about 4 billion tons of oil (MEMR 2007: 20–22). The economic exploitation of these reserves has become more attractive with rising oil prices, although there are technical feasibility issues which have led the Jordanian Government to investigate two main methods of utilising the oil shale:

(i) Surface ionisation of oil shale to produce oil.
Three companies (International Company for Oil Shale and Investments, Jordan Oil Shale Company, Jordan Company of Minerals and Energy) signed memoranda of agreement in November 2006 to prepare feasibility studies of Al-Lajjun region to produce oil from the oil shale. Also, an agreement was signed in July 2007 with the Brasilian company, Petrobras, to assess surface mining possibilities for oil shale in the Attarat region.

(ii) In-situ conversion process.
Recently the government has concluded a commercial agreement with Shell to assess the prospects for producing oil from deep oil shale layers using a thermal injection method, which is called in-situ conversion process as it involves no mining. The full project, costing US$450 million, is expected to last from 13–18 years, with initial appraisal and assessment over by 2014, followed by the building and testing of a pilot project and test model. If a final investment decision is taken, the capacity of this project is forecast to be 350,000 oil barrels per day.

The energy security benefits to Jordan from the exploitation of its oil shale reserves have to be set against the significant environmental impacts caused by mining and processing. These include the production of greenhouse gas emissions, a large use of water resources and issues regarding the disposal of spent shale. While innovations in mining and processing techniques, like in-situ conversion, can reduce these environmental externalities, oil shale will never be a clean energy source.

3. Present situation of the Jordanian energy sector

As recently confirmed by Faruq al-Hiyari, Secretary General of MEMR, the Jordanian energy sector currently faces a number of significant challenges (Zawya 2008):

1. A *high level of dependence* on energy imports, with approximately 96% of Jordan energy demands is imported from outside the country. This is likely to continue in the near future given the modest endowment of commercially available fossil fuel resources.

2. A *heavy fiscal burden* caused by a substantial energy import bill. This was estimated by al-Hiyari to be 2.28 billion JD (US$3.21 billion) in 2007. The sharp increase in the price of oil and its derivatives in 2008, means that this energy import bill has risen significantly since 2007. Table 3.2 illustrates the changes in oil prices as experienced by Jordanian consumers in the first half of 2008. The rises were accentuated by the abandonment of domestic fuel subsidies in February 2008.

3. *Rapidly rising energy demand*. According to MEMR, Jordan's primary energy requirements are projected to rise 5.5% annually from 7.6 million tons of oil equivalent (Mtoe) in 2007 to 15 Mtoe in 2020. Furthermore, demand for electric power is predicted to rise 7.4% annually from 2.1 gigawatts (GW) in 2007 to 5.77 GW in 2020, requiring an additional power generation capacity of 4 GW (Arab Union of Producers, Transporters and Distributors of Electricity 2008; Zawya 2008).
4. *High energy consumption density* in Jordan (where energy consumption density is defined as the amount of energy required to produce one unit of national production). In 2006, the energy consumption density for developing countries was on average 590 kg oil equivalent per $1,000, and for developed countries it was 310 kg oil equivalent per $1,000. However, the energy consumption density in Jordan was 640 kg oil equivalent oil per $1,000 (Khresat 2008).

The above challenges suggest an ongoing scenario of energy insecurity in Jordan, which has in recent years finally been acknowledged by the political regime. In January 2007 His Majesty King Abdullah entrusted HRH Prince Hamzeh to chair a Royal Committee to review Jordan's National Energy Strategy and propose means for meeting Jordanian energy demands for the next 15 years. The committee formed subcommittees on oil, electricity and natural gas, renewable energy and energy conservation. As will now be discussed, from the work of this committee, political support for investment in renewable energy has been significantly boosted as part of a strategy to utilise more fully domestic energy resources in Jordan. However, this is by no means a comprehensive commitment to clean energy, as the Royal Committee affirmed its support for the large-scale extraction of domestic oil shale and, over the long-term, investment in nuclear power for power generation and water desalination (The Jordan Times 2007).

TABLE 3.2. Increases of oil product prices for Jordanian consumers in the first half of 2008.

	January	March	May	July	Rate of increase (%)
Liquefied gas – 12.5 kg cylinders (JD/cylinder)	6.5	6.5	6.5	6.5	–
Gasoline – Octane 90 (JD/l)	0.430	0.585	0.645	0.735	171
Gasoline – Octane 95 (JD/l)	0.640	0.665	0.740	0.840	131
Kerosene (JD/l)	0.315	0.600	0.630	0.770	244
Diesel (JD/l)	0.315	0.600	0.630	0.770	244

Source: Khresat (2008)

4. The energy sector national strategy

The original National Energy Strategy for Jordan was released in 2004, covering as a planning timeline the decade to 2015. This strategy considered a range of options to address increasing energy demands in Jordan and to reduce the dependence on imported energy. The overarching aim was for local energy resources to supply 28% of primary energy generation by 2010. In its review of the National Energy Strategy in 2007, the Royal Committee decided that this target was too ambitious: it was revised down to 25% in 2010, though with an ambitious target that local energy resources would be supplying 39% of primary energy needs by 2020 (The Jordan Times 2007). On the demand side, a desire to reduce peak electrical loads saw a stress on rational load management, alongside more modest efforts to fund energy efficiency measures, as well as recommendations to introduce tax exemptions for institutions investing in energy conservation and encourage energy-saving vehicles.

The National Strategy for the energy sector includes clear goals for increasing energy security:

1. Diversifying the supply of energy resources used for electricity generation
2. Developing and intensifying the use of conventional energy and renewable energy resources with additional investment in oil shale exploitation and nuclear power
3. Modernising and liberalising energy markets
4. Attracting long-term private sector investment in the energy sector, with a focus on foreign investment sources and privatisation of state-owned assets
5. Developing a robust energy audit for promoting energy saving in domestic consumption

As shown in Table 3.3, this strategy has particular supply aims for particular energy sources, reflecting a desire by 2020 to cut back substantially the proportion of oil imports (from 66% in 2007 to 40%) and imported electricity (from 7% in 2007 to 1%). While natural gas imports from Egypt and elsewhere are expected to increase, the intent is to allow only a modest increase in the proportion of national energy needs being met by gas. As already noted, development of the Risha Gas Field means that growing domestic production is also anticipated to contribute here. However, the aspiration for localising local energy production rests above all on the development of renewable energy, oil shale and nuclear energy – meeting together, it is forecast, 30% of Jordanian energy needs by 2020.

In its review and revision of the Energy Strategy, the 2007 Royal Committee also highlighted a number of specific recommendations relating to these different sources (Royal Committee on the National Energy Strategy 2007; MEMR 2008).

Table 3.3. Energy sources for Jordan in 2007, 2015, 2020.

	Supply of national energy needs (%)		
Energy source	2007	2015	2020
Imported electricity	7	2	1
Renewable energy	1	7	10
Oil products	66	51	40
Natural gas	26	29	29
Oil shale	–	11	14
Nuclear energy	–	–	6

Source: Data from Royal Committee on the National Energy Strategy (2007)

1. Renewable energy
   Accelerating the development of renewable energy, with 1,200 MW of generating capacity targeted for wind energy and solar thermal energy (see Section 5 below)
2. Oil products
   Modernising and expanding the crude distillation and petroleum product capacity of the Jordanian Petroleum Refining Company, with US$1.3 billion sought from an outside private investor
3. Natural gas
   Accelerating development of the Risha Gas Field on the basis of a memorandum of understanding with Anadarco Company and searching for new sources of gas (e.g. negotiating with Iraq to supply Jordan with natural gas through the Arab Natural Gas Pipeline)
4. Oil shale
   Creating a specialised scientific unit for oil shale development and driving more effectively the implementation of agreements on oil shale already signed with a number of domestic and foreign companies (notably the Estonian Governmental Electricity Company and Shell)
5. Nuclear energy
   Completing and following up feasibility studies for using nuclear energy to generate electricity in Jordan

Alongside the modernisation and expansion of energy generating capacity and infrastructure, sector, total investments in these sectors are estimated to require $14–18 billion private capital by 2020. Legal reforms to attract this capital include modernising the General Electricity Law, a privatisation drive in the energy sector with provisions for constructing electricity generating plants under a ‘Build, Own and Operate’ basis, new investor protection laws, and the introduction of transparent pricing policies.

5. Renewable energy

5.1. WIND ENERGY

Jordan already established the technical feasibility of wind energy generation by means of a pilot plant established in the late 1980s in Ibrahimyya towards the northeast corner of the country, followed in 1996 by the establishment of a second (German Government-sponsored) plant in nearby Hofa By 2006 these two wind turbine plants were producing nearly 2.8 MWh in electricity (Jaber et al. 2004: 178–179; MEMR 2007: 23). Studies have also been undertaken to examine ways of improving the wind energy market in Jordan and to determine the economic feasibility of a range of promising sites for the location of wind turbines. On the basis of these studies, the 2007 Royal Committee called for an acceleration in the deployment of wind energy projects in Jordan to produce in total 600 MW by 2015. Six projects have been declared feasible and are in various stages of tendering and commissioning by MEMR: the Al-Kamshah project in Jarash (anticipated 40 MW capacity), the Al-Fujaij project in Al-Shobak (70 MW capacity), the Al Harir project in Al-Tafeleh (capacity ranging from 150–200 MW), Wadi Araba project (capacity ranging from 40 to 50 MW), Ma'an project (capacity ranging from 100–150 MW), and Al-Mafraq project (capacity ranging from 100–150 MW) (MEMR 2008).

5.2. SOLAR ENERGY

Jordan (like the Middle East in general) has a very promising solar energy potential. The average solar radiation intensity in Jordan equals 5.5 kWh/m^2 and annual sunshine duration is 2,900 h, which is favourable for a range of solar heating and cooling applications. At the moment the main application of solar energy is in terms of a decentralised network of domestic solar water heaters, which are estimated to provide hot water for about a quarter of households in Jordan (Jaber et al. 2004: 179).

The Jordanian Government has an explicit aim of increasing the use of solar thermal technology in all sectors of the economy (Elshuraydeh 2006). There has been interest in commissioning a 5 MW pilot solar thermal plant in the Al-Qweira area, as proposed by a German solar energy company, though this is awaiting funding. In addition, the National Energy Research Centre (created in 1998 with a mandate to conduct research on new and renewable energy sources in Jordan, as well as promote energy efficiency measures) has overseen a number of ambitious pilot projects in the field of solar energy. One of these is the Aila Oasis Project, which features a Concentrating Solar Power (CSP) plant to provide electricity for an up-market coastal tourist resort on the Gulf of Aqaba, including energy for water desalination. There have also been important research projects on solar-powered water desalination undertaken with the US National Renewable Energy Laboratory and the German Solar Energy and Hydrogen Centre. The potential for desalinisation of brackish water in rural areas by small solar energy units is being seriously investigated by the Ministry of Water and Irrigation: this has important implications for agricultural planning in Jordan (Kabiriti 2006; MEMR 2007: 23). In addition, there is already extensive use of solar collectors for water heating purposes, both for small household units and also large collector systems for hospitals, hotels and other public buildings. The National Energy Strategy has a target of 50% adoption of solar energy for water heating needs by 2020, although this rests on lower user costs from larger scale domestic production as well as improved efficiencies in collector technology.

The Government of Jordan has been reluctant to promote solar photovoltaic (PV) technology. This unwillingness has been attributed to the high initial costs of this technology (Jaber et al. 2004: 180), though the head of the National Energy Research Centre has indicated that technical shortcomings are more relevant, notably the low electricity storage capacity of PV systems and its unreliability for national grid applications (Kabiriti 2006). However, PV technology still has a high potential for electrification in remote rural communities. A pilot rural PV electrification programme was launched in 2002, which generated positive feedback from household users of the installed PV solar home systems (Al Soud and Hrayshat 2004). That this programme has not been extensively rolled out is due to the focus of national energy policy priorities on national grid expansion, and the capacity increases needed to meet fast growing urban and industrial demands for electricity.

5.3. BIOENERGY

As pointed out by Jaber et al., biomass energy in Jordan seems to have little potential given the severe constraints on vegetation growth imposed by an arid climate. At best, small-scale biomass burning can meet localised cooking and heating needs, as traditionally practiced by desert-dwelling Bedouins (Jaber et al. 2004: 178). Governmental interest in bioenergy has focused on the energy potential from burning municipal solid waste and organic waste. Funded initially in 1998 by the United Nations Global Environment Facility and the Danish Government (with a contribution also from the Jordanian Government), the Rusaifa Waste Landfill site near Amman has piloted electricity generation from the firing of waste gas emissions, whilst also producing fertilisers. A new state company, the Bio-Gas Company was created to further bioenegy exploitation in Jordan, although so far this company has concentrated on upscaling the capacity and electricity production of the Rusaifa plant, which had reached a voltage capacity of 3.5 MW by 2006, so biogas exploitation remains a negligible contributor to national energy production.

5.4. OTHER RENEWABLE SOURCES

The Government of Jordan has shown an interest in exploiting other sources of renewable energy. In 2006 a Japanese-funded World Bank consultancy study reviewed the potential for *geothermal energy* in the country, concluding that it was not commercially viable in terms of electricity production. Nevertheless, the study noted the possibility of using geothermal energy for minor agricultural applications (e.g. greenhouse heating, fish farming), with potential central heating applications in the future (MEMR 2007: 25).

There are currently two modest *hydropower* sources in Jordan – the King Talal dam and hydroturbines at the Aqaba thermal power station (Jaber et al. 2004: 178). The King Talal dam, situated in northern Jordan, was constructed in the 1970s with the dam heightened in the 1980s to increase capacity: it has an electricity generating capacity of 5 MW. At the Aqaba power station (fuelled by natural gas), which has a total electricity generating capacity of 656 MW, two hydroturbines utilise cooling seawater to generate 6 MW.

More substantially, there is the potential for major hydropower energy capacity to be exploited if the construction of a proposed Red Sea and Mediterranean-Dead Sea Canal takes place. In May 2005, Jordan, Israel and the Palestinian Authority agreed jointly to study the feasibility of such a conveyance channel to transfer seawater 180 km from the Gulf of Aqaba to the Dead Sea, and this "peace conduit" is currently the subject of a US$15 million feasibility study managed by the World Bank. The 400 m drop in height from the Red Sea would facilitate, it is estimated, a 310 MW hydropower station. However, such is the electrical capacity needed to power the large-scale desalination plants planned for this mega-project (producing up to 840–850 million cubic metres/year of fresh water), the hydropower capacity would save no more than 30% of the external energy which would otherwise be required to power the reverse osmosis desalination processes and associated water pumping (Beyth 2007). Thus, the substantial water supply potential is seen as overriding any concern to provide any net energy production gains to the region.

5.5. REGULATORY INCENTIVES FOR RENEWABLE ENERGY

In its bid to promote renewable energy in the country, the Government of Jordan has recently undertaken a number key of regulatory moves. These are supported by an IMF-guided restructuring of the energy sector that took place in 1999, with the unbundling of a single state-owned energy utility into three public companies responsible for generation, transmission and distribution. A new Electricity Law passed in April 1999 set up a regulatory framework creating conditions favourable for private capital investment, notably the shift to the Independent Power Production model of energy sector investment, which is internationally acknowledged by global investors and multilateral development banks. The recent fiscal and legal moves to encourage investment in renewable energy in Jordan must be seen in this wider regulatory context, and arguably have made more likely the possibility of the country reaching its National Energy Strategy target that renewable sources meet 10% of national energy needs by 2020.

Firstly, in April 2008 the Government approved the exemption of imported solar technology both from a 16% national sales tax and 23% customs duties. Combined with high oil prices, this has already boosted renewable energy investment and the shift by some Jordanian businesses to solar energy, with UAE-based Millennium Energy Industries a leading player facilitating the industrial and commercial adoption of solar technologies in the country (The Jordan Times 2008).

Secondly, a *draft renewable energy law* was published in 2007 and submitted for review to relevant energy sector institutions in Jordan, notably the Electricity Regulatory Commission, the National Electric Power Company and the National Energy Research Centre. This draft renewable energy law was based on the input of Lahmeyer International, a German engineering consultancy, and accords MEMR the authority to approve and license Qualified Renewable Energy Plants. Key regulatory incentives in the draft law include the state provision of development sites at favourable rates, 75% income tax exemptions for the first 10 years of profits of Qualified Renewable Energy Plants, and exemptions from other legal revenue charges otherwise due on construction, operation and maintenance contracts. Furthermore, renewable energy power plants would be able to reduce their electricity tariffs by Kyoto Protocol Clean Development Mechanism proceeds (Huse 2008). As at September 2008, the draft renewable energy law had passed pre-parliamentary legal scrutiny and was expected to receive approval during the 2008/2009 session of the Jordanian Parliament.

6. Conclusions

Jordan retains a substantial dependence on foreign energy sources with 96% of its needs served by energy imports. The US-led invasion of Iraq in 2003 exposed sharply the oil supply vulnerability of Jordan and prompted official efforts to diversify energy imports and develop domestic energy resources. These developments took place against the backdrop of an IMF-steered restructuring of the energy sector to render it more amenable to market liberalisation and foreign investment. Political support for investment in renewable energy in Jordan was boosted by the 2007 findings of a Royal Committee on the National Energy Strategy, and there is now a government target that renewable sources meet 10% of national energy needs by 2020. The positive environmental outcomes of this commitment to clean energy are somewhat diluted by a plan also to invest significantly in the extraction and processing of Jordan's large oil shale reserves. However, this is not surprising given that the move to renewable energy sources is driven far more by a national commitment to increased energy security than environmental protection considerations. The partial shift to renewable energy rests, therefore, on a correspondence to strategic political and economic motivations, but this is still an ambitious move that deserves support from those external actors (IMF, World Bank, US) still seeking to influence Jordan's development pathway.

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RENEWABLE ENERGY PROFILE FOR LEBANON

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Abstract: Renewable energy has not been a priority for the Lebanese Government, even though the country is dependent on fossil fuel imports for 97% of its energy needs. Renewable energy sources contribute less than 2% to domestic energy use, with most of this derived from hydroelectric power plants. However, there are plans to increase hydroelectricity from additional dam construction. In addition, the Lebanese energy ministry and state-owned energy company have expressed a strong interest in solar energy applications. International financial and technical assistance is necessary to enable Lebanon to increase significantly its capacity for harnessing renewable energy.

Keywords: Lebanon, solar energy, wind energy, hydro electricity, electricity, renewable energy

1. Introduction: geographical context

Located on the eastern shores of the Mediterranean Sea between the North Latitudes 33° 03′ 38″ and 34° 41′ 35″ and East Longitudes 35° 06′ 22″ and 36° 37′ 22″, Lebanon covers an area of 10,452 km^2, with an average width of 48 km and an average length of 220 km.

The climate of Lebanon is alpine in the mountains and Mediterranean along the coast. All four seasons are equally distributed throughout the year. The rain in winter can be torrential and snow falls on mountains above 1,000 m. There is high humidity in the coastal regions with hot, rainless summers.

There has been one official national climatic study performed in the 1960s, documented under the publication *Atlas Climatique du Liban* (Service Météorologique du Liban 1976). This atlas indicates the climatic specificity of the various Lebanese regions. These can be grouped into four general climatic zones (Figure 4.1):

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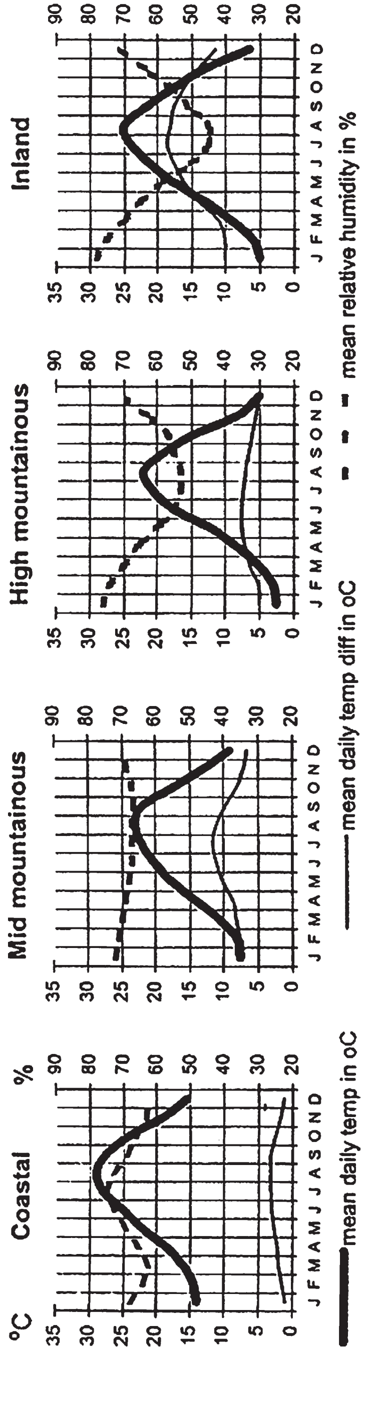

Figure 4.1. Climatic zones of Lebanon (Ministry of Energy and Water, Lebanon).

- Coastal zone: (altitude 0 to 500 m) exhibiting a Mediterranean maritime climate characterised by hot humid summers and mild winters
- Mid-mountainous zone: (altitude 500 to 900 m) a region characterised by mild summers and cool to cold winters
- High mountainous zone: (altitude over 900 m) a region characterised by cool summers and cold snowy winters
- Inland zone: (variable altitude) a valley plane exhibiting continental tendencies characterised by a marked diurnal temperature drop

2. The energy situation

2.1. CONVENTIONAL ENERGY SOURCES AND PRODUCTION

The energy sector in Lebanon plays an important role in the overall development of the country. Apart from a modest amount of hydropower and traditional energy (wood and charcoal) which together represent less than 2% of energy consumption, all energy in Lebanon is derived from imported petroleum products and some coal used by two cement factories. Prior to the 2006 war, there were two refineries in operation, but both were badly damaged and are currently out of operation.

2.2. RENEWABLE ENERGY RESOURCES

2.2.1. Solar energy resources

Solar data in Lebanon have been collected for both the coastal and interior zones. The coastal solar insolations are found from measurements made at Beirut Airport for the years 1965–1975. In the interior zone, the solar insolations are obtained from measurements made at Ksara station for the years 1956–1965. The following table illustrates the averaged values of the total solar insolation on a horizontal surface, as well as other important data (Table 4.1).

2.2.2. Wind energy resources

Historical data concerning wind speeds in Lebanon are taken from the *Climatic Atlas of Lebanon* (Service Météorologique du Liban 1976) which provides measurements made at nine stations. These are Beirut-Aerogare, Ceders, Rayak, Ksara, Beirut-Khalde, Marjayoun, Qlaiat, Tripoli-Mina, and Dahr-EI-Baidar. Only in four of these nine stations do the available data registrations provide information about the distributions of wind speeds over time. These are: Beirut-Airport, Ceders, Rayak and Ksara. The registrations for the five remaining stations provide only frequency distributions of wind speeds.

TABLE 4.1. Solar data for Lebanon.

Month	Coastal insolation kWh/m2/day	Interior insolation kWh/m^2/day	Coastal sunshine hours (h)	Interior sunshine hours (h)	Day length (h)
January	2.4	2.4	4.6	4.5	10
February	3.2	3.4	5.6	5.5	10.8
March	4.1	4.4	6.4	6.4	11.8
April	5.5	5.9	7.7	8.5	12.9
May	6.6	7.2	10.1	10.5	13.8
June	7.3	8.5	11.5	13.1	14.2
July	7.0	8.4	11.4	13.2	14
August	6.3	7.7	10.6	12.4	13.2
September	5.3	6.5	10.4	11.2	12.1
October	4	4.7	8.1	9	11
November	2.9	3.3	6.4	6.7	10.2
December	2.3	2.4	5	4.8	9.8

The stations where the wind speeds have been recorded are spread over the three zones of the Lebanese territory:

- The littoral zone: Qlaiat, Tripoli-Mina, Beirut-Aerogare and Beirut-Khalde
- The mountain zone: Ceders and Daihr-EI-Baidar
- The interior zone: Rayak, Ksara and Marjayoun

For each of these stations, frequency measurements within five wind speed intervals have been averaged over the years of operation of the stations. Since the variation of wind speed in time is needed, and since five stations have only frequency distribution, an attempt was made in to get time distribution from frequency distribution. The results of such calculations together with measured data for the remaining four stations are shown in the table below (Table 4.2).

2.2.3. Hydroelectric resources

The installed capacity of hydroelectric power plants in Lebanon is distributed as follows:

1. Litani plants: three power plants with a total capacity of 190 MW
2. Ibrahim River: three plants with a total capacity of 32.5 MW
3. Safa plant: 13 MW of capacity
4. Bared plants: two plants with a total capacity of 17 MW
5. Kadisha plants: three plants with a total capacity of 19 MW

The total installed capacity of the above plants is 283.1 MW but the actual capacity is 211.7 MW. The yearly average of the electric energy generated from these plants (calculated until 1994) was 994 GWh.

TABLE 4.2. Wind data for Lebanon.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg./year
Beirut-Airport	4.6	4.9	5.2	4.4	3.9	4.3	4.6	4.0	3.5	3.2	3.2	4.2	4.17
Ceders	2.9	3.1	3.4	3.0	3.3	2.9	2.7	2.4	2.1	2.8	2.3	2.8	2.81
Rayak	3.4	3.8	4.3	3.9	3.5	3.7	3.7	3.4	3.2	3.1	3.2	3.2	3.53
Ksara	3.2	3.8	4.2	3.9	4.5	4.8	4.2	3.4	2.6	2.4	2.9	3.68	
Khalde	3.35	2.97	3.26	2.72	2.42	2.85	3.45	2.86	2.08	2.07	2.06	34	2.76
Marjayoun	4.24	4.16	4.88	4.24	4.59	5.19	5.78	5.4	46	4.07	3.84	3.93	4.58
Qlaiat	5.33	5.51	5.41	4.19	3.74	3.75	4.16	3.57	3.47	3.89	4.41	5.56	4.42
Tripoli-Mina	4.23	4.38	5.12	.4.35	3.76	4.68	4.72	3.72	2.65	2.51	3.01	3.74	3.91
Dahr-El-Baidar	4.67	4.87	5.63	5.06	3.98	4.59	5.05	4.48	3.33	3.1	2.96	4.44	4.35

Lebanon aims at maximising its benefits from existing water resources. As such, two studies have already been completed which confirm the feasibility for building two new dams – Chabrouh near Faraya with a capacity of 8 million cubic metres and Bisri with 120 million cubic metres. As set out in the Lebanese 10-year strategic plan on energy and water (Comair 1999), other pre-feasibility studies are underway regarding the construction of up to 16 dams along Lebanese rivers:

– Rivers of north Lebanon: seven dams with a capacity of 220 million cubic metres
– Mount Lebanon: six dams with a capacity of 223 million cubic metres
– South Lebanon: one dam of 120 million cubic metres
– Bekaa: two dams with a capacity of 50 million cubic metres

It is estimated that 250 MW could be added from such an expansion in hydroelectric capacity.

3. Electricity production and consumption

Electricity in Lebanon is supplied through Électricité du Liban (EDL), an autonomous state-owned entity under the jurisdiction of the Ministry of Energy and Water (MEW). Established in 1964 following nationalisation of the main electricity generator in Lebanon, EDL took over the maintenance and operation of the bulk of national electricity generation and distribution, as well as all new electricity generating plants created since that year. EDL currently provides 85% of the electricity needs in Lebanon, and private generators owned by industrial plants and commercial facilities generate the reminder. As concessions to these private contractors expire, ownership and control reverts to EDL.

EDL's major generating units are thermal (steam turbines, gas turbines and combined cycles): 10–12% of EDL electricity production is generated by the hydro power plants with another 10–12% of capacity purchased from Syria. The electricity generating plants comprise the following units:

- Fifteen hydroelectric plants having a combined capacity of 281 MW constituting 19% of the total nominal capacity. The Awali plant is the largest of these with 109.5 MW capacity.
- Three major thermal plants with combined nominal capacity of about 1,300 MW, comprising Zouk (61% of capacity), Jieh (26%) and Hrayshe (13%).
- Four 35 MW diesel fueled open cycle gas turbines (on stream since 1996).
- Two 435 MW combined cycle plants (on stream since 1998).

TABLE 4.3. Electric energy generation and demand during 1996–1999.

Energy source/year	1996	1997	1998	1999
Thermal	6,008	6,973	7,560	9,280
Hydraulic	799	739	786	786
Import from Syria	684	609	654	655
Total	7,491	8,321	9,000	10,720
Demand	8,635	9,470	9,973	10,818

At the end of 1993, EDL had an operating capacity of about 700 MW while the demand was estimated at 1,200 MW. The generation capacity has since increased to 2,319 MW though the actual available capacity is 1,880 MW. Full power may be available only when the construction of a new 220 kV transmission network is completed. The table above (Table 4.3) provides information on Lebanese electricity generation and demand, in GWh, for the period 1996 to 1999.

Following the 15-year civil war (1975–1990), the work on the rehabilitation programme for power plants started in 1993 is now completed; yet there is still a lot of deterioration that has to be addressed, especially on the transport lines and distribution systems. Electricity is now available to consumers in Greater Beirut 24 hours a day, with the power supply temporarily being augmented by electricity purchases from Syria in the range of 50–100 MW annually.

4. The institutional framework

4.1. STRATEGIES, POLICY ISSUES AND PLANNING MEASURES

The Council for Development and Reconstruction (CDR) is the government agency that has been entrusted with the key role in the process of reconstruction and expansion of the electricity sector. The total value of contracts awarded so far in the electricity sector has reached approximately US$1.4 billion. At the end of the war, the rehabilitation programme permitted the restoration of generating and transmission capacity (starting, from the end of 1996, with a production capacity of 1,250 MW). The cost of this programme, which covers three parts, reached a total of US$341 million as follows:

- Contract for rehabilitation of thermal and hydroelectric power plants
- Contract for rehabilitation of power transmission network (66 kV)
- Contracts for rehabilitation of power distribution networks

Several complementary contracts concerning supervision, co-ordination and supply of equipment were awarded for a total value of US$35 million.

Electric energy demand in Lebanon has been increasing continuously since the early 1990s, and has been growing since 2000 at an average of 3–5% per year. To address this increasing demand, a plan was designed for the rehabilitation of the existing energy infrastructure and the modernisation of the electricity sector. This plan aimed in particular at increasing power generation capacity, extension of transmission networks, and implementation of administrative reform and provision of technical assistance. In brief, short and medium term measures have been adopted by EDL and are defined as follows:

1. *Short-term measures*. Interim operation contracting arrangements within the current legal framework will be considered by EDL including the new combined cycle power plants at Beddaoui and Zehrani. In addition, the Government intends to contract the management of the existing Zouk and Jieh power plants, and the new gas turbines at Baalbeck and Tyre.
2. *Medium-term measures*. The Government intends to present to parliament a comprehensive new electricity law which would provide a competitive power market through the separation of electricity generation, transmission and distribution functions. The private sector will be invited to participiple in electricity generation and distribution throughout Lebanon. As a further step towards greater private sector participation, the Government intends to authorise the setting up of independent power producers.

Of particular interest to this process has been the *Power Sector Restructuring and Transmission Expansion Project*, agreed on between the Government and the World Bank. The project, which took place between 1996 and 2003, entailed the implementation of a set of sector-wide structuring and reform actions designed to introduce competition and private sector participation in utility operations and also to reorganise EDL. Key elements of the programme included:

1. Unbundling the vertically integrated EDL into separate production, transmission a distribution functions
2. Establishing several privately-operated regional distribution concessions
3. Introducing new laws providing for the separation of electricity generation, transmission and distribution functions and the establishment of an autonomous regulatory agency
4. Adopting a programme to cut non-technical losses (currently over 40% of production is lost) and to continue to improve collection capacity
5. Implementing revenue-sharing arrangements with private sector companies pursuant to which private operators would lease and operate certain assets of EDL, with a view to a gradual phase-out of state subsidies (currently in excess of US$100 million per year)

Following the conclusion of the World Bank Project, a number of follow-up projects are under preparation by EDL: estimated to cost about US$600 million, they cover the following:

- A contract for the preparation of a study concerning interconnection of the Lebanese and Syrian networks by means of a 400 kV overhead line.
- A contract for the preparation of a study concerning the use of natural gas in Lebanese power plants.
- Installation of a national control and dispatching center, the management of which has gone out to tender: the offers received from potential contractors are currently under evaluation.
- Rehabilitation of the distribution network. EDL prepared the preliminary study for this project.
- Replacement of two Toshiba turbines (2 × 62 MW) at the termination of works at Jieh power plant.

On the technical assistance and management levels, the national plan stands today as follows:

- Technical assistance to EDL to cover the provision of experts to the various sections of power generation, transmission, equipment and planning.
- Improvement of the management system for MV subscribers. This contract has permitted the supply of the necessary equipment and meters for 1,100 private stations.
- Collection improvement plan. These services permitted doubling the amount collected from clients in the concerned zone (43 municipalities in Beirut suburbs).
- Training of EDL personnel in the fields of transmission and distribution.
- Management assistance for a period of 36 months. This contract aims at setting up in EDL a management system which meets international standards for energy utilities. Experts provided by the awarded consortium will work together with EDL's personnel in the main management sections.

4.2. THE RENEWABLE ENERGY INSTITUTIONAL FRAMEWORK

Renewable energy systems are still not a priority for the Lebanese government. This situation is confirmed by the fact that the contribution of renewable energy to Lebanese energy needs is less than 2% and comes mainly from hydropower, with a minor contribution from wood, charcoal and solar energy for the production of hot water.

On the other hand, officials at MEW and EDL have repeatedly expressed their support for renewable energy utilization, particularly concerning solar energy applications. So far nationally, only very modest applications related mainly to solar water heaters can be observed, which reflects the emphasis on these water heaters as the most important renewable energy application for long-term energy conservation in Lebanon. Yet there are many technical, financial and political obstacles to the widespread diffusion of solar water heaters (Chedid 2002). Major efforts are still needed to overcome this situation and promote the use of renewable energy more generally. These efforts are the shared responsibility of the government, EDL, NGOs and educational and research centres. Additionally, some efforts to promote renewable energy are being made by some international organisations such as UNDP, ESCWA, EU and other donor agencies operating in Lebanon.

The successful adoption of renewable energy in Lebanon will require the coordinated participation of a wide range of decision makers and stakeholder. The main stakeholders in the field of renewable energy are:

The Ministry of Energy and Water (*MEW*). The main governmental energy stakeholder in Lebanon is MEW, which holds the power of guardianship over the public authorities within its ministry. Among these authorities are the electricity utility (EDL) and the National Litani Authority (ONL). MEW also supervises energy concessions such as the Kadicha, Nahr Ibrahim, Jbeil and others.

The Energy Steering Committee (*ESC*). ESC is a government-approved committee (Decision no 119/1/a dated 21/11/97 by MEW) for coordinating activities related to energy conservation and the national use of energy. It is charged with directing the structural preparations leading to the eventual emergence of a fully autonomous Ministry of Energy in Lebanon.

The Council for Development and Reconstruction (*CDR*). The CDR is a government agency entrusted with a key role in the process of reconstruction and economic recovery. It was established in 1977 in response to the needs of reconstruction as a successor to the Ministry of Planning and was re-organised in 1991. The CDR is responsible for formulating and monitoring the implementation of public investment projects as well as seeking foreign funding, and in this capacity has a key role in facilitating finance for investment in renewable energy; e.g. see the recent renewable energy project discussed below at Section 6.1.3.

The United Nations Development Programme (UNDP). UNDP involvement in the energy and environment sector has been through the office of sustainable development. Through it Lebanese office in Beirut, UNDP has sponsored and is planning to sponsor several relevant activities as described in Section 5.2 below.

The Economic and Social Council of West Asia (ESCWA). ESCWA have their headquarters in Beirut. Their involvement in renewable energy is through the Energy Section which is a part of ESCWA's Energy, Natural Resources and Environment Division. ESCWA has been very active in promoting renewable energy, and stresses that there is a tremendous renewable energy resource potential in different ESCWA member states.

The European Commission (*EC*). The European Commission has been very active in all activities related to the National Emergency and Reconstruction Program (NERP) which was launched by the government of Lebanon in 1992. One of the major projects sponsored by the EC is the Investment Planning Programme (IPP) for Lebanon – a programme for economic and social development with an EC budget of €25,000,000. IPP includes a Management Support Consultancy (MSC) for Energy. The major focus of the MSC-Energy project is on energy efficiency, renewable energy and energy policy. Earlier in 1994, the European Union had sponsored the first solar energy symposium in Lebanon where experts from both Lebanon and Europe discussed the possibility of harnessing renewable energy.

5. The status of renewable energy development

5.1. RENEWABLE ENERGY ASSESSMENT

There are various initiatives underway to assess and monitor the penetration of renewable energy technologies in Lebanon. For example, the American University of Beirut is carrying out a renewable energy resource assessment, while the Lebanese Association for Energy Saving and Environment is developing a record of the penetration of renewable energy applications in Lebanon. In addition, the Lebanese Centre for Energy Conversation is monitoring the application on site on renewable energy facilities under the authority of the Ministry of Energy and Water.

5.2. RESEARCH AND DEVELOPMENT

Research and development in the area of renewable energy is being carried out by major Lebanese universities and by the National Council for Scientific Research (NCSR). NCSR was created by the law in 1962, as a public establishment to act as a consulting body for the government, to advance national scientific policy, and obtain optimum use of the country scientific resources for the benefit of all. NCSR has a renewable energy division that addresses, besides the promotion of renewable energy technologies, energy efficiency and conservation concepts.

Additionally, active research is taking place in major Lebanese universities in the following areas:

- Experimental and numerical studies of solar heating and radiative cooling systems for storing thermal energy
- The modelling and simulation of heating and cooling of buildings using a solar energy absorption system
- The development of decision support techniques for the analysis of autonomous and grid-connected renewable energy systems
- The modelling and robust control of wind energy conversion systems
- The environmental and operational assessment of distribution networks combining conventional and renewable energy sources
- The application of fuzzy linear programming to the allocation of energy resources
- The application of intelligent control to wind energy conversion systems
- The development of probabilistic approaches for the performance assessment of autonomous renewable energy conversion systems

6. Current coordination and cooperation programmes

6.1. WITH REGIONAL AND UN ORGANISATIONS

6.1.1. Climate change enabling activities (Participating parties: UNDP, Ministry of Environment, CDR)

This Global Environment Facility (GEF) climate change enabling activity was initiated at the Ministry of Environment in 1997. It was composed of three parts. Part one involved compiling an inventory of greenhouse gases (GHG) emissions for the year 1994 and also identifying major sectoral activities contributing to Lebanese GHG emissions. The inventory was successfully completed in March 1998. The second part involved the setting of mitigation options for GHG reduction (renewable energy systems constituted major mitigation options for the power supply sector, and solar water heaters were selected as the major mitigation option for the residential and commercial sectors). This part was initiated in July 1998 and finished in September 1999. The third part concerned climate change adaptation in order to identify the likely regional and local damage due to increase in global GHG emissions. This part was also initiated in July 1998 and finished in September 1999.

6.1.2. Promotion of the use of solar domestic water heaters in Lebanon (Responsible parties: UNDP, MEW)

Rising energy bills have become a considerable burden on Lebanese economy, both at the national and household levels. At the household level, energy intensity is high due to the large use of energy consuming appliances which make electricity consumption in the residential sector around 60% of total electric energy supplied of total household electricity consumption. By themselves, domestic water heaters consume around 22% of household electricity. Therefore, the provision of domestic solar water heaters (DSWH) will greatly contribute to reductions of electricity bills.

The activities and outputs of this project are the:

- Identification and removal of barriers preventing the widespread of DSWH
- Establishment of a national standard for DSWH
- Installation of DSWH in model villages
- Establishment of institutional mechanisms to disseminate DSWH in Lebanon
- Production of a national awareness campaign
- Development of capacity for the domestic commercialization of solar water heaters

6.1.3. Energy efficiency and renewable energy project in the public sector (Responsible parties: UNDP, CDR)

This project, which began in October 2007, assists directly in reconstruction of energy infrastructure in three areas (South, Bekaa and Akkar) heavily affected by the summer 2006 conflict. With a budget of US$2.73 million donated by the Spanish Government, the project is paying for the installation of energy efficiency measures (e.g. thermal insulation, energy efficiency lamps) and renewable energy equipment (e.g. solar water heaters for hospitals and schools, solar PV for external street lighting) in public buildings and facilities (Government of Lebanon and United Nations Development Programme 2007).

6.1.4. Lebanese centre for energy conversation project (Responsible parties: UNDP, MEW)

Lebanon imports about 97% of its energy needs in the form of fossil fuels, 30% of which is used by the power sector for electricity production. Additionally, the electric power demand is increasing yearly at a rate of 3–5% and threatens soon to exceed the supply. As a result, interest in renewable energy on the levels of both generation and end-use applications, as well as policies on energy efficiency and conservation, are increasingly gaining support (Comair 2006).

This proposed GEF project aims at creating a mechanism to launch and institutionalise short, medium and long-term energy conservation planning through the creation of an energy conservation center. The tasks of such a centre will first identify major barriers preventing the widespread implementation of both renewable energy and energy efficient measures, and second help the Lebanese government to adopt policies and measures to include and achieve energy conservation targets and promote renewable energy applications.

6.1.5. Regional awareness-raising on renewable energy in Lebanon (Responsible party: MEW)

MEW has presented the Lebanese experience on renewable energy at a diverse range of regional conferences and meetings, with a view to share expertise and domestic promote capacity-building on renewable energy. Recently this has included a February 2006 workshop in Beirut on efficiency and renewable energy, co-hosted with the Water, Energy and Environment Research Centre at Notre Dame University, the Lebanese Centre for Energy Conservation Project and ESCWA; and also a presentation at ENERGAIA, the International Exhibition on Renewable Energies held in Montpellier in December 2007 (Comair 2007).

6.2. WITH DONOR AGENCIES AND/OR COUNTRIES

6.2.1. Investment planning programme: Management support consultancy for energy (Responsible party: European Commission – Directorate General 1B)

As described in Section 4.2 above, the Management Support Consultancy for Energy (MSC-Energy) is one of the six modules in the EC sponsored Investment Planning Program (IPP) for Lebanon. Each individual module is managed by a line ministry or a Lebanese institution entrusted with the planning and implementation of nation-wide sectoral infrastructure investment programmes. Among the planned activities in the energy sector, managed with MEW, are the:

- Evaluation of technical and economic data concerning economic resources such as hydro, solar, wind etc.
- Assessment of the type and efficiencies of final energy consumption
- Formulation of energy efficiency policy to include both short-term measures for the adjustment of existing practices and long-term measures to improve energy efficiency throughout the energy cycle
- Promotion of renewable energy
- Provision of assistance to MEW in elaborating energy plans at national and local levels

The duration of the IPP project is 3.5 years. The total costs amount to €30 million shared between the Lebanese government (€5 million) and the EC (€25 million).

7. Potential fields of cooperation with other ESCWA member states

There is a significant potential for Lebanese cooperation with other ESCWA member states on renewable energy. From its side, Lebanon can offer, through its universities and its NCSR, theoretical research and training in the areas of solar, wind, hydro and biomass technologies. Major Lebanese consulting firms can offer services in feasibility and engineering studies related to the integration of renewable energy systems into existing power systems.

At the same time, Lebanon needs assistance in the following areas:

- Training in the manufacturing of solar and wind energy systems
- Training in the installation, operation and maintenance of various renewable energy systems
- Development of a wind, solar and hydro atlas to pinpoint the most favourable geographical areas for the uptake of particular renewable energies
- Awareness campaigns
- Technology transfer for demonstration purposes
- Exchange of practical knowledge with countries having working renewable energy installations

There are undoubtedly economics of scale and mutual learning to be reaped from ESCWA cooperation on renewable energy. Like other ESCWA member states, though, international financial and technical assistance is necessary to enable Lebanon to increase significantly its capacity for harnessing renewable energy.

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ENERGY PROFILE AND THE POTENTIAL OF RENEWABLE ENERGY SOURCES IN PALESTINE

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Abstract: The energy situation in Palestine is somewhat unique when compared to other countries in the Middle East. There are virtually no available natural resources, and due to the ongoing political situation, the Palestinians rely (or have to rely) almost totally on Israel for their energy needs. Palestine faces continuing growth in energy demands, especially electricity, across all sectors and by necessity future generation expansion will rely substantially upon increasingly expensive fossil fuels. These factors create strong economic and environmental incentives both to invest in renewable energy sources and also to undertake energy efficiency and conservation measures in sectors with high energy consumption. However, the Palestinian Authority has yet to take renewable energy seriously in energy planning.

Keywords: Palestine, energy, electricity, biogas, solar energy, wind energy

1. Introduction

Energy is of vital importance for the processes of production and manufacturing and also a key element of sustainable development in that the fossil fuels supplies are finite, and increasing attention is going to sources of energy that are renewable in the sense that they can be used without exhausting the source of the energy.

All fossil energy consumed today (coal, oil and natural gas) comes from the sun's energy, and is stored solar energy – but it was of course stored in plants millions of years ago, and once used, it cannot be regenerated on a human time scale. The earth's remaining fossil fuel reserves can probably provide us with energy for another 1 or 2 centuries, but this is an insignificant amount of time in terms of the whole past history of human civilisation.

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Palestine is a developing nation in great need of all types of energy for economic growth and human development. Most Palestinian people have access to electricity, whether by the general electricity network or by small community diesel generators (Palestinian Ministry of Energy and Natural Resources 2006). However, there are unusual constraints on energy development in the West Bank and Gaza. Palestine has no developed domestic energy resources, and relies heavily on imports from Israel. Energy insecurity is further reinforced by the fact that Israel controls the quantity and condition of energy imported into Palestine. For example, Israeli control of Palestinian borders prevents open trade in electricity and petroleum products between the Palestinian Authority (PA) and other countries: Israel is therefore able to impose non-competitive energy prices and tariffs on the Palestinian Authority (World Bank Sustainable Development Department: Middle East and North Africa 2007). Israeli threats to stop pumping fuels and to cut electricity – most recently for Gaza – demonstrate the precariousness of energy supply for Palestinians in a complex political and security situation.

In these circumstances, the possibility of using such renewable energy technologies as solar thermal and solar photovoltaic has become an option for the Palestinians, especially as Palestine is gifted with huge solar radiation. This type of renewable energy is already extensively utilised in domestic water heating in Palestine, but the commercial feasibility for producing electricity has been questioned because of the high cost of photovoltaic systems per watt. High oil prices and the desire for national energy sovereignty have recently led to a reconsideration of the potential for renewable energy in at least meeting part of growing Palestinian energy needs.

At the same time, reducing wasteful energy consumption through industrial modernisation and efficiency savings is considered another important means for reducing the problem of energy insecurity in Palestine (and this would also lower domestic environmental emissions). The energy demands of Palestinian industries account for approximately 6% to 7% of the national energy demand (Palestinian Ministry of Energy and Natural Resources 2006). Individual industries and businesses have different demands, which are met from various combinations of on-site heat and power generation from delivered fuels, electricity and gas consumption from mains supplies. Fuel and energy consumption rates and energy processes depend on the type of product produced. As the industrial sector is one of the largest energy consuming sectors in Palestine, this chapter also considers the scope for energy efficiency improvements and cost saving measures in different industries in Palestine.

This chapter highlights the importance and the need for the renewable energy applications in Palestine, addressing the potential and possibility of adopting renewable energy resources, in particular for sectors with high energy consumption. Such an uptake of renewable energy would reduce conventional energy consumption and imports, potentially releasing money for other public expenditures and also reducing environmental emissions. The discussion here on renewable energy is based on data collection and analysis conducted by the Energy Research Centre (ERC) at An-Najah National University (ANNU).

2. Energy sources in Palestine

In general, Palestine is considered as one of the poorest countries in the Middle East in terms of energy sources. Domestic energy sources are dwindling or non-existent. These indigenous energy resources are limited to solar energy for photovoltaic and thermal applications (mainly for water heating), and biomass (wood and agricultural waste) for cooking and heating in rural areas. The potential of wind energy is relatively small but not yet utilised in Palestine. Biogas also is not yet utilised in the large scale (see Section 5 below).

From the perspective of its energy sector, Palestine is in an unusual position in at least three respects (World Bank Sustainable Development Department: Middle East and North Africa 2007).

(i) Firstly, as a small energy market with no developed domestic resources of commercial energy, it is almost entirely dependent on imported energy supplies, specifically electricity and oil products. Palestine imports 100% of its needs of petroleum products and 95% of electricity from the Israeli market due to the absence of fossil fuel resources.

(ii) A second unusual challenge faced by Palestine is its physical fragmentation into two distinct geographical zones with divergent economic characteristics – the West Bank and Gaza Strip. The energy supply situation in Gaza is more favourable: British Gas Company discovered substantial offshore natural gas reserves in 2000. British Gas has signed a 25-year contract to explore for gas and to set up a gas network in the Palestinian Authority.

(iii) A third unusual challenge is the constraints imposed by Israeli policies and actions on the ability of the Palestinian Authority to operate and develop its energy systems.

The national independent power system of Palestine is still under construction and rehabilitation. The Palestinian Energy Authority conducted the construction of an electricity station in Gaza with a generation capacity of 140 MW at the first phase. Following extensive damage from an Israeli bombing raid in July 2006, this station is now partially operational producing one third of its full capacity, which is 60 MW. The main source of fuel for this station was supposed to be natural gas, but due to political obstacles which caused the halting of the project for production of natural gas from Gaza sea, the station uses diesel for energy: thus there is no production of natural energy products in Palestine as mentioned above. This has resulted in a full dependence on Israel for the import of all energy products (Ibrik 2004, 2006b).

About 95% of electric power consumed in West Bank and Gaza Strip is imported from Israeli power plants via 22 and 33 kV feeders and through three substations of 161/33 kV in the West Bank, while the remaining electricity is generated by decentralised small diesel generators. However, some 79 localities in the West Bank are not connected to a public electricity network, including 38 in the Hebron district. Of the 531 West Bank and Gaza Strip localities with connections, 165 receive their electricity from the Jerusalem District Electricity Co., 215 from the Israeli Electricity Co., 22 from private generators, 68 from community councils and 61 from other sources (Palestinian Ministry of Energy and Natural Resources 2006).

3. Energy consumption in Palestine

While energy production and trade is considered as one aspect of the "energy tragedy" in the Palestinian Territories, energy consumption is the other. Total energy consumption (primary energy supply) did not exceed 944 million tons of oil equivalent (Mtoe) in 2000, while this figure was 22,999 Mtoe for Israel (nearly 22 times as much). On the other hand, energy consumption for Jordan (with nearly 5 million habitants) was 4,455 Mtoe (four times greater), while for Lebanon (with 4.3 million habitants) this figure was 5,469 (five times that of west Bank and Gaza Strip) (Palestinian Central Bureau of Statistics and Eco-energy 2006).

A more comparable indicator, the energy consumption per capita, clearly shows the gravity of the energy problem for the Palestinians. Energy consumption per capita for the Palestinian Territories in 2006 did not exceed 0.3 tons of oil equivalent (toe), which is the lowest in the region. Israel's per capita energy consumption (3.5 toe) was ten times greater than the Palestinian consumption level, while that of Jordan and Syria was three times superior (respectively 0.9 and 1.1 toe). The American consumption per capita, with 9.7 toe, is 32 times higher than the Palestinian level.

Table 5.1 summarises the most recent comprehensive energy balance of energy supply and demand for Palestine. It shows that final energy consumption increased by 2% from 2001 to 2002, and by 9% from 2002 to 2003, despite the difficult economic conditions during this period.

The growth in final energy consumption can be partly explained by the fact that energy consumption by the household and other services sectors accounts for about 75% of the total as illustrated in Table 5.2. This is because energy consumption by these sectors is less responsive than the other sectors to adverse changes in economic conditions. Consumption can be sustained by substantial remittances from abroad that support household incomes and by an increase in non-payments for the supply of commercial energy. The breakdown of total final consumption of energy in 2006 is shown in Figure 5.1.

The household and other service sectors dominate energy consumption in Palestine. World Bank analysis of data supplied by the Palestinian Central Bureau of Statistics indicates that in 2003 these sectors accounted for nearly

TABLE 5.1. Summary of energy balance of Palestine 2001, 2002, and 2003 in terajoules.

Year	**2001**	**2002**	**2003**
Total energy requirements[1]	32,873	33,534	36,559
Primary production	6,189	8,775	10,126
Imports	26,646	24,773	26,389
Energy conversion[2]	−3,111	−3,835	−6,486
Final energy consumption[3]	26,853	31,052	36,365
Industry and construction	2,138	2,043	2,266
Transport	5,414	5,969	6,914
Household and other sectors	19,301	23,040	27,185

[1]Includes exports and stock changes.
[2]Includes electricity generation and losses in transport and distribution.
[3]Statistical differences account for the difference in data between Total Energy Requirements less Energy Conversion and Final Energy Consumption.
Source: Palestinian Energy Authority and Jerusalem Distribution Electric Company (2006)

TABLE 5.2. Sectoral composition of final energy consumption.

Year	**2004**	**2005**	**2006**
Industry and construction	8%	7%	6%
Transport	20%	19%	19%
Household and other sectors	72%	74%	75%

Source: World Bank Sustainable Development Department: Middle East and North Africa (2007: 11)

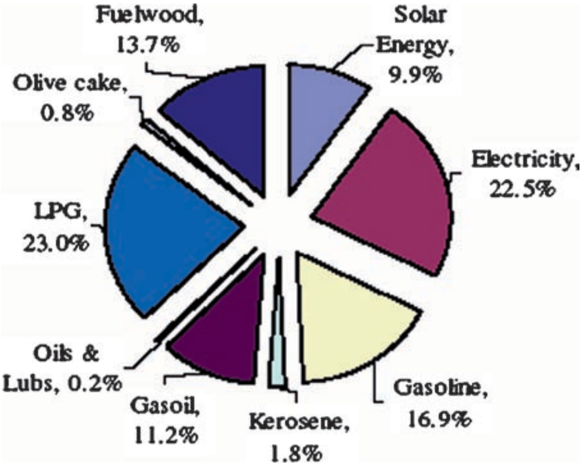
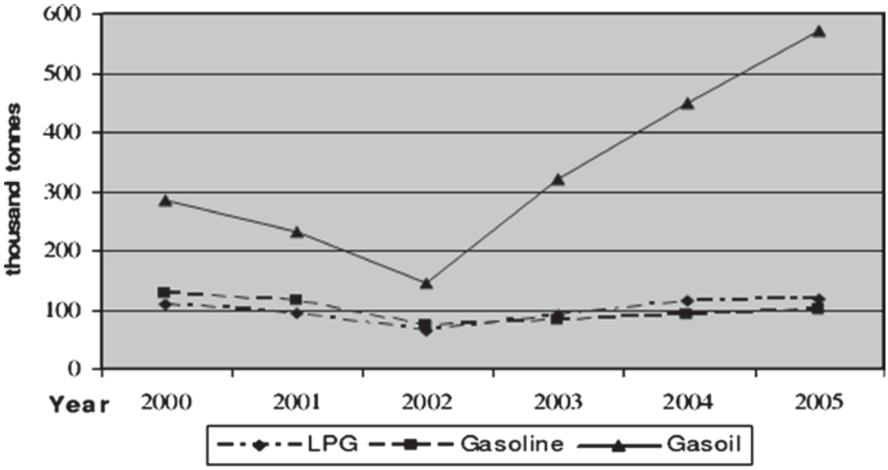


Figure 5.1. Breakdown of final consumption of energy in 2006 by source of energy Source: World Bank Sustainable Development Department: Middle East and North Africa (2007: 11) based on data from Palestinian Central Bureau of Statistics.

all consumption of solar energy, liquid petroleum gas (LPG), olive cake and fuelwood, for approximately 90% of electricity and kerosene consumption, as well as half the total consumption of diesel, oils and lubricants. LPG accounted for the largest proportion of energy consumption by the household and other services sectors in 2003 (29.5%), followed by electricity (26.6%), fuelwood (17.8%), solar energy (12.8%) and gas oil (9.2%). LPG serves as the main cooking fuel in Palestine, but is also used for heating and lighting if electricity is not available. Solar energy is used for water heating (World Bank Sustainable Development Department: Middle East and North Africa 2007: 11–12). With regard to renewable energy potential (Section 5 below), it is important to note that solar energy is used on a decentralised basis for domestic water heating.

Palestine is wholly dependent on Israel for imports of petroleum products through agreements between the Palestinian Petroleum Commission and private Israeli companies: from 1994 until 2006 a single Israeli company, Dor Alon was contracted to supply petroleum to the West Bank and Gaza, though another Israeli company, Paz Oil, was contracted in 2007 to supply the West Bank. Dor Alon owns the sole terminal – Nahaz Oz in Israel – for transporting fuel along a 700 m pipeline to a reception terminal in Gaza. This dependence on external Israeli companies is accentuated by the fact that there is no strategic or commercial storage capacity in Palestine. Imports of petroleum products into Palestine have been highly correlated



Source: World Bank Sustainable Development Department: Middle East and North Africa 2007: 12 based on Palestinian Central Bureau of Statistics and Eco-Energy 2006

Figure 5.2. Trends in imports of petroleum products to West Bank and Gaza Strip 2000–2005
Source: World Bank Sustainable Development Department: Middle East and North Africa (2007: 12) based on Palestinian Central Bureau of Statistics and Eco-Energy 2006.

with GDP (see Figure 5.2). Imports of petroleum products declined by between 40% and 50% from the onset of the *intifada* in 2000 to 2002, and then increased from 2003 onwards (World Bank Sustainable Development Department: Middle East and North Africa 2007: 12–13).

The Palestinian reliance on Israel for national energy needs extends to the supply of electricity further increasing its energy insecurity. The West Bank depends almost entirely on the Israeli Electric Company (IEC) for its electricity supply, and this need is increasing. The consumption of electricity in the West Bank – as measured by purchases of bulk power from IEC – increased at an average annual rate of 6.4% between 1999 and 2005. The maximum capacity of electricity supply to the West Bank is about 550 MVA, 30% directly by the Israeli Electric Company (IEC) which supplies electricity in bulk to 215 towns and villages, and 70% indirectly by IEC through the Jerusalem Distribution Electric Company (JDECO) which supplies electricity to East Jerusalem and in bulk to 165 towns and villages in the West Bank (World Bank Sustainable Development Department: Middle East and North Africa 2007: 14). Since an energy policy statement in 1997, the Palestinian Authority has improved the institutional stability and autonomy of its electricity supply infrastructure through the creation of three regional power utilities. However, new transmission and distribution facilities are needed to reduce energy insecurity, above all by linking with alternative power grids in Egypt and Jordan.

TABLE 5.3. Imported energy in the remaining WB* and GS by energy type and region: 2005.

Region	**Energy type Electricity (MWh)**	**Gasoline (1,000 l)**	**Diesel (1,000 l)**	**Kerosene (1,000 l)**	**LPG (t)**	**Oils and lubricants (t)**	**Wood and coal (t)**	**Total energy (tJ)**
Palestinian territories	**2,306,962**	**103,886**	**207,078**	**4,301**	**95,336**	**21,128**	**3,709**	**25,663**
North of West Bank	403,164	21,902	38,541	1,390	27,105	2,163	891	**5,100**
Middle of West bank	722,412	33,617	33,242	898	9,919	2,527	125	**5,844**
South of West Bank	452,668	19,747	34,529	997	23,304	14,417	2,405	**5,453**
Gaza Strip	728,718	28,620	100,766	1,016	35,008	2,021	288	**9,266**

*Remaining West Bank: includes all of the West Bank except for those parts of Jerusalem which were annexed following the 1967 Israeli occupation.
Source: Palestinian Central Bureau of Statistics and Jerusalem Distribution Electricity Company (2005)

Table 5.3 above summarises the imported energy for the year 2005 for the West Bank and Gaza Strip, which accounted to 25,663 TJ of energy, including 2,306,962 MWh of electricity, 104 million litres of gasoline, 207 million litres of diesel, 4 million litres of kerosene and 21 t of oils and lubricants.

As summarised by the World Bank, the West Bank and Gaza energy sector has a number of salient characteristics, which form the backdrop to an examination of the potential for renewable energy (World Bank Sustainable Development Department: Middle East and North Africa 2007: 2):

- Total energy consumption in West Bank and Gaza is small by regional standards, let alone global standards, which limits the scope for achieving economies of scale.
- West Bank and Gaza Strip have different energy supply options, which relate to their different social and economic profiles, as well as their geographical disconnection.
- Most energy demand (75%) in Palestine is accounted for by the service and household sectors, since manufacturing activity is not significant.
- Nearly all energy is provided by electricity and petroleum products, most of which has been purchased from Israel, though efforts are being made to diversify supply.
- In general, energy is lightly subsidised in comparison with most countries in the region, which means that energy prices are a reasonable approximation of economic opportunity costs.
- The only substantial domestic energy resource is the Gaza Marine Gas Field discovered offshore Gaza, which awaits development while the security situation and final status negotiations both remain to be resolved. This domestic gas field would provide a significant boost to Palestinian energy security.
- The most critical institutional constraints arise in the electricity sector, where there is a need for completing the reform of distribution companies in the West Bank and Gaza.
- The electricity system in the West Bank consists of numerous isolated distribution systems that are not integrated into an overall network: there is no independent generation capacity.
- There is currently no storage capacity for petroleum products in the West Bank and Gaza.

4. Energy problems in Palestine

The major overarching problem for the Palestinian energy sector is the shortage in supply of conventional energy – particularly electricity and petroleum products – and the lack of an institutional infrastructure for generation and transmission. The monopoly of supply of conventional energy resources (electricity and petroleum products) by Israel leads to a situation of high energy insecurity.A total dependence on electricity imports has increased the electricity costs paid by Palestinians. Despite the World Bank assessment above that market-based energy prices are a fair reflection of economic opportunity costs, these prices are a considerable problem for the Palestinian energy sector. Energy prices in Palestine are high compared to international prices, reflecting not only the reliance on monopoly suppliers but also the costs of high transmission losses within the West Bank and Gaza. Table 5.4 shows the prices of different energy sources in the Palestinian Territories.

These prices are high compared with other countries in the region. Although the electricity supply is assured by IEC, which uses the electric transmission and distribution network, no efforts have been made to rehabilitate this network. While the electricity transmission loss in the Palestinian Territories was 10% in 2002 of the total energy injected, it was no more than 3% in Israel. Some villages still suffer from either lack of electricity or insufficient services living mostly in rural areas.

Table 5.5 shows the percentage distribution of households by connection to electricity network

Average consumption per household is about 3,500 kWh/year. There are quite large geographical variations. For example, average consumption for the Southern Electric Company (SELCO) is about 3,000 kWh. Among Nablus households, the average annual consumption is only about 2,000 kWh. These variations may reflect differences in billing efficiency as well as genuine differences in consumption levels. As the average household size in West Bank and Gaza is about six persons, the estimated per capita consumption is about 675 kWh/year. Average consumption is highest in cities, lower in villages and lowest in refugee camps.

Billing efficiency is a major problem both in the West Bank and Gaza. IEC has been granted authority by the Israeli Government to receive monies collected by the Israeli Ministry of Finance as taxes on behalf of the

TABLE 5.4. Consumer energy prices in Palestine 2004–2007.

Price of electricity (Jordanian Dinar/kWh)	0.1–0.15
Price of gasoline (JD/l)	0.95
Price of diesel (JD/l)	1.25
Residual fuel oil #6 (JD/l)	0.76
Price of kerosene (JD/l)	1.15
Price of firewood (JD/t)	120

Source: Palestinian Central Bureau of Statistics

TABLE 5.5. Percent distribution of households in Palestine by connection to electricity public network by region and type of locality 2004–2005.

	Connection to electrical public network		
Region and type of locality	Public network	Private generator	No electricity
Palestinian Territories	**96.2**	**2.9**	**0.9**
Urban	99.3	0.4	0.3
Rural	88.8	8.9	2.3
Camps	99.3	0.4	0.3
West Bank	**94.7**	**4.3**	**1.0**
Urban	99.3	0.6	0.1
Rural	88.3	9.5	2.2
Camps	98.7	1.3	–
Gaza Strip	**99.1**	**0.1**	**0.8**
Urban	99.2	0.1	0.7
Rural	95.7	0.8	3.5
Camps	99.5	–	0.5

Source: Palestinian Energy Authority and Palestinian Central Bureau of Statistics

Palestinian Authority. These funds are transferred to IEC in lieu of unpaid Palestinian electricity bills, and they significantly increase the fiscal burden on the Palestinian Authority. In 2007 the World Bank initiated an Electric Utility Management Project for the West Bank and Gaza that is in part designed to reduce this fiscal burden through improved revenue collection and lower technical/non-technical losses. Ultimately the goal is to improve Palestinian energy autonomy by creating new supply substations in the West Bank and establishes supervisory control for energy in Gaza (World Bank: Middle East and North Africa 2007).

However, huge efforts are still required for the development of energy sector. There is an urgent need for research on energy demand/consumption, the implementation of R&D activities aimed at alleviating at least some of the energy problems and, above all, an efficient utilisation of renewable and local conventional energy resources. It is also envisaged by the Palestinian Energy and Natural Resources Authority that energy conservation should be at the core of energy planning with a view to reducing energy consumption. The prospects for employing renewable energy technologies will now be discussed.

5. Renewable energy sources in Palestine

5.1. CLIMATE CONDITIONS

Palestine is located between 34°20′–35°30′ E and 31°10′–32°30′ N. It consists of two areas geographically separated from one another – the Gaza Strip located on the western side of Palestine adjacent to the Mediterranean Sea and the West Bank, which extends from the Jordan River in the east to Israel in the west. Palestine's elevation ranges from 350 m below sea level in the Jordan Valley, to sea level elevation along the Gaza Strip seashore and exceeding 1,000 m above sea level in some locations in the West Bank.

Climate conditions in Palestine vary widely. The coastal climate in Gaza Strip is humid and hot during summer and mild during winter. These areas have low heating loads, while cooling is required during summer. The daily average temperature and relative humidity vary in the ranges: 13.3–25.4°C and 67–75% respectively. In the hilly areas of the West Bank, cold winter conditions and mild summer weather are prevalent. Daily average temperature and relative humidity vary in the ranges 8–23°C and 51–83% respectively. In some areas the temperature declines below 0°C. Hence, high heating loads are required, while little cooling is needed during summer. In Jericho and the Jordan Valley, almost no heating is needed during winter while high cooling during summer is needed.

5.2. THE POTENTIAL OF RENEWABLE ENERGY

The main renewable energy sources considered to have potential in Palestine are solar energy, biomass and wind energy.

5.2.1. Solar energy potential and solar radiation characteristics

Palestine has high solar energy potential. It has about 3,000 sunshine hours per year and high annual average of solar radiation amounting to 5.4 kWh/m^2/day on horizontal surface. The lowest solar energy average is in December, it amounts to 2.63 kWh/ m^2/day. The solar radiation on horizontal surface varies from 2.63 kWh/m^2/day in December to 8.4 kWh/m^2/day in June. These figures are encouraging to exploit the solar energy for different applications such as water heating, drying of crops vegetables and fruits, water desalination, water pumping and electrification of remote locations isolated from the electrical networks.

Since 2000 the Energy Research Centre (ERC) at An-Najah National University (ANNU) has carried out measurements on solar radiation intensity using modern meteorological stations equipped with automatic data loggers as shown in Figure 5.3. Figure 5.4 illustrates a sample of measurements at different stations (Ibrik 2007).

Since the area of Palestine is relatively small and solar radiation does not change significantly within short distances, the measuring data for Gaza is approximately similar to that one of the West Bank stations. With respect to the illustrated data, the daily average of global solar radiation

Figure 5.3. Meteorological station employed by Palestinian Energy Research Centre.

on horizontal surfaces in Palestine amounts to 5.4 kWh/m^2/day. This data is comparable with long-term measurements in Jordan, which has similar solar radiation conditions (Ibrik 2006a).

5.2.2. Biomass (biogas)

Palestine is an agricultural country. It has different types of plant products that can be used as energy sources. The main type of these products is a rejected residue of olive oil pressers called Jefit. Usually, Jefit is used in households for heating in the winter. Annual production of Jefit had been not assessed yet. This task is essential and hopefully will be carried out in cooperation

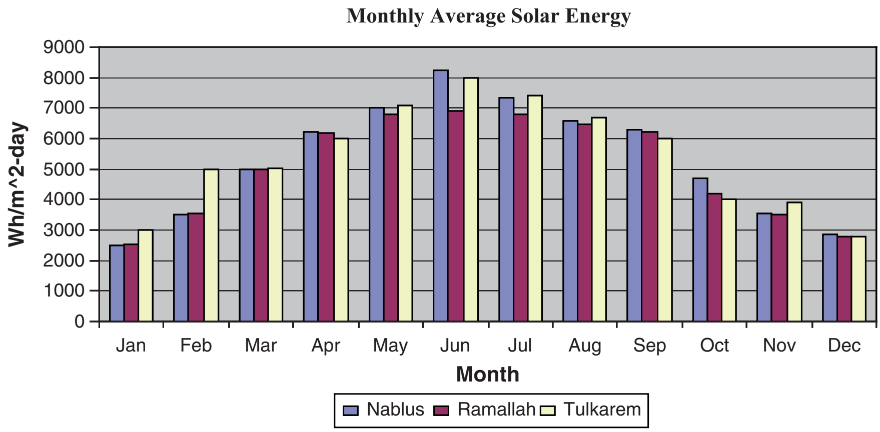


Figure 5.4. Solar radiation in different cities in Palestine.
Source: Energy Research Centre, ANNU.

between the Ministry of Agriculture and the Palestinian Central Bureau of Statistics.

The more important locally produced energy material is animal dung, which is already used in various developing countries (e.g. India, Nepal, China, Pakistan) for biogas production. Professional study for determination of the annual animal dung production in Palestine had been till now not carried out. Hence, it is not possible at this time to estimate the potential biogas of production in Palestine. However, since one cow produce about 24 kg of liquid gas per month, it is expected that the potential is considerable. As PCBS newly declared, they are preparing with the Ministry of Agriculture a counting process for all animal types in Palestine. Based on the counting results, the potential of annual biogas production can be determined.

5.2.3. Solar water heaters

Palestine is one of the leading countries in using solar water heaters for domestic applications A recent study by the Palestinian Central Bureau of Statistics showed that around two-thirds of Palestinian homes use solar water heaters. More than 90% of these systems are produced locally by about 25 Palestinian factories in the West Bank and Gaza. These factories produce between 2 and 12 units per day. It is estimated that the average total number of DSWH units produced in Palestine is around 35,000 units annually. The total collector area installed every year exceeds 59,000 m^2.

The domestic solar water heaters (DSWHs) used in Palestine are open loop systems. They consist of flat collectors – usually installed in roofs – water storage tanks, and a system for circulating the heated water (through "thermosyphnic" circulation). In Palestine DSWHs are mostly used to heat water for houses, residential apartments, hotels and some hospitals.

The quality of these systems is fairly good and varies from one factory to another. The flat plate collector efficiency ranges between 29% and 45% depending on the manufacturer and production materials. The average price of the locally produced DSWH unit consisting of two flat plate collectors (90 × 190 cm each) and a 200 l insulated tank ranges between $250 and $450 depending on quality and manufacturer. Up until June 2000, there had been no mandatory test for quality assurance. However, from July 2000, the Palestine Standards Institutes (PSI) has adopted a mandatory test for quality according to International Standards Organisation requirements. The PSI has a computerised lab for testing the efficiency of flat plate collectors and special lab for testing material, water leakage and tank insulation.

Another application of solar energy is greenhouse heating for agriculture. It is estimated that the total area of greenhouses in the West Bank and Gaza exceeds 200,000 dunums (200 million square metres). Most of these greenhouses are used for planting vegetables and flowers in winter (Ibrik 2006b).

5.2.4. Wind energy potential for power generation

In general, Palestine can be considered as a country of moderate wind speeds. The coastal strip region (Gaza) is characterised by a very low wind speed throughout the year, with an annual average of about 2.5–3.5 metres per second (m/s). The hilly regions, represented in Nablus, Ramallah, Jerusalem, and Hebron have annual average wind speeds varying in the range of 4–8 m/s. The Jordan Valley, represented in Jericho, also has very low wind speeds of an annual average of about 2–3 m/s. In fact, the wind energy potential in Palestine has, until now, not been professionally assessed by any Palestinian institution. In order to conduct a reliable wind energy assessment, modern computerised wind speed measuring stations equipped with automatic data loggers, should be installed in different topographical areas. As is well-known, the longer the measuring period is, and the higher the number of stations, the more reliable will be the assessment.

Since 2000, the Energy Research Centre (ERC) at ANNU has been carrying out measurements of wind speed and direction using modern meteorological stations equipped with above automatic data loggers, and Figure 5.5 illustrates a sample of measurements in different stations.

These measuring stations represent up-to-date technology since each one contains a data acquisition system and high quality sensors. Each station measures wind speed and wind direction at 10 m height, global solar radiation on horizontal surface, relative humidity, air pressure, precipitation and ambient temperature. These variables are being measured at a scanning rate of 2 s then

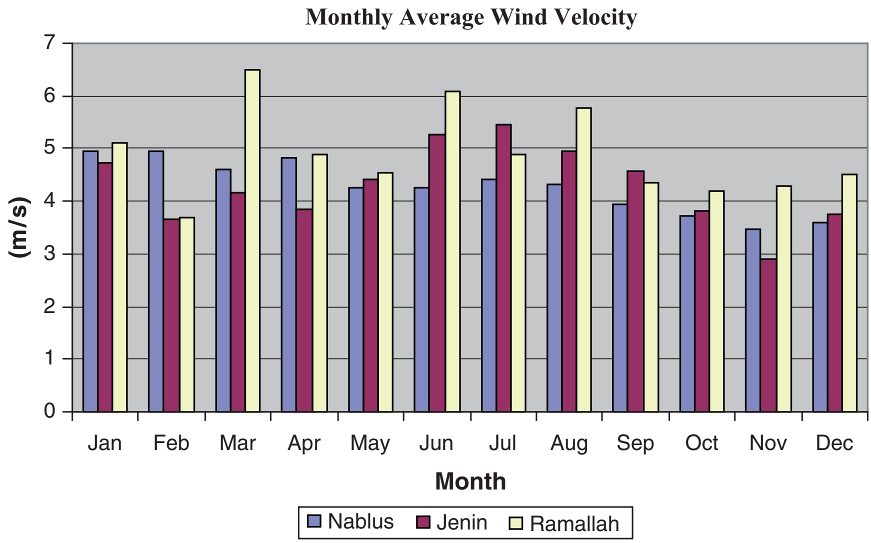


Figure 5.5. Monthly average wind velocity in different cities in Palestine.
Source: Energy Research Centre, ANNU.

an average over an integration period of 5 min will be calculated and stored. The stored measured data is periodically collected and processed at ERC.

The results show that some areas could have considerable wind energy potential. ERC will continue to work professionally for several years on this project and replace the stations in new locations and possibly install new ones to scan the most promising Palestinian areas for wind energy potential.

As is known, wind velocity average in the range of 3.5–6 m/s is appropriate mostly for water pumping by using multiblade windmills. For electricity generation annual average wind speeds in the range of 6–20 m/s are mostly required. Hence, at this moment it is not possible to make any responsible decision is concerning the wind energy potential or the possible capacity in the West Bank.

With regard to Gaza Strip, this area is characterised by very low wind speeds of an average in the range between 2 and 4 m/s. This velocity range is not feasible at all for electric power generation, but it can be feasible for water pumping from shallow wells that are available in the Gaza Strip. However, it is necessary to install modern computerised meteorological stations in Gaza Strip to determine the exact wind energy potential in that area.

5.2.5. Municipal solid waste combustion for power production

Waste output in the West Bank and Gaza Strip is in excess of 2,630 t/day, of which 800 t is generated in Gaza. This is currently being disposed of in unprotected landfills. It is proposed to implement environmentally more tolerable

TABLE. 5.6. Collected solid waste of Palestinian Districts.

District	**Collected solid waste (t/day)**
Nablus	200
Hebron	200
Ramallah **	350
Tulkarem	300
Jenin	200
Qalqilya	180
Jericho	150
Bethlehem	100
Salfit	50
Gaza	800
Total	**2,630**
Total annual collection	**960,000**

forms of disposal in the future, and both protected landfills and waste-to-energy plants are under consideration by the Palestinian Authority (Table 5.6).

There is an urgent need for a major physical cleanup, together with significant institutional development and physical investment in the solid waste sector in the Palestinian Territories.

The main objectives of the Palestinian Authority in the area of solid waste are to:

(a) Improve public health and community living conditions by providing adequate solid waste collection services

(b) Minimise the cost of solid waste collection services by selecting the most cost-effective collection, transport, and disposal systems

(c) Optimise the potential for economies-of-scale and minimise transport costs by the implementation of strategically selected transfer and disposal sites

(d) Protect sensitive groundwater regimes through the implementation of environmentally selected sites for sanitary landfills and following protective designs standards

(e) Reduce clandestine dumping and increase community participation

(f) Develop projects for recycling and waste-to-energy plants

6. Market penetration barriers for implementation of renewable energy in Palestine

It is not feasible to speak about the market penetration barriers before determining the exact potential of solar energy, wind energy, biogas and the appropriate applications. However, some areas in the West Bank have a promising potential for power generation. If such a project will be realised in the future, the main expected barriers are briefly the following:

- Renewable energy policies and strategies are not yet integrated into national energy policies.
- Financial resources for renewable energy investments remain limited.
- Coordination of efforts and experiences between concerned parties is weak.
- Databases are inadequate.
- Technology transfer and local manufacture activities are insufficient.
- Capacity-building programmes are limited.

7. Conclusions

The energy situation in Palestine is somewhat unique when compared to other countries in the region. There are virtually no available natural resources, and due to the ongoing political situation, the Palestinians rely (or have to rely) almost totally on Israel for their energy needs. Palestine faces continuing growth in energy demands, especially electricity, across all sectors and by necessity future generation expansion will rely substantially upon high priced fossil fuels. These factors create strong economic and environmental incentives to promote implementation of renewable energy sources and efficient use of energy and energy conservation in all sectors with high energy consumption rates.

The Palestinian people have learnt to utilise some renewable energy on a localised basis, most notably by using solar water heaters. The use of solar energy for water heating is widespread in the Palestinian Territories, and offers an opportunity to develop further the domestic production and uptake of DSWHs, making this sector more efficient and sustainable. Scaling up production of DSWHs would have economic benefits in terms of investment and employment, while an immediate environmental benefit of this would be a tremendous reduction of localised gaseous emissions.

The brief review in this chapter of the potential of solar, wind and biogas renewable resources in Palestine indicated some potential for growth in the decentralised use of solar energy, with technical potential for waste-to-energy plants and modest potential for a small-scale use of wind energy for water pumping in Gaza. There needs to be a comprehensive review of the potential of these renewable energy technologies, in order to provide solid information for energy planning.

The current major restructuring of the Palestinian energy sector offers an opportunity to consider a greater use of renewable energy in the future.

However, the Palestinian Authority has yet to take renewable energy seriously in its energy planning. Its hopes for increased energy security rest on future exploitation of the Gaza Marine gas field and a major modernisation of power transmission and distribution networks. Pursuit of these goals is reinforced by donor commitments from the international community and advice from the World Bank, which conducted a recent Energy Sector Review at the request of the Palestinian Authority (World Bank Sustainable Development Department: Middle East and North Africa 2007). The preoccupation with bulk power supply priorities in this review prevented a consideration of the positive role decentralised renewable energy projects could play in a more reliable and independent energy system in a future Palestinian state. Furthermore, it also missed the opportunity to link in with more ambitious support shown by the World Bank, within the Global Environment Facility, for solar thermal power plants elsewhere in the Middle East and North Africa (Egypt and Morocco). Renewable energy may yet play a larger part in the future construction of Palestinian energy sovereignty.

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FINANCING RENEWABLE ENERGY: THE CASE OF MOROCCO

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Abstract. Owing to its geography, Morocco has a variety of renewable energy sources. The government is committed to developing and exploiting these sources, with a goal of increasing the contribution of renewable energy to the energy mix from 4% to 10% by 2012. Moreover, at the international level, Morocco could become a regional hub for electricity transfer with the interconnections that already exist with Algeria and Spain. In order to exploit and develop renewable energy and reduce the energy bill burden on the government budget, sound financial structures are called for. The objective of this chapter is to review different financial tools for financing renewable energy. It first provides an overview of the Moroccan economy and the central role of energy in economic growth and social development. After a description of the energy situation and the potential for renewable energy, the chapter focuses on financial options for renewable energy. It then presents the structure of an energy fund that would create a partnership between the public and the private sector for countries where energy development is the core of their socio-economic development.

Keywords: Morocco, energy, renewable energy, National Initiative for Human Development, public–private sector partnership, financial instruments.

1. Sustainable development: The case of Morocco

1.1. POVERTY, INVESTMENT AND ENERGY

Morocco has a population of around 32 million and a GDP of $60 billion. Nevertheless, Morocco must increase its growth rate in order to attack the sources of poverty. In that regard, the government is currently focused on attracting and expanding foreign investment in order to improve the country's economic welfare – as measured by unemployment rates, GDP growth and international competitiveness – and also to ensure social development as

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measured by comparative living conditions, the Human Development Index (HDI) and the United Nations' Millennium Development Goals (Royaume du Maroc 2008).

Economic welfare and social development are often intertwined with the availability of natural resources, in particular water and energy. In Morocco, as in many other developing nations, lack of access to sustainable energy can deepen poverty and discourage investment, creating a vicious circle, which governments around the world strive to break. Cultivating reliable renewable energy is thus an essential step toward attaining greater economic security.

1.2. STRATEGIC PRIORITIES FOR MOROCCO

Moroccan society is built on four principles: political democracy, economic efficiency, social cohesion and universal opportunity. Morocco's social institutions, political actors, economic players, and individual families manifest these principles using the goal of poverty reduction and economic growth as a benchmark.

Morocco is an emerging country and has made significant achievements in three main areas:

- *Constitutional reform*: The government has implemented fundamental reforms and projects in human rights, freedom and women's inclusion, in addition to advances towards democracy and good governance.
- *The economy*: Important advances have been realised towards a modern, productive, competitive and efficient economy. In fact, a web of infrastructure and network has been set up to stimulate the economy and also to create the appropriate environment for both national and international investment. The private sector has grown significantly, while the opening of the economy through several free trade agreements has exposed Morocco to economic globalisation.
- *Social development*: The government continues to invest in human resources and deepen its commitment to social development through all levels.

However, despite all these efforts and achievements, many challenges remain. In fact, poverty indicators are still high in some areas with difficult conditions of living, such as the lack of access to basic services and the predominance of traditional, family based economies with low productivity. Although there are now fewer disparities between regions – mountains, desert, rural and urban areas – due to increased efforts to generalise access to basic services, rural exodus in search of employment in the cities remains a problem. In order to fight poverty, the growth rate must be boosted enough to generate sufficient benefits to improve the actual social situation. Economic globalisation also represents a major challenge for Morocco, creating an urgent need for public and private sector capacity building to face international competitiveness. Finally, the greatest challenge for Morocco is human development. As a response, in 2005 Morocco launched the National Initiative for Human Development (Initiative Nationale de Développement Humain – INDH).

1.3. THE NATIONAL INITIATIVE FOR HUMAN DEVELOPMENT (INDH)

The INDH programme represents the Moroccan Government's commitment at all levels to sustainable economic growth and social development, guided by the clear national vision announced by His Majesty King Mohammed VI. This vision is based on a participatory approach, with integrated and coherent planning; as well as sustained monitoring and a results-oriented process.

INDH has three main axes of focus:

- Fighting social deficits in rural and urban areas through access to basic infrastructure and social services: education, water, electricity, energy, roads, cultural and sports activities, etc.
- Creation of revenue-generating economic activities and employment (including already identified integrated social and economic programmes)
- Assisting marginalised groups with their human development specific needs

This initiative is unprecedented in the developing world in its placement of individual needs at the centre of social programmes. In fact, this initiative is making it possible to generalise energy and electricity access throughout the country and ensure a low price. After a couple of years of application, INDH has already resulted in some significant improvements in the condition of living in remote and poorer areas in Morocco.

The programme of generalising electricity distribution to rural areas is almost at 100% coverage. In fact, access to energy went from 55% in 2002 to 88% in 2006 and to 100% in 2008. This generalised access provides opportunities for rural areas to develop new activities in agriculture or industry. Thus, by improving living conditions through access to energy, INDH projects play the role of a catalyst for growth in the targeted regions, assisting in the development of revenue-generating activities.

2. Energy in Morocco

2.1. HEAVY ENERGY SPENDING IN THE GOVERNMENT BUDGET

Morocco is the largest energy imported in North Africa: the nation relies heavily on fuel imports to supply 95% of its energy needs. According to the National Office of Hydrocarbons and mining (Office National des Hydro-carbures et des Mines – ONHYM), total imports of hydrocarbons cost $5.15 billion in 2006. Thus, the recent increase in oil and gas prices is a real burden on the energy bill, and has significantly worsened the national balance of trade. Morocco's oil bill is now equivalent to 7.6% of its GDP. In terms of the balance of trade, oil products represent 21.6% of total imports and are covered by 42% of exports. Today, with skyrocketing oil prices, the gap is widening between imports and exports' remittances, and the government has been forced to increase its subsidies for oil related projects. Finally, because of an energy demand that grows at 8% per year, an annual investment of US$1.5 billion is required to keep up with increasing usage. The challenge is planning for this annual budget.

2.2. ENERGY CONSUMPTION IN MOROCCO

Morocco consumes around 14 million oil equivalent tons. As shown in Figure 6.1, oil represents the largest percentage of 60% of primary energy consumption, followed by coal with 32% (Berdai 2007). Coal use is particularly instrumental for electricity production, as 75% of total electricity in Morocco is generated by two coal-fired power stations at Jorf Lasfar and Mohammedia. Most coal is imported, with South Africa the primary source. Hydropower and renewable energy are today equivalent to 5% of total energy consumption.

The energy portfolio in Morocco has changed throughout the years. As an illustration, Table 6.1 shows the changing sources of power for electricity between 2002 and 2006. By 2006, Morocco had an installed generating capacity of 5.1 gigawatts (GW). It can be seen that, as a proportion of energy use in Morocco, there was a reduction in dependency on coal during this period, with renewable energy (hydropower and wind) staying between 5–6% of the energy portfolio. However, given that energy demand growth was approximately

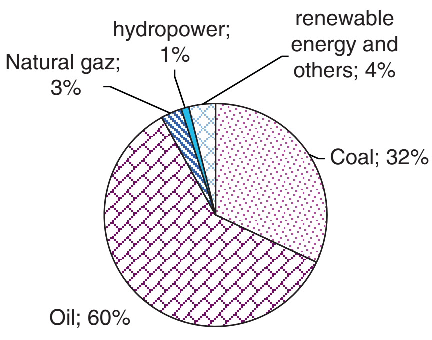

Figure 6.1. Structure of primary energy consumption in Morocco. Source: Based on data from Berdai (2007).

TABLE 6.1. Portfolio of sources of electricity in Morocco for 2002 and 2006.

Energy source	2002	2006
Coal and coal products	74%	59%
Oil and oil products	11%	12%
Natural gas	–	12%
Electricity imports	9%	9%
Hydroelectric power	5%	4%
Wind energy	1%	1%
Others	–	3%

Source: Ministry of Energy, Morocco

5% over this period, with over 8% for electricity, 5–6% for natural gas and 3% for other oil products, renewable energy consumption increased.

2.3. FUTURE ENERGY PROJECTIONS

Based on a projected energy demand that grows at 8%, Morocco's energy needs will double in the next 10 years (Royaume du Maroc 2007). A statistical projection shows that electrical consumption will go from $40 \cdot 10^9$ kWh in 2015 to $80 \cdot 10^9$ kWh in 2025. In other words, power demand will grow from 7,000 MWh in 2015 to 14,000 MWh in 2025. This translates in terms of development as:

- 1,000 MW/year starting 2015
- 1,500 MW/year starting 2025

3. Renewable energy in Morocco

Because of its geostrategic position, Morocco has a large untapped potential for renewable energy. In addition, Morocco's privileged partnership with neighbouring countries expands the country's ability to become a regional hub for developing and producing renewable energy. Moreover the liberalisation of Morocco's electrical sector, which is currently underway, increases the attraction of the sector both to national and international investors.

3.1. STARTING FROM A CHALLENGING SITUATION

Morocco is faced today with a challenging situation for energy production. There are few proven sources of oil and natural gas (though several foreign companies, including two Scandinavian companies – Norsk Hydro and

Maersk – and the China Offshore Oil Corporation are exploring possible offshore reserves), while coal-mining sources have dwindled. As a remedy to this poor fossil fuel endowment, since 2001 Morocco has imported coal to meet domestic demand, leading to an increase in CO_2 emissions.

The pressure from the demand side is coming not only from demographic changes and urban development, but also from the industrial sector. In addition, the generalisation for electrification in rural areas is raising energy demand. And finally, the government has identified a need for more energy efficiency. On the other side, setting national energy policy has its own set of challenges. Morocco not only has a high dependency on imports, but also is burdened by the increasing cost of primary resources and energy subsidies. Thus, the government is investigating more cost effective sources of energy.

3.2. GOVERNMENT COMMITMENT TO DEVELOPING RENEWABLE ENERGY

For the past 5 years, the objective of Morocco's energy policy has been to respond to the increased demand that accompanies economic growth. In fact, different public players in the energy sectors have made necessary investments to increase the country's access to energy and guarantee a reasonable energy production cost throughout the country.

Due to its high external dependency in energy, Morocco has directed itself towards diversification of energy sources and the use of new technologies. Thus, renewable energy has become a key commitment at all levels in the government. In this regard, Morocco is set to become the first Arab League country to use government funds to promote renewable energy sources. Currently, Morocco has the largest wind power production plant in Africa – the Koudia el Beida plant – which has a capacity of 190 GWh.

From an institutional standpoint, there are new legal initiatives to make funds available for renewable energy projects. As a consequence, a range of projects has been planned for renewable energy production, and new financial options are being encouraged. With an optimistic tone, some observers have stated that the country could in the long run sell electricity to Europe.

3.3. THE POTENTIAL OF RENEWABLE ENERGY

There is a large potential for renewable energy in Morocco, which up to now has remained largely untapped (Meisen and Hunter 2007). In particular, Morocco is privileged to possess:

- A 3,500-km-long Atlantic coast
- High levels of solar irradiance (4.7 kWh/m^2 in the north and 5.5 km^2, and in the south, for 280 to 340 days/year)

TABLE 6.2. Renewable energy projects in 2005.

		Electricity production	
Type	**Installed capacity**	**In GWh/year**	**%**
Wind farm	64 MW	250	86.73
Thermo solar	6 MW	11	3.82
Solar-photovoltaic	45,000 m^2	25.7	8.92
Biomass	3,000 m	0.26	0.09
Micro-hydraulic	150 kW	1.3	0.45
TOTAL		288.26	

Source: Centre for Renewable Energy Development

- A wind speed of up to 9 m/s
- A large wind power source of 6,000 MW and
- Significant potential for hydraulic systems on more than 200 sites

Within the country, the optimal solution for project development for renewable energy is acknowledged to be a combination of solar energy, wind power and hydropower (International Business Strategies 2007). As an illustration, in 2005 several projects were completed for a total of 288 GWh as shown in Table 6.2.

In 2007, Morocco tapped more of its renewable energy potential. In fact, the following renewable energy production capacity is now developed:

- 113 MW of wind power production
- 6 MW of photovoltaic production
- 45,000 m^2 of solar thermal absorption: the energy generation potential of incoming solar radiation is around 5 kWh/m^2/day

However, this production capacity meets only 1% of the national energy demand. There is obviously room to develop more projects and more options throughout the country.

3.4. GOVERNMENT OBJECTIVES FOR RENEWABLE ENERGY DEVELOPMENT

The Moroccan Government has been committed to providing general access to electricity for rural areas. At the same time, rather than trying to link all isolated villages to the national grid, Morocco is promoting the use of solar panels. This initiative was facilitated by the Moroccan Association for Solar and Renewable Energy (AMISOL), which envisages an important social impact from solar energy development in terms both of employment and also of economic synergy with remote areas: the development of solar energy may stimulate the emergence of new economic opportunities in rural areas. In addition, according to AMISOL, job creation could be equivalent to 7,400 jobs in 2012 and 23,000 to 38,000 jobs by 2020.

Thus, aware of the potential that Morocco has in terms of renewable energy, the government has defined very ambitious objectives for 2011:

- 1,000 MW of wind power production
- 40 MW thermo-solar
- 50 MW biomass
- Rural electrification of 10,000 villages
- 3,000 water points equipped with renewable energy production
- 400,000 m^2 of solar water heaters

The development of these new sources will not be effective without an increased awareness of optimum energy use and energy waste reduction. This is why the government has set the objective of increasing yearly energy efficiency by 150,000 tons of oil equivalent (toe) in the residential sector and 360,000 in industry. Under government targets, by 2011 renewable energies would reach 12% of total energy production, by 2020 this would be 19%, and by renewable energy sources are expected to account for more than a quarter of national energy production.

4. Financing renewable energy

4.1. INCENTIVES FOR RENEWABLE ENERGY DEVELOPMENT

In order to stimulate renewable energy, the government has been very active putting into place a fully developed system of financial incentives. In Morocco's 2004 budget legislation, the following major financial incentives were selected by the government: reducing taxes from 20% to 14% on solar equipment; raising the self-production limit from 10 to 50 MW for industries; allowing access to the national grid for self-producers; launching a regulatory reform project for renewable energy and energy efficiency; and reorganising the Centre for Renewable Energy Development.

From the standpoint of household energy users, there is increased desire for small solar panels in order to cut electricity bills for middle-class families. In order to encourage this behaviour further, payment facilities for the required equipment or perhaps even subsidies for families in need could be considered by the government. This is particularly promising for remote rural families. In fact, the government has already been promoting solar power as the most effective solution for renewable energy production, with the cost of photovoltaic units being shared by Morocco's leading energy utility company, Office National de l'Electricité (ONE) and the beneficiaries.

Private players can also contribute significantly to renewable energy production. In particular, wind farm owners now have the possibility of taking full advantage of carbon credits as an additional source of revenue. This will not only encourage the switch to environmentally sound options, but also provide producers with more funds to further develop their commercial structures and manufacturing capacity.

This set of incentives cannot be implemented without a financial structure to accompany them. This is particularly important, since the government is faced with the challenge of generating US$1.5 billion in yearly investments to meet increasing energy demand.

4.2. DEVELOPING FINANCIAL TOOLS

In order to finance the development of renewable energy, the government needs to set up a structure conducive to public and private financing. Furthermore, fiscal constraints mean that the private sector is expected to cover the bulk of investment needed to meet the country's growing power needs. However, local resources are not sufficient to finance all that is required. In fact, total local bank equity is equivalent to 35 billion Moroccan Dirham (MAD) and their capacity is limited to 7 billion MAD by project. Thus, given the prudential constraints, local banks' capacity remains limited; and more foreign investment and government involvement are called for.

Thus, in order to respond to the financial requirement of renewable energy production, the development of financial instruments, financial engineering and capital market operations, is called for. For example, as shown in Table 6.3, a total planned renewable energy capacity of 933 MW requires almost US$1 billion in investment. The preparatory phase for a total of 300 MW projects is already underway.

The first renewable energy project to be launched was a 140 MW wind turbine plant near Tangier, which will come online in 2009. This turbine will supply 2.5% of Morocco's energy needs, with annual productivity of 510 GWh. Thus, this project is expected to reduce the reliance on fossil fuels by

TABLE 6.3. Renewable energy projects in the pipeline.

Projects	**MW**	**Investment**	**Year of completion**
Wind turbine facility near Tangier	140	∈235 million	2009
Wind turbine facility in Essaouira	60	$91.86 million	Construction already started
Hydropowerin Afourer	463	$186.04 million	2005
Hydrocomplex	40	$108.37 million	2008
Thermal-solar plant Ain-Beni-Mathar	230	$264 million	

Source: Ministry of Energy, Morocco

15% and save around 470,000 t/year in CO_2 emissions. The project requires an investment of ∊235 million financed by the European Investment Bank and KfW, as well as ONE's equities. The project in Essaouira is also benefiting from KfW financing. The other renewable energy projects also enjoy sophisticated techniques both in their conception and their financing. For example, the hydropower station in Afourar uses reversible turbines to pump water and store excess power, and the thermo-solar plant relies on a combined cycle generator and a solar field to create thermal energy for planned output. Afourar is the first such plant on the North African Atlantic coast.

The intention is to tailor financial options according to project structure. In that regard, a range of financial options are being evaluated by the Moroccan government, including the following:

- Accelerating the legal reforms for securitisation
- Setting up regional investment funds dedicated to energy sector in association with financial institutions from Europe, Maghreb and Middle East
- Developing a mechanism to allocate institutional savings to long-term maturity, by authorising or requiring insurance companies and retirement funds to invest in those energy funds
- Creating a marketplace for energy products and power distribution at a regional level (Africa)

4.3. PUBLIC–PRIVATE SECTOR PARTNERSHIP MODEL

In Morocco a public–private sector partnership model has been selected as the preferred vehicle for the development of financial tools conducive to renewable energy investment. On the one hand, the government plays an important role in providing guaranties for international institutions' involvement and preparing the legal and fiscal environment. On the other hand, the private sector is expected be the one to execute the projects, to look for loans (with medium and long-term maturities) from the banking system, as well as to tap into foreign investment.

These linkages are shown in Figure 6.2. For developing countries like Morocco, the government can play an important role in stimulating private sector financing. In fact, the government can set the tone for this sector's development, as well as ensure a healthy environment for foreign investors. In other words, the government should plant the first financial seed and then the private sector can grow on its own. This is line with international institutions' involvement in development funding (including in Morocco), notably the IMF and World Bank. A renewable energy fund is now proposed as the optimum vehicle for ensuring effective public–private sector cooperation over investment in renewable technologies. It is argued that this is an idea deserving consideration in other countries in the Middle East and North Africa region.

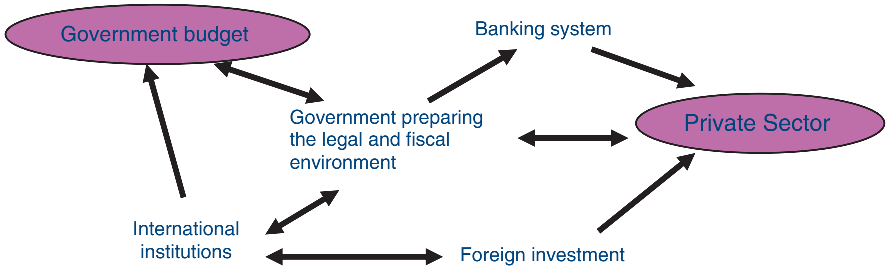

Figure 6.2. Public–private sector partnership.

4.4. CREATING A RENEWABLE ENERGY DEDICATED FUND

Creating a renewable energy dedicated fund is one of the best solutions to achieve Morocco's goal in terms of renewable energy development. Such a fund would regroup all actors in the energy sector and make it possible to finance both private initiatives as well government programmes. As set out in Figure 6.3, each player would have a clear role:

(a) **The government** would contribute through an energy-dedicated budget, annually voted by the parliament as part of the broader government budget. In addition, specific incentives would be defined for projects selected for financing by the energy fund. Such incentives would include:

- Tax reduction on equipment production
- Raising self-production with buy back guarantees
- Building all network connections
- A dedicated budget, and
- Institutional investors' quotas for the energy sector

(b) **International organisations** could play an important role in terms of knowledge-sharing and the transfer of technology from countries where such a structure was set up either for energy or the development of other sectors. In addition, multilateral financial institutions such as the World Bank, which defines Country Assistance Strategies, would have a major role in identifying and promoting projects that would stimulate development of the renewable energy sector. The next paragraph discusses an energy reform project in this same direction. The Global Environment Facility (GEF) of the World Bank is particularly well suited for this type of structure, as it corresponds with their mission of providing grants for environmental programmes (Global Environment Facility 2006). Morocco has just been approved for a US$43.2 million GEF grant towards a combined solar thermal/gas power plant. This grant will finance part of the integrated

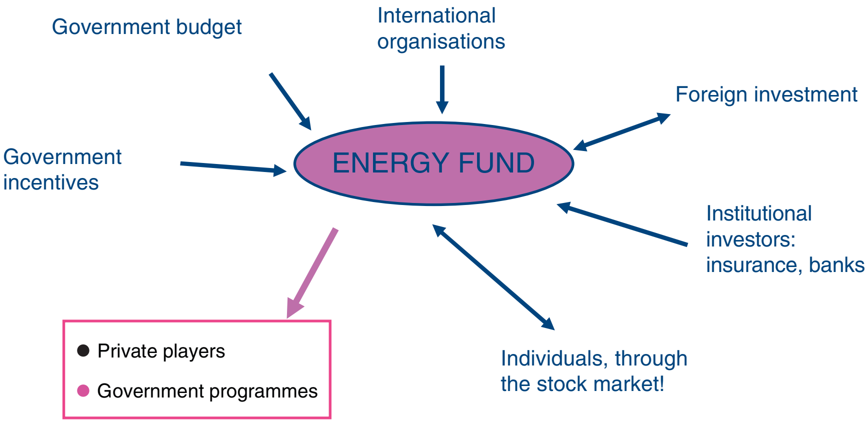

Figure 6.3. Proposed energy fund.

plant, by covering about two thirds of the total capital cost of the solar component – a 20 MW parabolic concentrating solar power trough. The rest will be covered by ONE through a US$390 million loan from the African Development Bank and ONE's own equity contribution of US$135 million. In June 2007, the Spanish company Abener was contracted to build this plant, due to be commissioned in December 2012 (United Nations Environment Programme 2008: 61–62).

(c) **Investors:** There are several types of investors, and their attractiveness to any sector within a developing country depends on how healthy the economy is and how attractive the country appears to be. Foreign investors are becoming increasingly attracted to emerging markets and particularly to Morocco, thanks to its political stability and sustained moves to economic liberalisation (under the guidance of the IMF and World Bank). In fact, there is a large amount of liquidity within the country that could be tapped for the energy fund either by providing attractive returns or by setting up a minimum requirement as part of the prudential rules. Finally, individual investors could also be interested if the fund were listed in the stock market, thus reaching a lager pool of investors.

4.5. THE ROLE OF THE NATIONAL OFFICE OF ELECTRICITY

The Office National de l'Electricité (ONE) is the main actor in Morocco's electricity sector (Office National d'Electricité 2007). ONE is a state-owned utility responsible for electricity transmission and is the largest in-country distribution grid. Power generation has been extended to the private sector by the creation of Independent Power Projects – an energy investment model favoured in North Africa and the Middle East for inviting in private capital to a sector previously controlled firmly by the state. So far, the Independent Power Projects produce 35% of all the power, with a total installed capacity of 1,770 MW, while the total production of ONE is equal to 3,482 MW. While the private sector is expected to take over the majority of electricity generation by 2020, ONE will retain sole responsibility for electricity distribution.

As mentioned earlier, Morocco also has foreign sources of energy supply from Spain and Algeria. The submarine electrical cable with Spain was established in 1997 and ensures an exchange of 1,400 MW. In addition, the electrical grid interconnection with Algeria was established in 1992 and provides 1,200 MW. Morocco also benefits from Algerian natural gas, from being a transit point for the movement of Algerian natural gas exports via the Strait of Gibraltar to Europe.

The strategy of Morocco is to liberalise the energy sector in order to meet the country's projected 8.5% growth in demand for electricity and provide a reasonable price to the final consumer. ONE is linked to the independent producers with a contract, while the distribution and the concession elements are not based on any central contract with ONE (see Figure 6.4).

The National Office of Electricity had launched three main initiatives to encourage investment in renewable energy from private companies:

- The promotion of the development of Independent Power Projects. In practice, ONE launches tenders for energy contracts, and the chosen developers are given a long-term take-or-pay contract with ONE. For example, this is the case for the 300 MW Tarfaya wind farm project, for which the pre-qualification process was launched in early 2007.

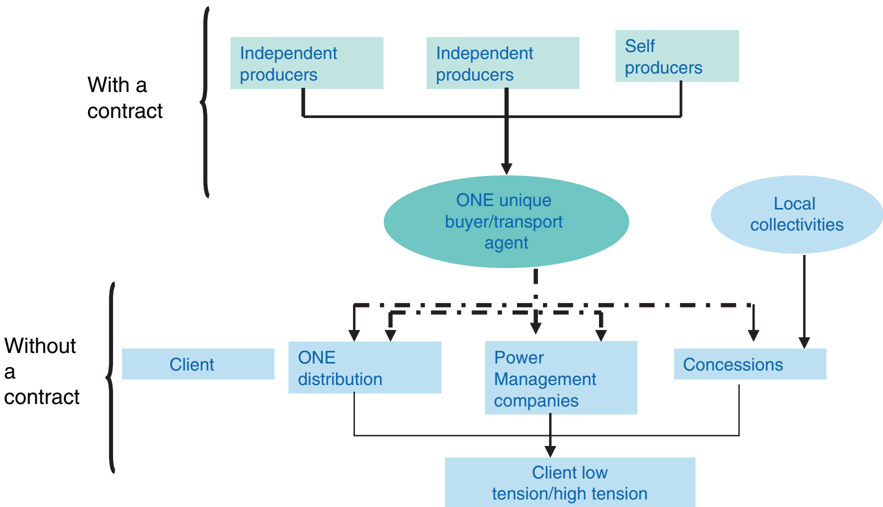

Figure 6.4. Electricity production and distribution network in Morocco.

- The *EnergiPro* initiative, which gives large industrial customers the option to develop their wind farms for their own energy consumption and to sell any excess to the grid.
- The development of wind farms in Morocco dedicated to energy export. With the existing infrastructure, such as the 1,400-MW-transit-capacity electric interconnection between Morocco and Spain, this initiative assist in the inception of a pool market and further foster regional energy trade.

5. Energy reform

In order to develop renewable energy, a further range of both institutional and structural reforms is required in Morocco. In 2007 the World Bank approved a US$100 million loan to the Government of Morocco for energy reform (World Bank 2007). The main objectives of the reforms are: (1) to join energy security with sustainable development by reducing environmental risks and enhancing the public health of energy consumption; and (2) to encourage energy independence and the valuing of national resources. The ultimate goal is to promote renewable energy to the point that it can provide 10% of Morocco's total energy usage by 2012.

The World Bank-financed programme encompasses three main components:

1. Conjoining energy security with sustainable development
2. Developing economic competitiveness within the energy through the reorganisation of the electricity sector and consolidating its partial openness to competition, whilst guaranteeing production security and
3. Reinforcing the evolution of energy policy by evidence-based strategic planning for a better-targeted energy policy in Morocco

At the heart of the reform measures is a restructuring plan for the institutions that are responsible for renewable energy development – the Centre for Renewable Energy Development and ONE. This is coupled with the preparation and planned adoption of a law for energy efficiency and renewable energy. Regarding the supporting fiscal framework, several proposals are advanced to improve the competitiveness of renewable energy projects; for example, reducing taxes for solar water heaters.

The principal economic consequences of policy reforms related to renewable energy are both direct and indirect. On the one hand, the direct advantages include the cumulated reduction of CO_2 emissions by 16 million of tons. This is equivalent to US$115 million for 2009–2015 at $7/ton of CO_2, in line with the government objectives of the renewable energy contribution to the national economy. On the other hand, the indirect advantages are the cumulated economies on energy imports (US$0.55 for 2009–2015), in addition to reducing economic vulnerability to price instability for the primary fuels on which the country still depends.

5.1. ENERGY IN THE CAPITAL MARKET

Morocco has undergone many positive changes and has laid the foundations that give it an attractive image at the international level. As a consequence, foreign direct investment has increased. As an illustration, the amount of investment for 2007 is equal to $70 billion: this indicates that the government-signed conventions for investments are higher than $20 million.

This new confidence has earned Morocco a new foreign currency long-term rating – BBB – in April 2007 (Table 6.4). With this new investment grade, Morocco is increasing foreign direct investment (FDI) in the country. A significant portion of this FDI can be channelled towards the development of renewable energy and the infrastructure on which its development depends. So far, 5% of foreign investment goes to the energy sector, while the government is multiplying the efforts to attract more investors to the sector (Figure 6.5).

The Moroccan stock market is also witnessing a big boom. In fact, capitalisation is equal to $50 billion with newly listed companies (73 listed companies).

Investors are looking for sector diversification, and the energy sector is starting to attract interest from both individual and institutional investors. Today, this sector represents 3.10% of the stock market as shown in Figure 6.6. The newly-listed energy companies are enjoying great success.

TABLE 6.4. Countries' notations.

Countries	Date of the last change	Foreign currency long-term rating	Local currency long-term rating
Egypt	December 2004	BB+	BBB
Iran	April 2006	B+	B+
Kuwait	June 2002	AA−	AA
Lebanon	July 2006	B−	B−
Morocco	**April 2007**	**BBB−**	**BBB**
Tunisia	May 2001	BBB	A−
Turkey77	December 2005	BB−	BB−

Source: Office of the Prime Minister

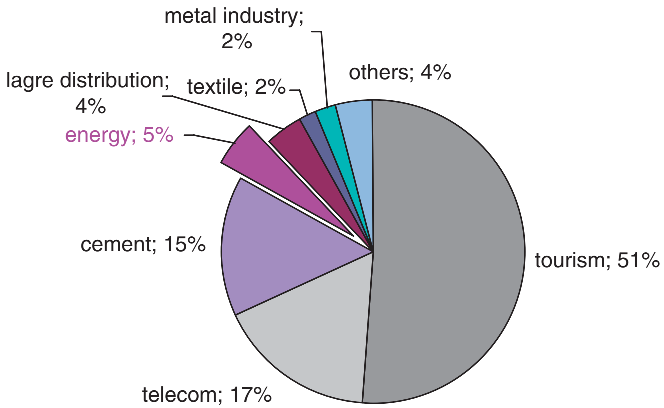

Figure 6.5. Foreign direct investment in Morocco. Source: Office of the Prime Minister.

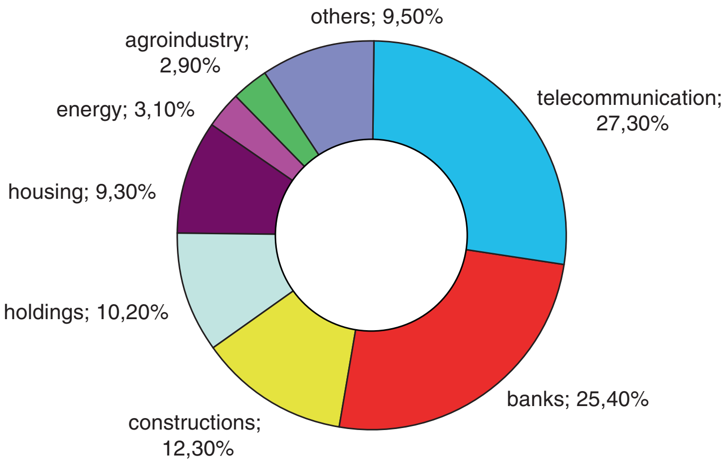

Figure 6.6. Structure of the Moroccan stock market.

6. Conclusion: Beyond financial policy

Investing in energy is not only about financing energy; it starts by encouraging prudent energy consumption. In fact, raising awareness of energy and promoting sensitive behaviour will moderate the rising energy bill faced by Morocco in the midst of high oil prices. In addition, the price of energy should be managed in a way to create incentives to change current behaviour without erecting barriers to the international competitiveness of Morocco's companies. To use the least energy, the government should encourage energy efficient construction and product consumption. The government could also use tariffication as a policy element in order to ensure an efficient use of energy.

The many projects in the country that are planned for renewable energy development will require sound coordination. The legal environment of the electricity sector and oil products will also need to be improved in order to proceed to effective liberalisation in sustainable conditions. In particular, the electricity sector calls for a division of the market into segments and the evaluation of the possibility of energy market liberalisation on a case-by-case basis. Segments of the electricity sector include: distribution, transport (high and very high tension), production, and the regulation of transfers between providers and distributors in the electricity market.

Finally, in order to develop renewable energy and stop environmental degradation, we need to be more dynamic in project development through the use of sophisticated financial solutions, making a sound bet on the newly available technologies in renewable energy and respecting the Kyoto Protocol in terms of reducing CO_2 emissions.

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SUSTAINABLE 'GREEN' RURAL MUNICIPALITIES

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Abstract. The chapter suggests several ways to reduce carbon emissions from rural communities. Both the waste and the energy sectors are significant producers of greenhouse gases (GHG), but with proper management it is possible not only to reduce the amount of GHG, but also to obtain other ancillary benefits. In the field of sustainable waste management, both the city and the agricultural sector gain from cooperation in which the agricultural sector serves as the recipient of an increasing volume of the rich organic waste produced in the city. This means of waste management is significant for countries characterised by high organic content of the waste, poor organic content of agricultural land, and generally inferior waste-management practices. According to this method, each ton of waste reduces 0.25 t of CO_2 equivalents by avoiding methane emission at landfill sites, and furthermore, the addition of compost to agriculture soils can increase yields: the production of 1 t of dry vegetative matter leads to the sequestration of 2 t of CO_2. Another means to reduce carbon emission is by increasing energy efficiency in the community. Several alternative measures are presented in the chapter, including advanced solar technologies. In addition to carbon emission reduction, the suggested alternatives can reduce air pollution and energy expenditures.

Keywords: Israel, rural communities, waste management, energy conservation, renewable energy, solar thermal technologies, photovoltaic technologies, carbon emissions

1. Introduction

Greenhouse gases (GHG) emissions and global climate change have clearly emerged as one of the most important environmental challenges confronting the world today. The reduction of carbon emissions is a technological challenge, a social obligation, and the centre of an economic debate. Urban and rural

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communities are setting policies and goals to reduce carbon emissions, creating a need to integrate energy technologies and implement various schemes in the design and development of new and existing communities.

In 2004, the Israel Ministry of National Infrastructure published a set of policies to promote the use of renewable energy. The main purpose of this policy was to reduce Israel's dependence on foreign oil. However, using renewable energies, improving energy efficiency and proper waste management can also contribute significantly to GHG reductions.

Although Israel is classified as a developing country under the United Nations Framework Convention on Climate Change (http://www.unfccc.int/), a comparison of Israel's carbon dioxide emissions from fuel combustion with that of other countries shows that Israel is not far behind some of the more developed countries listed in Annex I. Therefore, although not obligated to do so, the government has resolved to undertake voluntary activities to restrict or reduce emissions of GHG.

Central and local communities often seek useful tools and indicators for performance evaluation and public information. The Israel Ministry of Environmental Protection (www.sviva.gov.il) has formulated ten principles for a sustainable local authority, to encourage local authorities in Israel to move toward sustainability. These principles are listed in Table 7.1

The principles for a sustainable local authority are similar to other indicators, such as the recently published set of 198 measures of the Communities and Local Government team in the UK (www.communities.gov.uk). It is clearly seen that energy and waste management are key indicators for environmental sustainability.

Although local authorities in Israel often face financial problems and some (especially the poorer communities) rely completely on funds from the Ministry of Interior, and although these principles and indicators are ambitious and only partially implemented in practice by local authorities, they are expected to be the first step in the creation of sustainable local authorities. This chapter will demonstrate the role of the rural communities in Israel in developing modes of action to reduce carbon emissions, as well as increasing the volume of waste recycled and composted, leading to reductions in the total amount of landfilled municipal waste. These models include both interaction between the urban and the rural communities and specific alternatives that could be implemented in local, closed communities.

Another sector that can contribute significantly to GHG emission reduction is the energy sector – by means of energy conservation, increasing energy efficiency, and of course, implementing renewable, non-polluting technologies.

According to a ministerial publication (Gabbay 2000), the energy industries contribute nearly 60% of the total GHG in Israel and the waste sector contributes an additional 13%. The significant contribution of the waste

TABLE 7.1. Indicators of environmental sustainability.

1. Rational management of urban natural resources

Water and Sewage

Access of the entire population to good quality water; water savings in the private and public sectors; parks and landscapes using low water-consumption plants; urban planning sensitive to water conservation; reduction of water loss; use of treated water and urban runoff; treatment of urban wastewater

Land

Efficient use of land; utilization of underground space

Energy

Electricity conservation in municipal buildings and facilities; energy-saving construction; promotion of alternative sources of energy; environment-friendly fuel in the municipal vehicle fleet; improvement of air quality and reduction of air pollution

2. Public participation in decision making and municipal action

Participation

Open communication with all residents to assure an ongoing dialogue; joint city-resident teams to plan and implement urban activity; support of local non-profit organizations; integrated activities among different sectors; empowerment of a public representative of future generations; enhanced visual appearance of the city with the aid of local artists

Transparency

Transparency of municipal activities and information dissemination; adoption and development of environmental/social indicators; opening of plenary meetings to residents; presentation of the municipal budget for public opinion

3. Protection and enhancement of parks and landscaping

Statutory protection of green lungs in the city and surrounding areas; high ratio of parks per capita located equitably and offering universal access; support of local biological diversity by preserving habitats in cities

4. Development of transport systems that are environmentally friendly and provide accessibility to all

Preference of public transportation; promotion of bicycle paths alongside new roads; bicycle and pedestrian paths throughout the city; public transportation to schools, workplaces, and entertainment centres; safe access to pedestrian crossings and entrances to public buildings; slowing down of traffic at junctions and near public institutions

(continued)

TABLE 7.1. (continued)

5. Minimization of municipal waste Waste minimization and separation at source in municipal and public institutions; encouragement of domestic and industrial waste recycling; separation of hazardous materials from domestic waste; neighbourhood collection and recycling centres for cardboard, newspaper, plastic containers and textile wastes; backyard composting and composting centres; waste minimization and recycling in municipal and public institutions; implementation of a deposit law for beverage containers; municipal second-hand centres	**6. Promotion of the local economy** Support of local industries and businesses employing local residents; enforcement of plant compliance with emissions standards; rejection of proposals for new plants that may impose pollution or risk; encouragement of employers to adopt sustainable behaviour and health codes; linking the education system with local industry and business; participation of local industry and business in urban activity
7. Adoption of a policy of environmental and social justice Identification and reduction of gaps in environmental and health status of different groups and neighbourhoods; access of households and users to water, electricity, and sewage treatment; urban renewal with emphasis on neglected or run-down areas; incentives to residents for improving properties and for 'green' building; rent assistance to the needy in return for contribution to the community	**8. Advancement of environmental/social education and education for health** Incorporation of environmental and health programs in formal and informal educational institutions; transformation of municipal institutions into 'green' and health promoting institutions; promotion of voluntary and resident activity on behalf of the environment; animal welfare with the participation of the local educational system; participation of children and adolescents in urban action on behalf of the environment, community, and health; local culture, heritage, and landscape as environmental and social resources; access to environmental information and data; safe access to community educational institutions by foot or by bicycle
9. Environmental management of the municipality and its institutions Preference of purchasing 'green' products; pooling of resources among municipal units; incentives to use public transportation and shared transport systems; increased awareness of sustainability and health among municipal workers; long-term planning according to sustainable development principles; adoption of ISO 14000; enforcement of environmental and health-related laws and bylaws	**10. Advancement of interurban and international partnerships to promote the environment** Partnerships between local authorities and international activities to promote sustainable development and health; pooling of resources from different sources for environmental protection; twinning cities with sustainable cities and healthy cities worldwide; participation in professional forums on local sustainable development and public health; joining the International Council for Local Environmental Initiatives (ICLEI)

sector is due to the high organic content of the waste (ca. 40% by weight) and the absence of pre-treatment of most of the waste that is landfilled. According to the mitigation option suggested in the study, energy conservation is expected to reduce total GHG emissions by 5–10% and proper waste management could reduce them by an additional 10%.

2. Urban and rural cooperation to reduce carbon emissions through waste management

Most of the European national strategies for the reduction of biodegradable municipal waste going to landfills, set up according to Article 5(2) of the EU Council Directive 99/31/EC (http://eur-lex.europa.eu), stress the importance of diverting organic municipal solid waste (OMSW) from landfills, and using the organic fraction as a source of energy, either by producing methane in anaerobic processes or by aerobic composting of this fraction. The compost is then applied to agricultural lands and contributes to agricultural production.

There is a vast body of scientific knowledge on various aspects of organic waste treatment and its agricultural uses, addressing, for instance, logistic processes (Redd 1991), air pollution (He et al. 2001), compost productivity (Avnimelech 1997), and socioeconomic aspects (Hayashi et al. 2004; Janzen et al. 1999).

Biological treatment (composting or anaerobic digestion followed by composting) seems a promising disposal solution in Israel, as well as in other countries in the Mediterranean region: first, OMSW comprises more than 40% of the total municipal solid waste (MSW) produced; second, in this semi-arid region compost productivity is high due to the low soil-organic content. In addition to the above, landfill capacity is expected to be exhausted in Israel by the year 2014 (Hoshva Consultants 2005).

Local authorities in Israel are required by regulation to recycle MSW (www.sviva.gov.il). Consequently, the amount of recycled OMSW has increased from approximately 48,000 t in 1998 to almost 200,000 t in 2004. This is about 14% of the total OMSW, which amounts to 1.47 million tons per year. Today, 85–90% of all domestic waste is disposed of at landfills, at prices relatively low compared to those in developed countries (ca. $10–15/t). These wastes are liable to cause severe environmental effects; for example, Ayalon et al. (2001) found that methane produced at landfill sites accounts for approximately 13% of the total GHG contributed by all sectors in Israel.

These special characteristics of the 'supply side' of rich organic waste of the urban community, and the 'demand side' for the reduction of GHG emissions, coupled with the potential productivity enhancement associated with the addition of organic matter to agricultural soils cultivated by the rural community, create a unique opportunity for a more efficient waste management practice in Israel, and in other countries with similar characteristics. In other words, biological treatment is a sustainable solution (Ayalon et al. 2000a; Eunomia 2005).

The external costs of landfilling, which are mainly due to methane emissions, have been estimated in the range of US$5–10/t waste (Eshet et al. 2006). Application of compost (at rates of 20–40 m3/ha) leads to a 10–20% crop yield increase, or an approximate gross contribution of US$20–40/t of compost. In addition, plants and agriculture crops serve as a sink that sequesters carbon dioxide. The production of 1 t of dry vegetative matter leads to the sequestration of 2 t carbon dioxide (Ayalon et al. 2000b). A world market for trading CO_2 can benefit from cooperation where waste produced in the city is utilised as a resource in farmland. The main benefits of this cooperation are increased yields, mitigation of methane from landfills, and carbon sequestration by agriculture crops.

Kan and Ayalon (2006) further studied and optimised the allocation of organic wastes (municipal solid waste, wastewater-treatment sludge, etc.) to composting plants; that is, the compost produced in the plants, as transported to agricultural-rural regions, and distributed to the various crops grown there. The total potential compost production in Israel is 1,534,000 t/year and the value of the objective function (net benefit) is $88,576,000/year. This value expresses the financial return to the Israeli economy from the composting array relative to sending the organic wastes to landfills. Table 7.2 summarises the costs and benefits of the suggested scheme.

This benefit can determine the cost sharing between cities and the agricultural sector and can create a market between the agricultural sector,

TABLE 7.2. Benefits and costs under optimal waste management.

Benefits	**$/year**
Revenue increase in agriculture	103,121,000
Savings of organic waste landfill	56,741,000
Total benefits	159,862,000
Costs	
OMSW separation at source and collection	41,556,000
Organic waste transportation	8,982,000
Compost variable production costs	7,966,000
Compost fixed production costs	556,000
Compost transportation	5,405,000
Compost application in the field	6,821,000
Total costs	71,286,000
Net benefits	**88,576,000**

a supplier of environmental services to the urban society, and the sustainable city. Since, each ton of waste can reduce 0.25 t of carbon dioxide (see Ayalon et al. 2000b), the suggested scheme could directly reduce 750,000 t of CO_2 annually, in addition to the elimination of methane emissions from landfills.

Both the city and the agricultural rural sector could gain from such cooperation, in which the agricultural sector serves as for a recipient of the increasing amounts of the wastes produced in the city. A significant environmental benefit can be achieved if the organic fraction of the waste is separated and composted and used in the agricultural sector. The specific gain was calculated for typical waste composition and agriculture in arid or semi-arid soils, areas threatened by shortage in water, desertification, and similar water-stressed environments.

It must be emphasised that despite the clear benefits described in the above study, the Ministry of Environmental Protection has not yet developed comprehensive implementation plans for the suggested waste management scheme.

3. Energy in rural communities

About 10% of the population in Israel lives in rural areas. In 2004, 39.4% of the rural population lived in moshavim, 19.7% in kibbutzim,[1] and the rest in other community villages. This small fraction of the populace produces the bulk of the Israeli agricultural output that is used both for internal consumption and for export.

These communities, especially the kibbutzim, are relatively small. Characteristically, each is a closed community in which residents share common utilities like a dining room and kitchen, central laundry, and so forth. Until recent years, the population of any given kibbutz shared the same resources, income, and expenditures, which were evenly distributed among the members. Consequently, environmental 'free riders' were common, mainly in the field of energy and water consumption. (A free rider [Johnson 2005] is a person who chooses to receive the benefits of a 'public good' or a 'positive externality' without contributing to paying the costs of producing those benefits.) On the other hand, this 'collective' structure enables projects for reduction of the community's energy demand or implementation of technologies to produce energy from renewable resources. Another characteristic of the kibbutz is the power of the community council – after a democratic vote has

[1] The moshavim and kibbutzim are rural communities with an emphasis on communal labor and social life.

been held, the council can make autonomous decisions and execute them rather efficiently.

In the following discussion, a detailed plan of a 'green kibbutz' is presented, as well as possible energy conservation, improved efficiency, and implementation of technology in remote villages.

3.1. THE GREEN KIBBUTZ

Kibbutz Ein Harod Ihud (EHI), located in northern Israel facing the eastern Jezreel Valley and Gilboa ridge, is a 'green kibbutz'. A small group of members developed the philosophy of a green kibbutz, which the kibbutz authorities then approved. A 'green team' has been set up, including professionals in areas such as engineering, economics, electricity, water, agriculture, heating, and business consultation, to help transform theory into practice.

The energy demands of EHI include residential units (cottages and apartments) for its members and communal institutional facilities such as a dining hall, a central kitchen, a central laundry, and an ironing facility. The kibbutz also operates two industrial plants in addition to its livestock operations of dairy cows and sheep. The energy needs of the kibbutz are met by connection to the national electrical grid and by on-site hot water and steam plants. As a communal settlement, the kibbutz has only one main connection to the external grid; it owns and operates internal transmission and distribution systems itself. In 2003 the kibbutz consumed over 9,500 MWh (megawatt hours) inclusive for residential, institutional, industrial, and agricultural usage. During the same year the district hot water and steam supply plants consumed over 160 t of LPG (liquefied petroleum gas) and nearly 150 t of fuel oil.

An energy survey of EHI was conducted and the project was designed and partially funded in cooperation with SNI (the Samuel Neaman Institute for Advanced Studies in Science and Technology), within the framework of an agreement between the Institute and the US Department of Energy to promote clean and sustainable energy development. The project is consistent with the goals and role of SNI in setting environmental policy (Ayalon and Avnimelech 2007).

Further details of current energy requirements for the various operations in the kibbutz are summarised in Table 7.3.

Once an energy survey was conducted and key consumers were identified, energy conservation and renewable energy goals were set. The project was designed to test and demonstrate the suitability of various measures to reduce excess demand for electricity and to introduce renewable energy technology options that can be replicated in other kibbutzim and agricultural settlements. The project's overall goals were:

TABLE 7.3. EHI energy demand.

Description	Energy demand	Comments
Hot water and steam for laundry, kitchen, dining room, and industrial plants	Laundry boiler produces hot water and steam with a 40% utilization rate. Used about 100,000 kg of LPG in 2004	Reverse osmosis system is used to soften the water for laundry and the communal dining room
Air-conditioning for institutional and industrial operations	Each of the two plants requires 300 t of cooling power Institutions require 172 t of cooling power	A/C is currently provided by multiple small air-conditioning units and chillers
Residential hot water	The kibbutz has a total of 350 residential apartments Hot water used to be provided by three district plants that used #2 fuel oil In 2004 they consumed 59,300, 37,750 and 54,350 l of #2 fuel oil, respectively	District plants are being phased out Apartments were outfitted with individual 200-l electric boilers with heat exchangers Units are designed to allow the installation of solar heating capability
Hot water for cowshed	Boiler fired by #2 fuel oil, consumes 450 l/month Storage tank of 1,000 l System produces 1,800 l of hot water at 70°C per day	Alternative strategies are being considered to capture the wasted heat created in refrigerating the raw milk
Hot water for sheep pen	A system of three electric boilers produces 550 l of hot water at 70°C per day	Alternative strategies are being considered to capture the wasted heat created in refrigerating the raw milk
Overall electricity usage	In 2003: used 9,567,120 kWh	Based on main meter where reconciliation with the external grid operator (Israel Electric Corp.) is done

1. Cost-effective, energy-efficient operations and energy demand responses appropriate for typical agricultural rural settlements
2. Maximum utilisation of appropriate renewable energy resources and efficient integration of local energy systems with existing energy grids
3. Reduction of greenhouse gas emissions and environmental impacts from residential, institutional, industrial, and agricultural operations on-site

In light of these goals, several options and projects were proposed. Further investigation is required to evaluate the technological and economic feasibility of each of these according to the criteria set forth in the project goals cited above. Some of the projects have already been approved and financed, while others are still in the stage of development. The following describes the status of current energy conservation and renewable energy projects in EHI:

- **Energy conservation in the kitchen and dining room.** At present, the steam produced for the laundry also serves the kitchen and dining room. The steam line is not insulated; as the kitchen requires lower temperature and pressure than the laundry, there is considerable loss of energy. This steam line will be deactivated and hot water for the kitchen and dining room will be produced by solar water-heating systems. The solar system will provide 27.5% of total energy needs of the kitchen and dining room. Other water heating needs will be met by heating the water during night hours when the rates are much lower. The hot water will be stored in insulated tanks for use during daytime. The Ministry of National Infrastructure recently approved this project and began providing partial funding for it.

- **Heat recovery from milk cooling systems.** Heat energy that is removed from the milk during cooling will be used to preheat water needed for operation of the dairy farm. Further heating of the water will be based on solar water-heating systems. The technology and rationale are well known, but accurate measurements and planning are required in order to replicate this project in other dairy farms in the region. The Ministry of Agriculture is providing partial funding for the design and installation of the system.

In addition, there are a number of other energy conservation and renewable energy projects planned for EHI:

- As stated earlier, due to the communal characteristics of the kibbutz, there are no electricity meters in the homes and many of the common facilities. Installing them will not only raise awareness but may reduce the electricity consumption significantly.

- In addition, old inefficient air conditioners are very common in EHI. The requirement that households pay according to their electricity consumption will create an incentive to replace old air conditioners with new and efficient ones.

- Construction and planning regulations by the local planning committees require the domestic sector to install solar water heating systems. Due to the de facto autonomy of the kibbutz from the national planning committees, this regulation has not been enforced. EHI is now introducing solar water heating for residences.

- Other, more ambitious projects include using cow and sheep manure to generate biogas, installation of solar air conditioning for institutional and industrial operations, and generation of solar photovoltaic power.

Once these energy-related measures and technologies are installed, monitoring of the systems will be essential. An economic analysis will be performed in order to assess the effectiveness of emission reduction, energy efficiency, and costs associated with the energy technologies tested. Once tested and proven, these projects can be readily replicated in similar non-urban and agricultural communities.

3.2. PHOTOVOLTAIC (PV) SYSTEMS IN REMOTE VILLAGES

PV systems are becoming increasingly important amongst renewable energy sources used to generate electricity; despite the comparatively high cost, their utilisation growth rate exceeds that of other sources. Worldwide installed capacity of electricity generated by photovoltaic systems currently exceeds 2 GW with a growth rate of 30% per annum, valued at $7 billion (EC 2005). Photovoltaic cell technology, which was very expensive in the past, has developed very quickly and the global price has decreased to $5,000–6,000 per kilowatt-peak (in megawatt-sized systems) – this amounts to about half of what it used to be 5 to 10 years ago. Today, one of the obstacles preventing more rapid growth of this industry is the worldwide shortage of crystalline silicon (which can be produced from abundantly available inexpensive material). However, in light of growing efforts and with increased investment, it can be expected that this problem will be overcome and the price will continue to decline. Several countries, predominantly China and Japan, have set targets for themselves of building, with major investment, a PV cell production capacity that could supply the entire world.

The efficiency of existing silicon panels reaches about 17%. Concurrently, another technology has been developed, based on the multi-junction solar cells coupled with radiation concentration (CPV) that have been utilised in the space industry. These systems would be able to obtain enhanced efficiency (currently reaching approximately 35%). The price of these cells is quite high but their integration in an optical concentrator unit enables reduction of the system's cost while allowing several different possibilities for utilising the residual heat – that same solar energy residue that impinges on the solar cell that is not converted into electricity.

Several developed countries provide generous subsidies for photovoltaic electricity generation within the framework of general programmes to encourage increased utilisation of solar energy. For example, in Germany the subsidy is €0.45–0.60/kWh; in France, €0.087–0.153/kWh; and in Austria €0.036–0.073/kWh. In Korea the support reaches up to €0.57/kWh (EC 2005).

Such commitment from national authorities provides the leverage for entrepreneurs seeking financial support for photovoltaic projects in these countries. In the US and Japan, for example, there are subsidy programs that apply both to the capital investments and to the price of electricity sold to the grid.

In Israel today the market is small and insignificant. There are now incentives that enable inclusion of PV systems in the grid (feed-in-tariffs for solar systems have recently been introduced by the Israel Public Utility Authority Israel, www.pua.gov.il). The cost of a system in Israel today is about $10/Wp for small systems and up to $7–9/Wp for megawatt-sized systems. However, in some cases the installation of a PV system should offer external benefits: since wired electricity infrastructure is expensive, remote villages usually use diesel generators, which are expensive and noisy and contribute both to local and global emission of air pollutants. Therefore, installation of PV systems may replace current polluting and expensive diesel generators, as well as eliminate the need for costly physical and electrical infrastructure.

The Arab village of Drejat, situated 50 km northeast of Beer Sheba, is populated by 850 inhabitants. The village is not connected to the national electricity grid: energy and lightening are provided by small domestic generators operating with diesel fuel. During the past 2 years, the village has installed 20 PV solar systems in addition to six solar streetlights, a system in the local school that will enable students to conduct research, and a solar system for the village mosque. The current cost of the project, which is funded by the Israeli Ministry of National Infrastructure and the Negev Development Authority, is $300,000. An additional $900,000 is needed to supply the entire village with solar energy from PV systems. Economic analysis of this project must take into account the absence of any existing land infrastructure.

4. Concluding remarks

As global climate change is one of the most important environmental challenges confronting the world today, local municipalities can and should play a role in GHG reduction. This review of different means to reduce CO_2 emissions shows how rural communities can exploit their advantages, both as part of the agriculture sector and as a remote and distant communities, to implement means that reduce energy demand as well as advanced solar technologies.

In many articles and inventory statistics, the agricultural sector is described as a significant contributor to GHG emissions (e.g., DESTATIS 2004; Ridolfi et al. 2008; etc.). Cooperation between the city and the rural agricultural sector in waste management can create a win–win situation benefiting both city and farmland. Compost produced from the organic fraction of urban waste is an essential amendment to the arid and semi-arid regional soils characteristic of the Mediterranean area. It has a particular relevance in certain regions of southern Europe, where it plays a valuable role in overcoming organic matter depletion, desertification, and soil erosion, as well as in areas continuously used in arable production, where the level of organic matter is decreasing. The application of compost leads to a significant increase in crop yield and therefore, to increased benefits to farmers.

Another means of reducing GHG emissions in rural settlements lies in the energy sector. The motivation for installing solar systems in grid-connected settlements (such as EHI) and in non-grid-connected villages (such as Drejat) differs. The desire of EHI to become 'green' is based on sustainability considerations, but also on altruistic and fashionable motives. In the case of Drejat, the considerations are more practical, since the use of PV systems provides a better quality of life. The developments in both these examples may be replicated in other rural settlements, according to their characteristics.

It should be noted that 'green fashion' is liable to result in high expenditure that is not economically justified. Therefore, a rational and scientific analysis is required. Academic research plays a significant role in the field of environment in general, and regarding the issue of reducing CO2 emissions in particular, by developing new and economic technologies, capacity-building for the adoption of these systems, and bridging between diverse players that have intrinsic limitations and are often driven by different agendas. Many other universities and independent research centres in the region (and further beyond) could play an active role in addressing the energy challenges in their countries.

Governments, academia, industries, local communities, and the residents of any country or village share the energy challenge. The examples presented here clearly show that each of the measures discussed produces a double dividend: while addressing this challenge, they also gain additional advantages, including very significant environmental improvements such as reduction of air pollution and sustainable waste management.

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SOLAR ENERGY FOR APPLICATION TO DESALINATION IN TUNISIA: DESCRIPTION OF A DEMONSTRATION PROJECT

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Abstract. For southern Mediterranean countries, small-scale solar desalination might be the most economic solution for providing potable water to remote communities lacking access both to the electric grid and the national water supply infrastructure. However, these communities have significant solar energy potential, enabling the use of solar power for fresh water production. This chapter identifies the potential of solar energy for water production in Tunisian rural communities. Three pilot research desalination concepts based on solar energy are described and analysed: solar multiple effects distillation; reverse osmosis driven by photovoltaic panels; and membrane distillation. The first demonstration desalination plant, for supplying 300 inhabitants, is located at Ksar Ghilène, southern Tunisia: it uses solar energy to power a reverse osmosis desalination unit with a capacity of 15m3/day. This chapter gives an analytical description of the plant components and reports experimental results for a 6-month operating period. Several problems challenges remain unsolved (e.g. brine rejection, low efficiencies, high cost). For this reason more research is required to optimise the technical and operating parameters and to improve the economic feasibility of the process.

Keywords: Tunisia, solar energy, water scarcity, electricity, reverse osmosis, renewable energy

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1. Introduction

Located on the southern border of the Mediterranean basin, Tunisia has very limited water resources with much of this water brackish, unsuitable for drinking or irrigation. Having an arid to a semi-arid climate, the country suffers from a lack of precipitation, which is also extremely variable in space and time. Some northern regions get an annual rainfall average of more than 1,300 mm/year (e.g. the northwestern region of Tabarka). On the other hand, regions in the far south (more than 60% of the total area of the country) receive less than 100 mm of rain per year. Moreover, domestic water in many regions of the country, especially in rural regions, has a salinity level of more than 3 grams per litre (g/l), which means that it is not suitable for drinking.

To resolve this problem, Tunisia has resorted to brackish water desalination since the 1980s. Several desalination plants have been constructed in the south; for example, on the islands of Kerkena and Djerba, and in the city of Gabes. Under the 2005–2009 national development plan, 13 desalination plants are eventually planned, with a combine output of 2.3 million cubic metres (Mm^3) a day.

In rural areas, inhabitants are scattered and lack the proper energy and water infrastructure for the implementation of large-scale desalination plants. The conventional desalination technologies are not adapted to this situation due to the small requested quantities of water (decentralised demand). In fact, these techniques are economically feasible only for large production (thousands of cubic meters per day). Furthermore, in many rural regions, the conventional energy needed for the functioning of desalination plants is not available (electricity, fuel, etc.).

On the other hand, these regions have an important potential for renewable energy (RE), especially solar energy where sunshine in southern regions can reach 2,500 h/year. RE can be harnessed to power small-scale desalination plants in order to produce the fresh water necessary to cover basic requirements (notably drinking and cooking). Hence, a few experimental pilots have been implemented in the rural regions of Tunisia since the 1950s. These have experimented with (solar distillation, multiple effect distillation (MED), and reverse osmosis (RO) desalination driven by solar photovoltaic (PV) energy. The latest one is a photovoltaic-driven reverse osmosis (RO-PV) desalination plant has been installed in the southern village of Ksar Ghilène under the framework of a Tunisian–Spanish cooperation project.

This chapter aims first to identify the problematic of water and energy in Tunisia and especially in the rural regions. It illustrates the water demand and the quality of distributed water in rural communities. Second it analyses the potential of solar energy in the country. It reviews several studies that were carried out about desalination pilots driven by renewables, including solar multiple effects distillation, reverse osmosis driven by photovoltaic panels, and lately membrane distillation. The experimental results show technical promise; however, more investigations will be needed to optimise the operating parameters and improve economic feasibility.

We will focus in this chapter on the most recent RO-PV desalination project installed in Ksar Ghilène, which started in May 2007 with a capacity of 15 m^3/day. The technical and experimental data of the project will be presented in detail. Finally the prospect for the development of similar projects in the southern Mediterranean countries will be discussed.

2. The water situation in Tunisia

The water situation in a country largely depends on water resource availability and the population growth rate. The global potential of water resources in Tunisia amounts to only 4,545 Mm^3/year (1,845 Mm^3 are ground water resources and 2,700 Mm^3 originate from surface waters), as shown in Table 8.1. Potential water resources (i.e., surface water and ground water) are unevenly distributed within the country (Houcine et al. 1999). Table 8.1 shows the available quantities of water and their respective sources within each region.

The northern part, covering an area of only 17% of the country, has 60% of the total water resources. On the other hand, the larger southern part of the country (61% of the total area) has only 23% of the total water resources.

Moreover, in many parts of the country and particularly in the south, ground water resources are often brackish, and are thus unsuitable for drinking or irrigation. Figure 8.1 shows a detailed classification of water resources in Tunisia according to their salinity (Ben Jemaa et al. 1999). Knowing that water is considered as drinkable if its salinity is less than 1.5 grams/litre (g/l) and according to the Figure 8.1 we observe that only 8.4% of the total shallow groundwater can be considered as potable.

TABLE 8.1. Water resources availability in Tunisia by region.

	Region (Area %)			
	Northern (17)	**Central** (22)	**South** (61)	**Total** (100)
Surface water (Mm^3/year)	2,185	290	225	2,700
Ground water (Mm^3/year)	550	465	830	1,845
Total Water resources (Mm^3/year)	2,735	755	1,055	4,545
Overall water totals (%)	60	17	23	100

At the regional level, the examination of the water demand in the North African countries shows that Tunisia has the smallest increase in the water demand over the 30-year period 1995–2025 (Figure 8.2). This is due to the fact that Tunisia has the lowest population growth rate. Demographic studies predict that the growth rate of the Tunisian population will decrease from 1.9% in 1990 to reach 1.3% by the year 2015 and will remain constant thereafter. However, due to expected increases in living standards, the specific water consumption is expected to increase from 132 l consumer per day (LCD) in 1990 to 262 LCD in 2025, corresponding to total potable water demand of 877 Mm^3/year.

The notion of specific water consumption is a very important factor in estimating future demand: taking into account the population growth alone will give an inaccurate water demand projection. As illustrated in Figure 8.3, water consumption per capita in the North African region will increase dramatically in the next years. This increase, which is due to progressive urbanisation and a steady rise in standards of living, will have a considerable impact on the increased rate of demand in the region for potable water.

Given the overall limited water supply in the region and the increase in the demand, it is estimated that the North African region will suffer from a huge deficit in trying to meet its water needs in the near future, as denoted by Figure 8.4. By the year 2025, the potable water deficit is estimated to reach 500 Mm^3/year in Tunisia alone and approximately 15,000 Mm^3/year for the

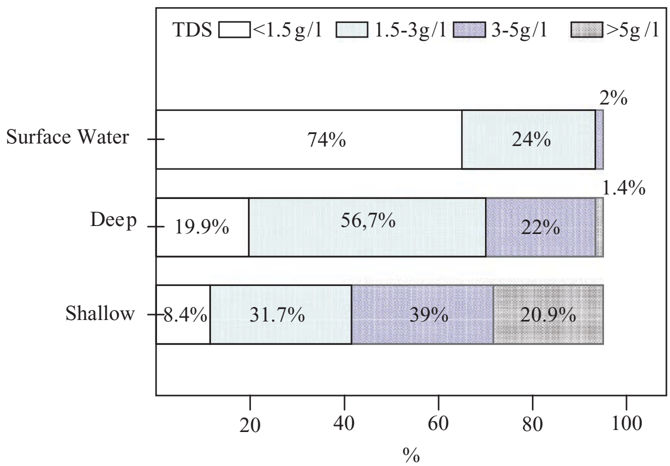

Figure 8.1. Water resources classification according to salinity levels. Source: Ben Jemaa et al. (1999).

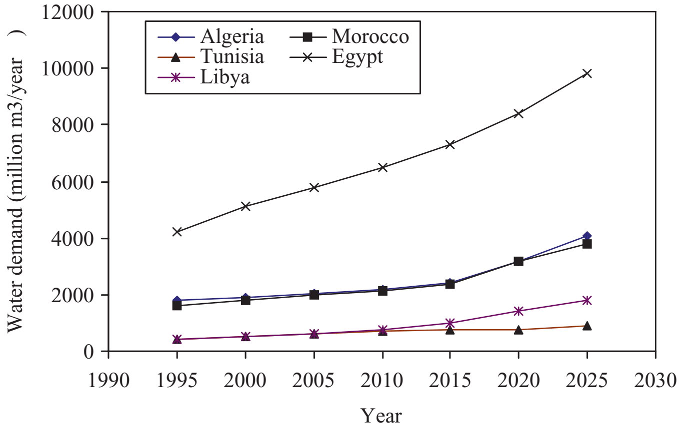

Figure 8.2. Water projection demand in the North African countries.

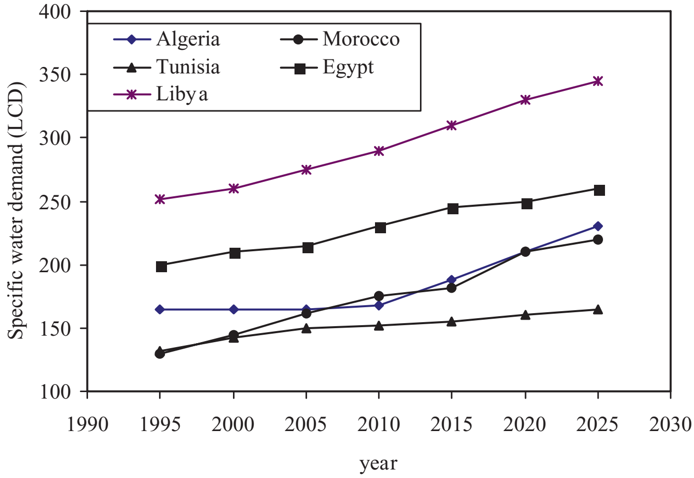

Figure 8.3. Projected specific water demand in the North African region.

whole region (Ben Jemaa et al. 1999). Potential water resources development in the future – such as dam construction, water transfers and water conservation projects – can only partially cover this deficit. For remote and isolated locations (e.g. the south of Tunisia, the northwestern coast of Egypt, the southern region of Morocco, and the Western region of Algeria), brackish and sea water desalination projects are estimated to be the most economic and practical solution for solving the problem of fresh water scarcity.

Tunisia has mobilised a large proportion of its water resources (surface and underground waters) using dams, transport aqueducts, small lakes, deep

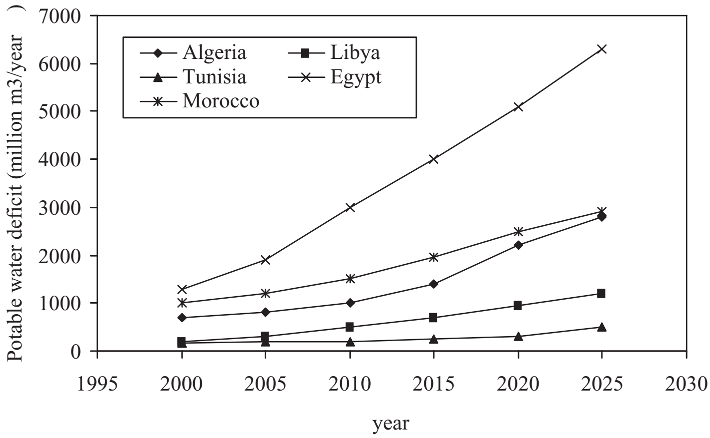

Figure 8.4. Projected water deficit in the North African Countries.

wells and desalination plants. For the bulk of the population living in cities and other large-scale agglomerations, the problem of fresh water has been resolved. However, in rural regions the population is still suffering from a lack of water resources.

3. The energy situation in Tunisia

3.1. CONVENTIONAL ENERGY RESOURCES

Unlike its immediate neighbours, Algeria and Libya, Tunisia only has modest fossil energy reserves. In fact, crude oil reserves in the country (at an estimated 308 million barrels in 2006) are well below those available in other North African countries, with slightly more significant gas reserves (2.75 trillion cubic feet). In addition, Tunisia receives some natural gas as an in-kind payment for serving as the transit point for the Trans-Mediterranean (TransMed) pipeline, which transports Algerian gas to Italy.

Similar to the projected trends in water demand, energy demand in Tunisia keeps increasing exponentially and is expected to reach 10,200 thousand tons of oil equivalent a year (Ttoe/year) by the year 2010. However primary energy (crude oil and natural gas) is progressively declining due to reserve depletion. In fact, from the late-1990s, Tunisia started to have an energy deficit and domestic production no longer covers demand (Table 8.2).

Regarding the rate of electrification in the country, the national electricity and gas company, STEG (Société Tunisienne de l'Electricité et du Gaz), announces coverage higher than 98%, supplying more than 2.5 million customers.

TABLE 8.2. Energy demand and availability in Tunisia (1990–2005).

Year	National energy supply (Ttoe)	National energy demand (Ttoe)
1990	6,000	4,500
1995	5,400	5,500
2000	6,300	6,500
2005	7,200	6,400

Aware of the challenges of energy availability, Tunisia was a pioneer in exploring the use of renewable energies in rural regions for electrification and desalination. This policy choice was reinforced by the abundance of different forms of renewable energy throughout the country (solar, wind and geothermal).

3.2. SOLAR ENERGY POTENTIAL

Unlike its poor endowment of fossil energy sources, Tunisia has an abundance of renewable energy sources. Located within the solar belt of the world, Tunisia has ample solar energy throughout its territories. Being the most abundant form of renewable energy, solar energy constitutes a big asset for arid and semi-arid regions. Unfortunately, this abundant and free form of energy is being under-exploited due to the lack of economically competitive conversion processes that take advantage of it. Tunisia receives an average of 350 cal/cm^2/day of solar radiation in the north (Maalej and Ben Jemaa, 1998). The intensity of solar radiation gets even higher in the southern part of the country reaching an average of 450 cal/cm^2/day with a total insolation period of 3,500 h/year and 350 sunny days per year. Figure 8.5 shows a contour map of the mean yearly solar radiation intensity in Tunisia.

The estimated annual solar energy potential can reach a magnitude of 266 Ttoe (Bahri 1991). It is important to note that the southern part of the country with a higher solar radiation is the region where the problem of fresh water shortage is most acute. The most used applications of solar energy in the country are rural electrification, solar pumping and water desalination.

3.3. THE RURAL POPULATION IN TUNISIA

In Tunisia 15% of the population (1.5 million) is still living in rural regions as dispersed communities. The distributed water volume in these regions is

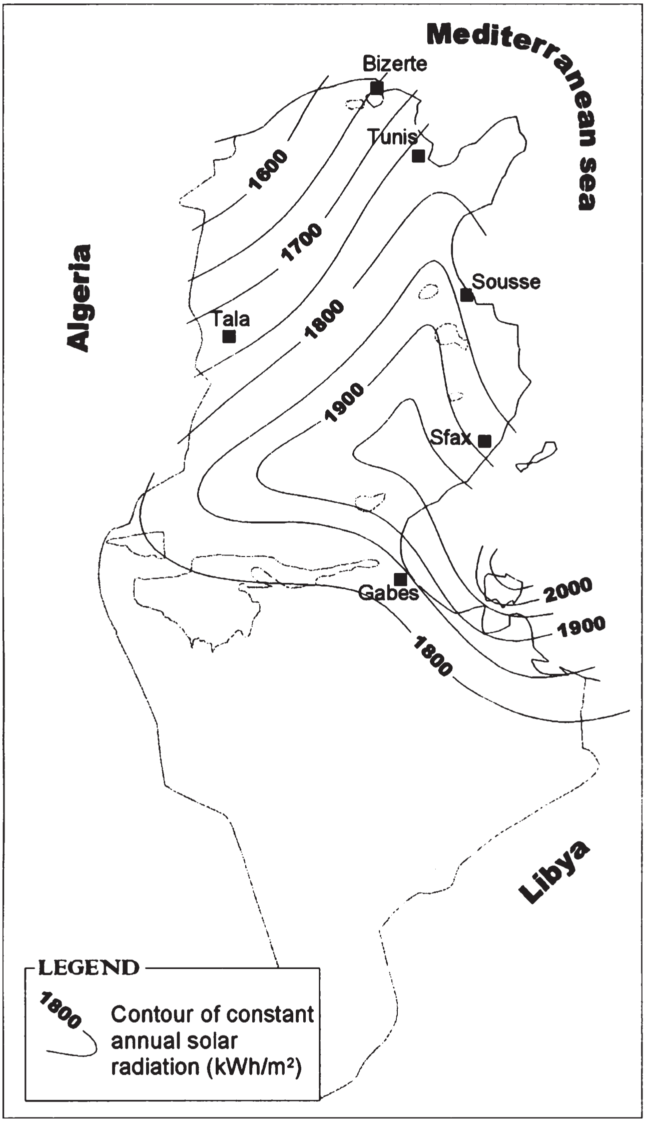

Figure 8.5. Contour map of mean yearly solar radiation intensity in Tunisia.

only 19 Mm^3/year. Moreover in many rural areas there is no drinking water network. The average specific consumption is estimated at 45 l/capita/day, which is considerably lower than the national average (130 l/capita/day). In addition, 8 Mm^3 of the distributed water has a high salinity, making it unfit for human consumption. For these reasons in remote rural communities, the problem of potable water remains unsolved.

The farming population is supplied through public fountains provided mechanically from cisterns. Water is not treated and cisterns are often non-hygienic (as a result of corrosion and the development of bacteria). In addition, brackish water can cause irritation of digestive tracts and skin diseases, especially for young children. In some cases, people have to move more than 10 km to reach potable water. This is the case of many communities in central Tunisia within the Kairouan Governorate. Water in remote rural areas is typically managed by cooperative associations, which maintain irrigation networks and distribute water to members. The Tunisian Government encourages water cooperatives in order to control costs and promote more efficient water use. The price of this water (non-drinkable) is about US\$0.4/m^3. However, for the potable water in remote areas, as sold by private persons, prices can reach US\$32/m^3.

An investigation carried by Bourouni and Chaibi (2007) showed that the average water demand per village in remote areas is about 15 to 50 m^3/day. Water salinity in Tunisia can be divided into five regions:

- *Areas with very high salinities*: In the south-western regions, the salinities of distributed water are often more than 4.3 g/l and the percentage of water falling within this category is nearly 100%.
- *Areas with high salinities*: In the extreme south, south eastern and the Cap-Bon regions, the salinities of distributed water are between 3.5–4.3 g/l. The percentage of water having salinity about 3.5 g/l is higher in the southwest than in the extreme southern parts. Their respective percentages are 100% and 80%.
- *Areas with medium salinities*: Some regions of the central part of the country have salinity levels between 2.7 to 3.5 g/l. Their respective percentages are 100% and 80%.
- *Areas with moderate salinities*: in the central parts of the country, the quality of water distributed is acceptable overall. Nevertheless, the percentage of high salinity in the distributed water (over 1.9 g/l) reached 40–60%. Then localities were supplied with a bad water quality.
- *Areas with low salinities*: Only north-western regions benefit from very high water quality with the percentage of water with salinity exceeding 1.9 g/l, is practically zero.

An examination of the situation of rural populations in Tunisia (water quantity and quality, population dispersion, renewable energy availability) shows that conventional desalination techniques are not adequate. Moreover, a great part of these rural populations also lack connections to the national electrical grid. For these reasons, desalination by renewable energy is a promising prospect.

4. Water desalination in Tunisia

4.1. WATER DESALINATION: CONVENTIONAL PLANTS

To address the fresh water deficit in the southern part of the country and in the Kerkenah and Djerba Islands, desalination installations have been constructed and future projects are planned. The first RO station was constructed on the Island of Kerkenah in 1984. Afterwards, a second one was built in the city of Gabes in 1995. Two RO stations similar to the one built in Gabes were constructed on the Island of Djerba and the other coastal city of Zarzis in 1999, with a production capacity of 12,000 m^3/day each. After completion of these RO plants, the share of RO desalinated water in the country was increased to comprise more than 82% of total national production of desalinated water (the second technique used is electrodialysis with 8%). The key characteristics of these plants are set out in Table 8.3.

The total installed desalination capacity is 110,000 m^3/day, which represents 3.7% of the total water demand in the country. A few other desalination projects are planned – such as the ones on the tourist island of Djerba (the first seawater desalination project in Tunisia) and the industrial city of Sfax – to reach a total capacity of 500,000 m^3/day by the year 2050, representing more than 8% of the total water demand projected for the country.

The number of the desalination units installed in Tunisia is about 70 (including small units in hotels and industries). The utilisation of this desalted water by sector is presented in Figure 8.6. An examination of this figure shows that the most important sectors using desalted water are drinking and industry.

Given the statistics on water resources availability and water demand, desalination is expected to be carried out on a wider scale in the near future. The installation of desalination plants requires the provision of energy for their operation, and therefore a total power dependency. It is here that the renewable energy sources can play a fundamental role as the power source to supply water vital for human use.

TABLE 8.3. The principal desalination plants in Tunisia.

City	Starting year	Capacity (m^3/day)	Technology used	Water salinity input (g/l)	Water salinity output (g/l)	Desalted water
Kerkenah Island	1984	4,500	RO	3.7	0.7	Brackish
Gabes	1995	30,000	RO	3.2	0.2	Brackish
Zarzis	1999	12,000	RO	6	0.2	Brackish
Djerba Island	2000	12,000	RO	5.5	0.2	Brackish

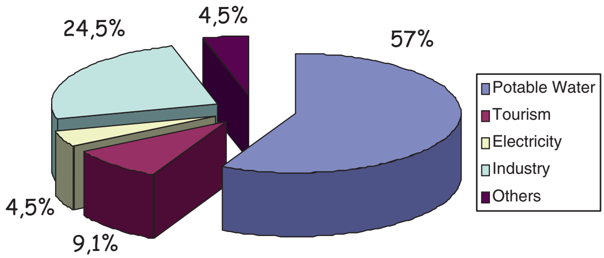

Figure 8.6. Desalted water utilisation by sector activity in Tunisia.

In addition, conventional desalination technologies are not suitable for the decentralised population located in the rural regions of the country due to the high costs of water distribution from large-scale plants.

4.2. WATER DESALINATION BY RENEWABLE ENERGY SOURCES

Renewable energy sources are expected to have a promising future in Tunisia, and in particular to have an important role in the domain of brackish and seawater desalination. Of special interest here are small desalination plants which can be operated with modest quantities of energy. Small-scale renewable energy driven desalination plants might be the most economical solution for providing potable water to the remote and isolated communities where access to the electric grid is lacking and where there is no significant water supply and distribution infrastructure. By exploiting renewable energy sources for fresh water production, three main problems can be addressed: fresh water scarcity, fossil energy depletion and environmental degradation due to gas emissions and hydrocarbon pollution.

Numerous attempts and experiments have been carried out throughout the world in an attempt to find suitable coupling procedures between desalination processes and renewable energy sources. The suitability of a given renewable energy source for powering certain desalting processes depends on both the requirements of such processes and the form of energy that can be obtained from the considered source. Different plausible combinations between renewable energy sources and desalination technologies can be envisaged (Rodrigues et al. 1996). The forms of energy which can be obtained from renewable energy sources are mainly: thermal energy, mechanical energy and electrical energy. Since the end form of energy needed by the desalting process is the main factor in determining the suitability of certain renewable energy sources for powering certain desalination technologies, a flow chart relating different desalination technologies to potentially suitable

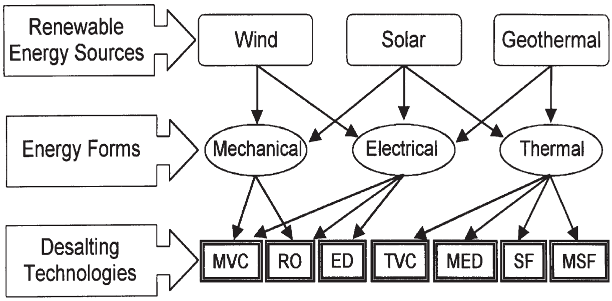

Figure 8.7. A flow chart representation of different options for renewable energy coupling with desalination technologies.

renewable energy sources is developed in Figure 8.7 based on the works of Rodrigues et al. (1996) and Hunter (1996). From this figure it can be seen that the solar energy is the only renewable source that can provide all forms of energy (mechanical, electrical and thermal) and hence coupled to the different desalination technologies.

Given its geographical location, its topography and its geomorphology, Tunisia is blessed with a number of renewable energy sources. These sources of energy vary in their importance and distribution from one region to the other. A survey of these sources shows that at any territorial region of the country, at least one or more sources of renewable energy is readily available, especially solar energy which is present over the entirety of the country.

Solar radiation intensity can reach an average of 349 cal/cm^2/day in the southern part of the country. In addition to the abundant solar energy source, Tunisia is blessed with at least two other forms of renewable energy sources: a number of geothermal groundwater sources can be found in various parts of the country, and in many areas of the country, in particular the coastal regions, the average wind speeds exceed 4.5 m/s.

The main renewable energy source available is solar energy. Its potential suitability for powering water desalination plants is now discussed.

4.3. SOLAR DESALINATION IN TUNISIA

Desalination by means of renewable energy sources is a suitable solution for providing fresh water to a number of regions in Tunisia and in the Mediterranean Basin in general. In an era of high fossil fuel prices, this solution is becoming more and more competitive, especially for remote and rural areas where small quantities of water are needed. Nowadays, and given the advances in desalination technologies, small and medium size desalination units can easily be designed. These plants can be operated at temperatures as low as 50°C which make them suitable for use with renewable energies.

It is worth noting that the most investigated mode of coupling between renewable energy sources and desalination processes is the use of direct sunrays to produce fresh water by means of solar stills. Many solar stills have been constructed across the world since the turn of the twentieth century. Numerous attempts to harness solar thermal energy for water desalination have been carried out. Many studies have investigated the effects of different design parameters on the overall performance of solar stills. To mention a few, we cite the works of Garg and Mann (1976), Rajvanshi (1981), Tiwari et al. (1997), Zaki et al. (1993), Al-Hussaini and Smith (1995), and Singh et al. (1995).

Currently trends have changed, and the most studied coupling at this time corresponds to RO units driven by PV. Several pilots were installed and tested worldwide (Canary Islands, Egypt, Greece, etc.), as shown by Rodrigues et al. (1996) and Mahmoud and el Nathar (2003).

In this context, Tunisia has been a pioneer in exploring the possibility of water desalination by solar energy. Research and development in the domain has since progressed steadily. In contrast, applications at the commercial scale have been hindered by economic constraints and the lack of inexpensive and sufficiently advanced technologies that make renewable energy-driven desalination competitive or at least equivalent to conventional desalination techniques. Beyond these economic considerations, the main concern that arises when coupling desalination plants to renewable energy sources is the reliability of the system given the intermittent supply character of most renewable energy sources.

A number of ambitious pilot plants consisting of single basin solar stills have been constructed to produce fresh water from brackish groundwater under the supervision of the Tunisian Atomic Energy Commission in the late 1960s. More recently, an experimental desalination station of brackish and seawater desalination using renewable energies (mainly solar and wind) was built in 1981 within the National Institute for Scientific Research (INRST) at its site of Borj Cedria in the southern suburbs of Tunis city (Ben Jemaa et al. 1999). In recent years, a number of research experiments have been undertaken in Tunisia in order to model and investigate the feasibility of coupling desalination units, mainly MED (Multiple Effect Distillation) and MSF (Multiple Stage Flash distillation), to solar thermal energy via the use of a solar pond (Safi 1996; Ouni et al. 1996; Bouguecha et al. 2005) and for solar collectors (Ben Becha et al. 1996).

Bourouni et al. (2003) and Houcine et al. (2006) have investigated the process of air humidification and dehumidification coupled to solar desalination collectors. Bouguecha et al. (2005) studied several desalination concepts as RO driven by PV, or membrane distillation. In the next section three of the studied pilots are presented and discussed.

5. Experimental pilot studies of solar desalination in Tunisia

The following three desalination experimental pilots driven by solar energy installed in Tunisia are now presented and discussed:

1. Multiple effect distillation plant
2. Experimental set-up RO-PV
3. Membrane distillation

5.1. MULTIPLE EFFECT SOLAR STILL (MESS) DISTILLATION PROJECT

Based on the experimental distillery, designed and patented by P. Le Goff, Bouguecha et al. (2005) have constructed a pilot distillation plant with the dimensions of 1 m length and 0.5 m width (Figure 8.8). It is composed of three stages; each stage consisting of one plate, a very thin fabric comprising a single finely woven layer, and a steam chamber. This fabric is held in contact with the overhanging plate through the interfacial tension which is much greater than the force due to gravity. The aluminium front plate is black painted and oriented to the sun (absorber face). The other plates are stainless steel, with a thickness of 0.3 mm. Each plate has a condensation and an evaporation face. A cover glass and a mirror are used to improve performance. The different parameters of temperature, solar radiation, wind and velocity are measured.

It was shown that the cover glass used in this set-up increases the black plate temperature about 5°C and the production by over 17%. With mirror and covered glass, temperature increases reach 11°C and the production increase is 39%.

The variations of ambient temperature, condensate plate, evaporator condenser plates temperature, and black plate temperature as a function of time were investigated. It was found that the temperature difference between successive plates is about 2°C. The difference between the black plate and the later condensate plate is 7°. On cloudy days, flow rate decreased up to 50% and the black plate lost about 6°C (Bouguecha et al. 1998).

The authors showed that the distillate flow rate increases when intensity of solar flux increases in a Gaussian distribution. Production is respectively 56%, 29% and 15% for the first, second and third stages. This result illustrates that the number of stages must be less than or equal to three. The average production of multiple effect solar still (MESS) is estimated to 7–8 $kg/m^2/day$: this result agrees with the Algerian findings of Bouchekima et al. (2001a, b).

The experimental results show the significant superiority of this type of distiller over the conventional basin type solar still. It was also found that gauze is very suitable for practical applications. However, irregular wetting gauze surfaces, the existence of an air gap between the plaques and gauze, and the loss of vapour from gaskets are all responsible for the limited performance of MESS. These technical shortcomings need addressing.

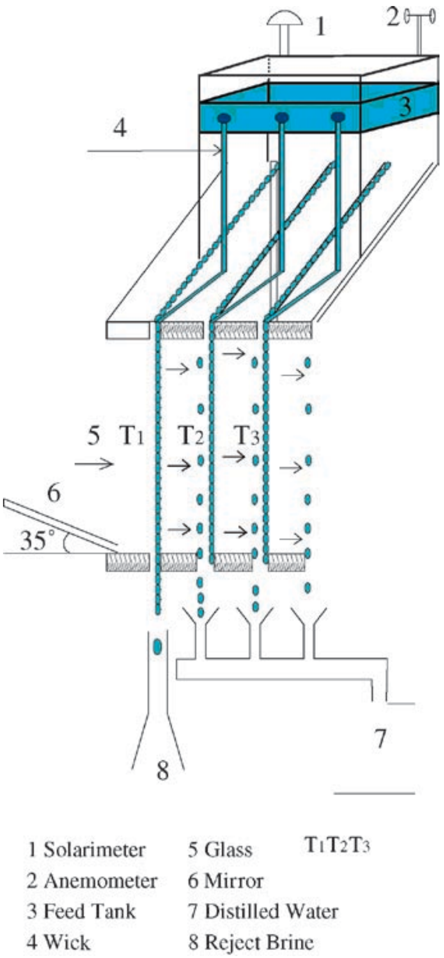

Figure 8.8. Experimental set-up of multiple effect solar still project.

5.2. EXPERIMENTAL SET-UP RO-PV

The technological design of this prototype, as is typical of RO installations, has three compartments: pre-treatment, desalination and post-treatment (Figure 8.9).

Bouguecha et al. (2005) studied this kind of pilot for a total production of few kg/h. The obtained results showed that both solar radiation and available power have a Gaussian curve function. Absorbent power increases when solar radiation increases; at solar radiation of 640 W/m^2 nominal power is reached, and the storage dissipation system began its automatic intermittent mode.

The authors studied also the product flow and pressure vessel as a function of motor pump group cycle. They found that pressure and product flow were strongly correlated, in accordance with the solution diffusion model prediction. At the end of the cycle, pressure continues to decrease, while product flow remains constant (2.04 kg/h). This phenomenon was attributed to the elasticity of integrated membrane vessel. Finally it was found that during a cycle, the product flow oscillates between 2.38 and 2.03 kg/h, which corresponds to a variation of 14%.

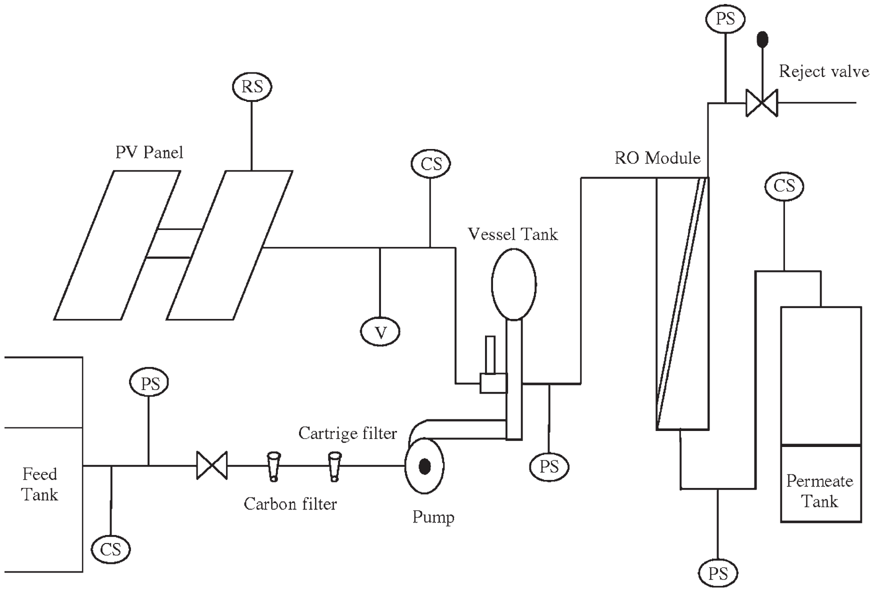

Figure 8.9. Experimental set-up RO-PV.

5.3. MEMBRANE DISTILLATION PILOT (MD)

The desalination of brackish or seawater can be accomplished by essentially two procedures: thermal distillation processes and membrane processes. The thermally-driven membrane desalination is considered a kind of hybrid process, in which a micro-porous hydrophobic membrane separates a warm solution from a cooler chamber, which contains either a liquid or gas. Vapour molecules migrate through the membrane pores from the high to the low vapour pressure side; that is, from the warmer to the cooler compartment. The separation mechanism of membrane distillation is based on Vapour-Liquid Equilibrium (VLE).

Bouguecha and Dhahbi (2003) have experimented with an MD system (Figure 8.10) that can function by solar or geothermal energy. Problems in the geothermal systems arise mainly from the loss of carbon dioxide as the pressure is reduced. When the geothermal water (GWa) in the well moves close to the earth surface, conversion to calcium carbonate takes place with the loss of CO_2. A fluidised bed crystalliser is used first as a pre-treatment compartment.

The authors found that the permeate flux decreases insensitively for a variation of feed concentration from 3 to 35 g/l, the permeate quality stills constant at 6 s/cm. The flux reduction can be attributed to several causes, such as vapour reduction due to the salt effect, as well as temperature and concentration polarisation at the membrane surface.

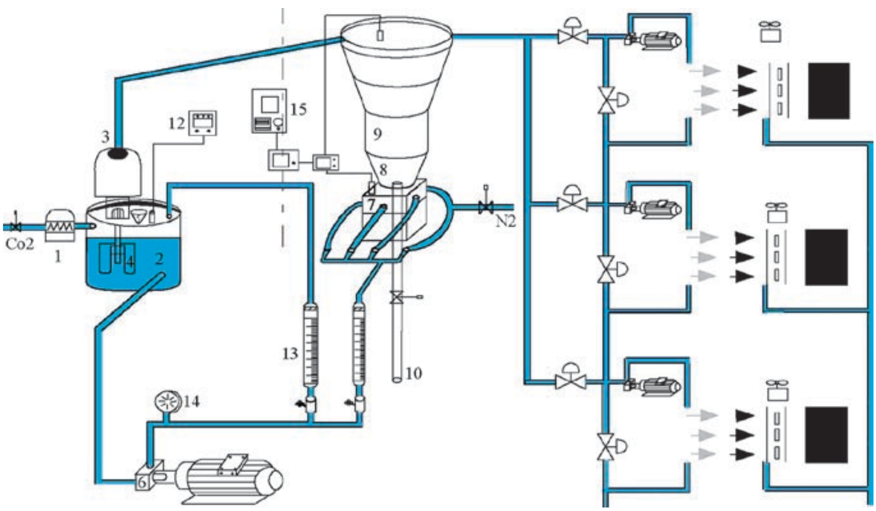

Figure 8.10. Experimental set-up MD-GW.

The global conversion rate reaches 25% (10% by the first stage, 9% and 6% are respectively realised by the second and third stages). Hence, the authors concluded that the MD configured in three stages improves the energy conversion significantly.

5.4. COMPARISON OF THE SYSTEMS' PERFORMANCES

To compare between the three presented systems we focused on their specific energy consumption. Specific energy consumption corresponding to MESS, RO-PV and MD-GWa set-ups is summarised in Table 8.4. We note that RO-PV for optimum reject brine aperture has the lowest value and MESS has the highest one. The minimum Es (80 kJ/kg) was obtained for 16% reject rate or 3/4 aperture reject brine valve value. Therefore, this position offers the best operating condition for a direct renewable energy coupled during a clear day. The single effect solar still produces 4–5 l/m^2, with specific energy consumption around 7,000 kJ/kg, and the multiple solar stills and evaporation type solar stills, respectively, with energy consumption about 1,800 and 800 kJ/kg.

Joyce et al. (2001) have obtained a minimum spe?cific energy consumption of 92 kJ/kg. The large difference between predicted and experimental values can be attributed to:

- MESS cannot produce 15 kg/day (the theoretical value advanced by Le Goff); the maximum is 7–8 kg/day for a sunny day.
- RO driven by PV panels has higher energy consumption than RO using conventional energy, because its storage dissipation system has a low efficiency.
- In MD, the flux has an exponential form versus temperature. The second and third stages of MD coupled to solar or geothermal resources operate at low temperature; consequently, the flux and efficiency have low values.

6. The desalination demonstration project of Ksar Ghilène

Ksar Ghilène is a village of 300 inhabitants, located in the desert of the Sahara, in the south of Tunisia and belonging to the region of Kébili (Figure 8.11). The main activities of the village are agriculture (in the oases), a cattle ranch and tourism. The principal infrastructures in the village are a

TABLE 8.4. Specific energy consumption of the different desalination pilots.

	MESS	RO-PV	MD-GW
Experimental results (kJ/kg)	1,500	82	111
Theoretical results (kJ/kg)	180–240	14, 4–18	40–50

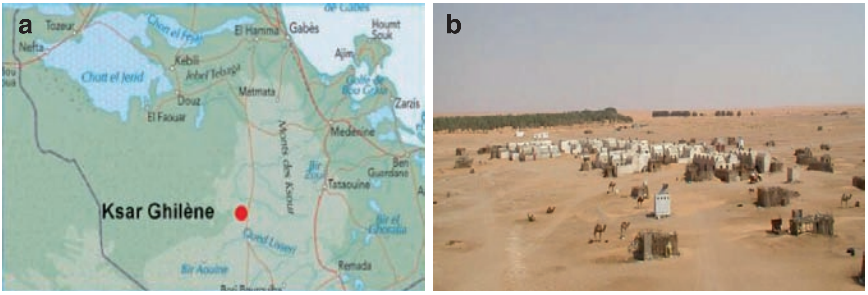

Figure 8.11. Position (8.11**a**) and view (8.11**b**) of the village of Ksar Ghilène and the oases.

school, a mosque, an office of the National Guard and a clinic. The houses are electrified by means of paving home systems and the public lighting system is made by means of photovoltaic lampposts. Figure 8.11b depicts Ksar Ghilène Village.

Until the introduction of the desalination project, the village relied on a water distribution network consisting of a 30m^3 volume storage tank connected to five sources. There was no working well in the proximity of the village, so potable water came from a well located 60km from the village. In addition, the village is 150km from the nearest electricity grid, making it unfeasible to pump water over long distances.

The main potential of water resources in Ksar Ghilène comes from water from a platform of the North African continental margin, collected by drillings of depth which can reach 1,000 m. These water resources are characterised by high pressure and temperature, salinity exceeding 3 g/l and a physicochemical composition limiting their exploitation in the field of drinking water. The detailed physical and chemical properties of the feed water are set out in Table 8.5.

Within the framework of Spanish–Tunisian cooperation, a project for supplying freshwater through a RO desalination unit driven by stand-alone solar photovoltaic energy has been executed (Figure 8.12). The partners for this project are the Spanish International Cooperation Agency (AECI), the Tunisian National Agency for the Control of Energy Consumption (ANME), the Regional Directorate for Agricultural Development of Kèbili (CRDA), and the Government of the Canary Islands through the General Directorate for Relationships with Africa and the Canary Islands Institute of Technology (CTI). The project aim is to produce freshwater from the existing brackish water well located in the near oases, through a 15 m^3/day RO desalination unit. This unit is an autonomous system driven by a 10.5 kWh PV solar generators with energy accumulation by batteries. The whole system is controlled

TABLE 8.5. Physical and chemical parameters of feed water (25°C).

Parameters (mg/l)	NH_4	K	Na	Mg	Ca	Sr	CO_3	HCO_3	NO_3	Cl	F	SO_4	SiO_2	TDS (25°C)	pH
Feed water	0.2	20	744.7	243	392	11.2	19.4	183	6.4	1,243	1.4	1,625	13.2	4,502.9	8.6

Figure 8.12. Schematic view and photo of the Ksar Ghilène photovoltaic power station and treated water tank.

automatically and 15 m^3/day freshwater is produced and distributed in the village through five public fountains.

6.1. PRESENTATION OF THE PROJECT

The constructed building to lodge the system (photovoltaic plants – desalination unit) was designed in a way to attenuate the impact of extreme climatologic conditions: high temperatures in summer (exceeding 48°C) and frequent sand storms, by giving it the greatest possible thermal inertia. Hence, it was decided to make a half-buried construction, placing the photovoltaic generators on the South roof with the building shaded by facades. The interior of the building consists of a room where there is located the desalination plant, feed-in water tank, a room that lodges the electrical installations and the power command system (regulating-inverter) and the room for batteries. The brackish water comes from an artesian well located in the interior of the oasis, to 2,000 m of distance of the building of the desalination plant. The treated water is introduced in an elevated tank, with a capacity of 30 m^3.

6.2. PROPERTIES OF THE DESALINATION PLANT

The desalination plant is a compact mix of equipment producing brackish water desalination by reverse osmosis with nominal capacity of 50 m^3/day (2.1 m^2/h) for 8 h of daily operation (Castellano 2005).

The gross water is chlorinated at the entrance of the plant (3 m^3/h), and transferred by a group of pumps (located in the interior of the building) to feed the reverse osmosis membranes. The water is treated by a sílex filter, in which the solids in suspension are eliminated. Later, and after fixing pH and adding anti-incrustante, the water flows through an activated-carbon granular filter, in order to eliminate particles in suspension containing chlorine and organic compounds. As a last step, the water is sent through a filter of cartridge (5 mm). Once pre-treated, the water goes through the RO module, to obtain a water product (2.1 m^3/h) with a conductivity less than 300 us/cm, stabilised in pH and transferred to a treated water tank. The process is completed with the displacement of part of the brine residue and the chemical cleaning of membranes.

The brine rejection of the desalination plant (0.9 m^3/h) is conducted into a tank located outside the main plant building, where it is mixed with feeding water. The mixture allows water use for the irrigation of the forest bands of the local oases.

6.3. THE PHOTOVOLTAIC POWER STATION

The present installation is constituted by seven photovoltaic generators in parallel that add up to a peak power of the solar panel field of 10.5 kW. The installed module is the I150S of ISOFOTON, with a power tip of 150 W. Each generator is constituted by ten photovoltaic modules connected in series, so that the total nominal voltage of each generator is 120 VDC (volts direct current) and the power peak is 1,500 W. The modules are mounted on seven metallic structures with a fixed slope of 40° 5 from the ceiling and two others are located on the south facade of the building.

The field of panels provides energy to an isolated electric network composed by a large stone bench of batteries and an electric reverser of 10 kW nominal power in charge to convert the current signal from direct current (120 VDC) to an alternating current, 230 volts alternating current (VAC), at 50 Hertz (Hz) adapted for the elements of the desalination plant.

The large bench of batteries with a nominal capacity of 660 ampere hours is formed by 60 glasses of stationary batteries of the type TUDOR OPzS. The system of power control, INGECON HYBRID, 10 kW is the heart of the photovoltaic power station, since it has the mission to control the load of batteries as well as working like a reverser. This equipment is able to ensure that the photovoltaic field achieves maximum power and allows modulation of the exit AC signal (sinusoidal pure) in order to keep it constant at 230 V.

6.4. CONTROL SYSTEM: LOAD MANAGEMENT

The INGECON power control system facilitates effective load management of the system, maintaining batteries for a minimal capacity that guarantees consistent daily operations and system longevity adapted to the desalination plant, with the minimum number of shutdowns and starts.

Due to the difference of running hours of the installation between summer and winter, and considering that a continuous production of water is needed, the methods of plant management have seasonal variations with regard to the energy availability in each battery. In winter the depth of unloading must be restricted, so that batteries work in a higher mode.

6.5. RESULTS: PERFORMANCE OF THE RO-PV SYSTEM

After the technical feasibility of the project was demonstrated, it was possible to give an approximate investment cost. The global project cost was estimated at US$385,000 (approximately US$26,000 for each installed cubic metre of desalted water).

To supervise the installation and ensure the maintenance operations, two technicians were maintained at the desalination plant in Ksar Ghilène. One of their most important functions is the control of the different plant parameters, cleaning the collector area from the sand, collecting the operational data, etc. Some sensors were placed to measure the different parameters: pressure, flow rate, voltage, salinity, solar radiation, etc.

Table 8.6 reports the average parameters characterising the plant, based on 6 months functioning (June 2007–November 2007). The findings demonstrate that the RO-PV unit met the requested performance requirements set for it. A desalted water flow rate of 2.10 m^3/h was maintained, with a feed pressure of 11.4 bar.

Additional data show that maximum consumption is obtained in summer with 35 kWh/day (June 15th, 2007), with a water production of 15 m^3/day in 7.5 h of operation and a minimum in winter (November 20th, 2007) of 16 kWh/day for a 7.5 m^3/day water production. The average production of the plant during the 6 first months of operation was about 12 m^3/day with a standard deviation of 2 m^3/day: a Gaussian distribution describes this latter observation.

However, due to the dependency of the plant on solar radiation (resulting in shutdowns and starts according to the variability of this radiation), the energy consumption of the unit is higher than the classical RO plant: Table 8.6 reports an energy consumption of 0.98 kWh/m^3 for the RO-PV plant. This compares to 0.5 kWh/m^3 for a conventional RO plant.

TABLE 8.6. Results for the Ksar Ghilène desalination plant.

Volume flow at the membranes entrance	5.20 m^3/h	Working temperature	35.0°C
Feed water volume flow	3.00 m^3/h	Feed water TDS	4,502.94 mg/l
Feed Pressure	2.35 bar	Number of elements	3
Pressure at the membranes entrance	11.43 bar	Feed water SDI	<3
Product flow water	2.10 m^3/h	Power	2.06 kW
Recovery	70%	Energy consumption	0.98 kWh/m^3

Concerning issues of physical sustainability and maintenance, until now we have not registered any system failure. The membranes of the RO units have so far maintained a high efficiency level.

7. Conclusion

The problem of fresh water shortage is not merely restricted to a few countries. In the Mediterranean region alone, no less than six countries (including Tunisia) are already below the threshold of 1,000 m^3/capita/year. This rate is commonly considered as the critical threshold before the move to water scarcity. Tunisia is one of the southern Mediterranean countries with a potentially serious water deficiency problem, since the water capacity in the country is below 500 m^3/capita/year, given the population growth and the progressive urbanisation and industrialisation. Hence, available fresh water from conventional sources is assessed not to be enough to cover the forecasted total demand in the near future.

As a result, resorting to non-conventional water supply means, such as desalination, to make up for the deficit is becoming inevitable. In recognition of this situation, since the 1980s the Tunisian Government has commissioned several desalination plants in the south of the country to provide drinkable water in this water scarce region.

If desalination of brackish and seawater is emerging as a promising solution to the water scarcity problem, a number of related predicaments have to be urgently addressed so as to guarantee a sustainable and long lasting development of the water desalination industry in Tunisia. Of paramount importance is to make provision for the huge amount of energy required by different desalination technologies: these sources of energy generation and transmission have their own environmental costs (e.g. air and water pollution). Moreover, Tunisia is suffering also from a problem of fossil energy scarcity, while oil and gas prices remain high. For all these reasons, the development of renewable energy sources is needed more than ever before.

The prospects of renewable energy development in Tunisia are positive. As the most promising renewable energy source, solar power has been assessed to be available in huge quantities throughout the country and all year round. With a higher potential in the southern part of the country, solar energy is in perfect synergy with locations where water desalination is most needed. It is also encouraging to know that a large percentage of the population in the south lives in small agglomerations and remote villages, making the implementation of small size desalination plants a perfectly adequate solution to water scarcity. These small desalination plants can be operated with minimal energy requirements, making them suitable for coupling with renewable energy sources.

In this chapter we presented several solar desalination projects installed and experimented with in Tunisia: solar multiple effects distillation, RO-PV, and a membrane distillation pilot. These prototypes were tested only for research purposes. We discussed in detail an RO-PV pilot project in the Tunisian village of Ksar Ghilène. A project of Tunisian–Spanish cooperation, this successful pilot plant allows the supply of potable water by means of the desalination of brackish water by means of reverse osmosis exclusively driven by photovoltaic energy. The installed RO-PV system at Ksar Ghilène presents a sustainable solution to the potable water supply in isolated zones, allowing the survival of the villages and the creation of economic activities by using simple technologies for water treatment.

The first results of the Ksar Ghilène RO-PV plant are encouraging; in fact a maximum water production of 15 m^3/day was obtained in the summer for 7.5 h of functioning. However the cost of this kind of installation remains expensive (more than US$25,000 per installed cubic meter). To find solutions to these problems, further investigation is required in order to optimise the technical and operating parameters and to improve the economic feasibility of this kind of process. With this consideration in mind, an important national project was recently launched in Tunisia to propose technical and economical investigations in the south of the country on the possibilities of coupling desalination technologies to solar energy.

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WIND ENERGY IN MOROCCO: WHICH STRATEGY FOR WHICH DEVELOPMENT?

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Abstract. Morocco has a very large potential for harnessing renewable energy sources. However, there is a large gap between the estimated potential for renewable energy and the cumulative achievements made so far. This chapter discusses the role of wind energy in the development of strategies for supplying clean and renewable energy in Morocco. The authors examine policy options for promoting an increased adoption of wind energy technologies by industry. They explore options for Morocco to promote this form of energy on a larger scale, with the target also of achieving social development and environmental protection objectives. In the chapter an emphasis is put on regional security and sustainable development, with security related to economic, social and environmental aspects.

Keywords: Morocco, energy, water resources, renewable energy, wind energy, integrated wind hydrogen systems.

1. Introduction

With the exception of human beings, every organism's total energy demand is its supply of energy in the form of food derived directly or indirectly from solar energy. This represents its metabolic energy needs which may not exceed a certain limit fixed by the physiological nature of each organism.

The ability to use energy extrasomatically (outside the body) enables human beings to use far more energy than any other heterotroph that has ever evolved. The control of fire, the mechanical conversion of heat into labour, and the shift to fossil fuels have made it possible for mankind to release, in a short time, vast amounts of energy that accumulated long before the species appeared.

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Despite their solar inefficiency, fossil fuel deposits from the last 500 million years have been large enough to supply substantial extrasomatic energy to humans: over the last 250 years, fossil fuels have provided a growing human population with ample, relatively cheap energy. Today, the extrasomatic power used by people around the world is equal to energy exerted by some 131 billion men. It is as if every person in the world has 20 ‘energy slaves’. In the United States, it is as if every American has more than 100 such slaves.

However, there is a dawning awareness that Planet Earth faces a crisis of unprecedented magnitude – notably, climate change largely induced by current methods of extracting and mobilising fossil fuels, which supply three quarters of this energy. Furthermore, fossil sources are threatened by regional depletion and increasing economic scarcity: they are also becoming the cause of international conflict.

To be sure, the challenges of the twenty-first century are numerous, but the most important ones are environmental: the increasing scarcity of fossil energy resources and the concentration of remaining reserves in very few regions of the world, the growing scarcity of fresh water and expansion of deserts. And global climate change is the most severe problem of all, accentuating these other environmental problems and also causing social and economic challenges (Trieb et al. 2002). All these problems threaten the future security and prosperity of mankind. To be credible, concepts of security can no longer be limited to the military form: they need to include a range of other potential, economic, ecological, social aspects that threaten human health and welfare (Kullenberg 2002).

2. Morocco's energy situation

Morocco, with a land area of 710,850 km^2 and a population of 31 million, has a coastline of more than 3,500 km. Over the last 3 decades, economic growth has created substantial changes in the economic structure of Morocco: the GDP in current prices rose from US\$16.17 billion in 1980 to US\$65.4 billion in 2006, and per capita from US\$788.6 in 1980 to US\$2,144 in 2006.

With twice as many inhabitants between 1971 and 2006, commercial primary energy consumption rose nearly fivefold from 2.47 to reach 13 million tons of oil equivalent (Mtoe) at the end of 2006 (Direction des statistiques 2006).

Nevertheless, if the increase of the total primary energy seems to be important, it should be pointed out that, as Table 9.1 shows, Morocco is still amongst those countries with low per capita consumption level of primary energy and electricity, not just in comparison with developed countries (e.g. Germany, Spain, UK) but even countries with comparable economic development (e.g. Algeria). However, it should be pointed out that electricity

TABLE 9.1. Comparative table of primary energy and electricity consumption in 2005.

Countries	Primary energy/capita (tons oil equivalent/capita/year)	Electricty consumption/capita (kWh/capita/year)
Algeria	0.99	898.6
France	4.2	7,707
Germany	3.9	7,112.3
Morocco	0.52	666
Spain	3.4	6,146.8
United Kingdom	3.8	6,254.2
USA	7.9	13,639.6

Source: Direction des statistiques (2006), Beyond Petroleum (2007), International Energy Agency (2007).

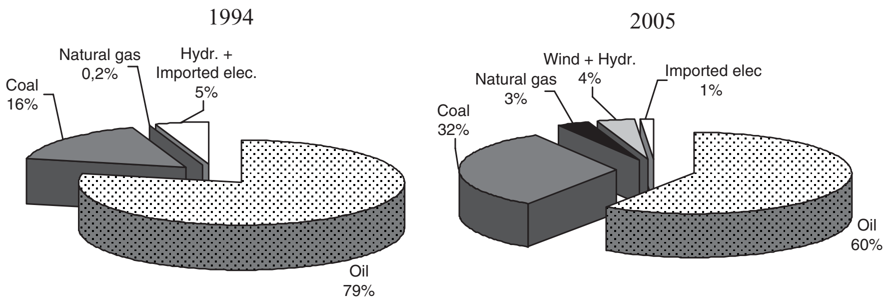

Figure 9.1. Breakdown of the commercial primary energy consumption in Morocco
Source: Dakkina et al. (2008).

consumption in Morocco has risen in recent years thanks to the acceleration of rural electrification and growing industrial development.

Morocco is highly dependent on coal, petroleum and gas in its energy mix, with these forms of energy together accounting for almost 97% of the total commercial energy supply in 2007. Contributing to 7% of the country's GDP and absorbing 42% of Morocco's export revenues in 2006 (Haut Commissariat au Plan 2007), the impact of such dependency on budgetary spending is very significant. This fiscal burden may soon become unsustainable if nothing is done.

Taking a look at the structure of the primary energy consumption (Figure 9.1), one can see that its breakdown has changed between 1994 and 2005. Although its share dropped from 79% to 60%, oil continues to make up the largest fraction of consumption. It is followed by coal, whose share in primary energy consumption doubled from 16% to 30%. 2005 marks the first year in which natural gas made a significant appearance in the Moroccan energy balance at 3% of primary energy consumption. This reflects the appearance of a 384 MW combined cycle power station at Tahaddart (30 km south of Tangiers), which consumes almost 500 million cubic metres/year.

The traditional energy sources (wood, charcoal, plant waste) are still used extensively, especially in rural areas, but they do not appear in the national energy balance. Because of the over-consumption of firewood, between 30,000 and 50,000 ha of forests are estimated to have disappeared in recent years – a serious level of deforestation.

The electric sector in Morocco has been characterised in the last years by a high and constant growth of the demand at an annual rate of 8%. More than 80% of the electricity is produced from coal, oil and gas; the rest comes from renewable energy and imports.

The generation capacity of the national power system was approximately 5,312 MW in 2007. Of this hydro-electric plants comprised 1,729 MW, and thermal power comprised 3,469 MW. In addition, approximately 110 MW of generation was supplied by wind parks.

3. The water situation in Morocco

In the last few decades, increased pressure on water resources caused by population growth, urbanisation, industrialisation and growing needs of agriculture has been putting a severe strain on water resources in Morocco. Indeed, the volume of mobilised water per capita under normal climatic conditions has, in recent years, already reached its maximum.

Without additional water sources, the water deficit will keep growing, even if more dams are built in the future, since they, alone, will not create more water per capita. Morocco must extend its efforts to find the means for supplying new water in the future: sea water desalination is claimed to be one feasible option. Morocco has access to sea-water along a coastline of more than 3,500 km.

For several decades, desalination has been a solution to water shortages in many countries. However, the direct and indirect use of fossil fuels as the energy source utilised for desalination processes could be considered as incompatible with the concept of sustainable development. It contributes to the shortage of fossil fuels and participates in the increase of CO_2 emissions (Zejli et al. 2004). Furthermore, desalination is an intensive energy technology that makes the desalinated water cost very high for those developing countries not producing fossil fuels, such as Morocco.

In these conditions, we are facing a water/energy nexus where water problems can be significantly reduced if energy is easily available. However if energy security (affordable and reliable access to energy sources) is a problem, the situation becomes much more complicated (Galvez 2006). In the last case, which constitutes the Moroccan one, the problem of water can be converted into an energy problem. This means that the future energy demands required to address water scarcity – e.g. desalination, new water infrastructure demands – make the problem of energy availability even more urgent. This is potentially a huge problem in need of an urgent solution.

4. Status of renewable energy sources in Morocco

4.1. POTENTIAL OF RENEWABLE ENERGY

Morocco enjoys abundant renewable energy sources. Developing technologies harnessing these forms of energy in the best way should be adopted. This will be a challenge, but at the same time, it is an opportunity that Moroccans should grasp as soon as possible. Taking up this challenge could contribute significantly to the national energy balance and could offer the economy of the country a tremendous number of jobs that is important to its future prosperity and security (Zejli et al. 2006, 2007).

Morocco is characterised by intensive solar radiation, and wind is an abundant resource in nearly all the coastal regions. Mean daily global horizontal radiation varies between 4.7–5.7 kWh/m^2/day, with the south of the country receiving on average more hours on sunshine (3,000 h) than the north (2,800 h): this makes viable the consideration of solar energy technologies (Bahraoui-Buret et al. 1981). The first large-scale development of solar energy is a combined cycle natural gas/solar thermal plant at Ain Beni Mathar (100 km from Oujda) due to be commissioned in 2012. As noted in Chapter 6, in the discussion of renewable energy financing in Morocco, this US$626 million contract includes substantial financing from the African Development Bank and the Global Environment Facility (see also United Nations Environment Programme 2008: 61–62).

Wind resources are, if anything, even more promising for renewable energy development, both in terms of intensity and constancy. In the south of the country, average wind speeds reach 7.5–8.5 metres/second (m/s), while wind speeds in the north are higher, averaging at 8–11 m/s: they are at their highest on the southern Atlantic coast (Centre de Développment des Energies Renouvelables au Maroc 1995). There is also far more land available for wind power development in Morocco. Furthermore, the southern region is dominated by the global winds called the trade winds, which create one of the largest and steadiest wind systems on earth.

4.2. CURRENT RENEWABLE ENERGY MEASURES IN MOROCCO

The use and development of renewable energies has become a major policy incentive in the country. Morocco has formulated various strategy measures to accelerate the development of renewable energy technologies in order to enhance the long-term energy security of the country and to contribute to the global reduction of climate change.

Under a Renewable Energy and Energy Efficiency Law passed in May 2007, the Moroccan Government has set ambitious targets for renewable energy sources for the next 5 years. The objective is to ensure that 10% of the commercial primary energy and 20% of the electricity consumed in Morocco will be supplied via these forms of energy by the year 2012 (Taoumi 2007).

Furthermore, there is an ambitious target to install 1,000 MW of wind turbines by the end of 2012. Wind projects underway include 60 MW wind turbine plants at Cape Sim (Essaouira) and Taza, along with 140 MW plant development at Ain El Alak, El Haoud and Beni Mejmel while many other sites are being surveyed for wind energy potential. It should be noted that wind energy is not just being developed to feed the national grid; there is also the utilisation of wind energy to power desalination, though not yet on a large scale. A project at Tan-Tan city (930 km south of Rabat near the Atlantic coast) will employ wind energy to produce 6,048 m^3/day of desalinated water, which is expected to reach over 9,500 m^3/day by 2010 (Haddouche 2006).

The wind energy plan will likely approach its installation limits and cannot be expected to grow significantly beyond the 1,000 MW target because of the high variability of wind energy, its limited predictability in terms of power output, and the limits of the Moroccan hydraulic power plants. Thus, there remains a large gap between the potential of wind energy and what may realistically be achieved in the long run without overcoming these current technical constraints. Furthermore, such an expansion in wind energy strategy will not have any significant benefits on the socio-economy development of the country unless there is a substantial development of a wind turbine industry Morocco.

To take advantage of its huge wind energy potential, a large penetration of wind-electricity within the Moroccan economy is necessary. This is the purpose of the strategies set out below in this chapter. The challenge is to develop local wind energy technology manufacturing industries to serve the increased uptake of wind energy in national energy production and consumption. There are certainly domestic conditions that favour such a shift:

- Tremendous wind energy potential, mainly in sparsely populated areas
- Well-developed education and research capacity
- Active development of small and medium businesses
- Proximity to a large electricity market

A local wind industry may aspire to manufacture complete wind turbine systems, to manufacture certain components and import others, or perhaps just to serve as an assembly base for wind turbine components imported from abroad.

4.3. POTENTIAL BENEFITS OF DOMESTIC WIND INDUSTRY DEVELOPMENT IN MOROCCO

The potential benefits of wind turbine manufacturing in Morocco could include:

- New business development
- Creation of new jobs (the largest positive impact in terms of employment would come from the investment into new wind energy systems rather than component manufacture or assembly)
- Cost-savings from economies of scale resulting in lower costs for wind-generated electricity
- Increased tax base for the state, reducing also the fiscal burden caused by importing energy and electricity
- Additional income for the country by exporting higher value-added products (electricity instead of agricultural products)
- Inward investment in the development of the energy sector
- Wind industry acting as a template for other renewable energies
- Enhancing the prospects for further local economic development
- Reduction of incentives to emigrate for employment

5. Proposed strategies for better wind energy development in Morocco

5.1. INTRODUCTION

Given that wind power generation is intermittent and generally difficult to predict, and acknowledging also that the most promising wind energy resources in Morocco are often found in areas with limited grid capacity, the future of wind energy (and other renewable energy) resources rests on successfully increasing energy system flexibility. Introducing *electricity storage facilities* may increase this system flexibility.

The use of energy storage would enable power plants to run at a higher percentage of capacity and ensure that electrical demand was met at all times, thus reducing the need for peaking power plants that generally have the lowest efficiency, greatest harmful emissions, and highest operating cost (Schaber et al. 2004).

The appropriate operation of energy storage could increase the value of wind power in the power system by ensuring a closer match between wind power generation and demand (Figure 9.2).

There are a number of existing and emerging energy storage technologies (Benchrifa et al. 2007). Also, in recent years the combined use of wind

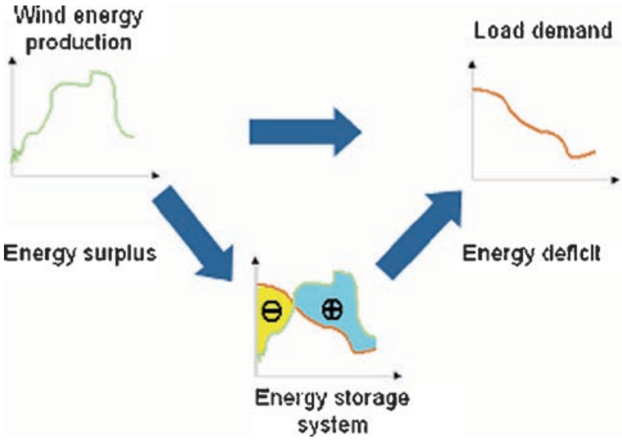

Figure 9.2. Energy storage scheme principle.

and storage capabilities has started receiving attention from the scientific community. This chapter will now emphasise two promising technologies: pumped hydro-storage plants and integrated wind hydrogen systems.

5.2. PUMPED HYDRO-STORAGE PLANTS

Pumped hydro-storage system is the oldest and largest of all of the commercially available energy storage technologies. Conventional pumped storage facilities have been in commercial operation since the 1890s (Harty et al. 1994). It is most practical technology at a large scale with discharge times ranging from several hours to a few days. There is currently over 90 GW of pumped storage in operation worldwide, which is about 3% of global generation capacity (Schaber et al. 2004). Furthermore, since hydroelectric power plants can be used to supply peak-load power, they are an ideal means for storing wind-generated energy and providing power when wind is unavailable (Benitez et al. 2007).

Conventional pumped hydro uses two water reservoirs, separated vertically. During off-peak hours water is pumped from the lower reservoir to the upper reservoir. Energy is, thus, stored in the upper reservoir in the form of potential energy. When electricity is in short supply, because there is insufficient wind and/or at peak times, water is released to generate power. Morocco installed a pumped hydro-storage system in 2005: the Afourer pumped storage power plant. It is composed of four reversible units and has an output of 471.6 MW (Figure 9.3).

It is proposed here that this kind of storage could be effectively utilized to deal with a hybrid wind-sea water pumped storage power plant.

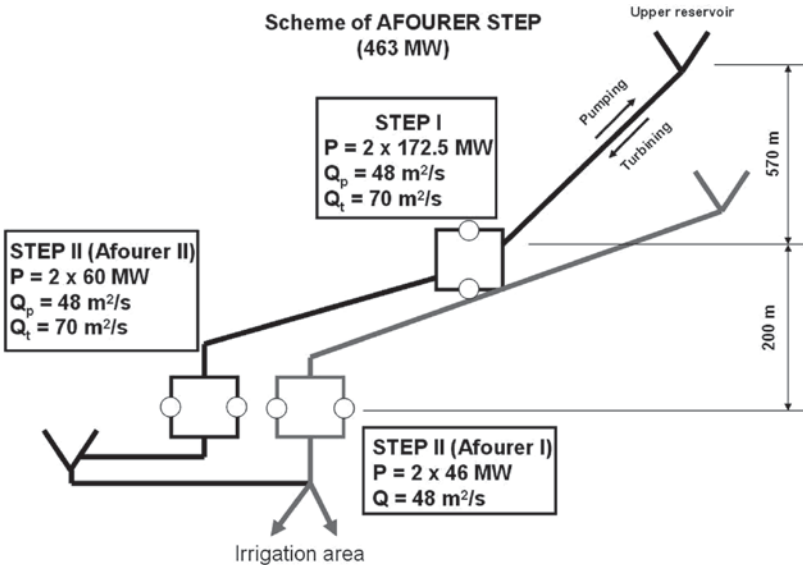

Figure 9.3. Scheme of the Afourer pumped storage power plant. Source: Office National d'Electricité (2005).

As is shown in Figure 9.4, this concerns the connection of the sea in the south of Morocco with an especially shallow basin below sea level and 11 km away from the sea (Sebkha Tah). The preliminary study of this concept has been conducted by the authors' research unit – TEER (Renewable Energy Economy and Technologies) since the beginning of 1990s.

Such pumped storage installation uses the sea as the upper reservoir and an especially shallow basin (Sebkha) below sea level as the lower reservoir (Figure 9.5). This basin has an area of 360 km^2 and an optimal volume storage capacity of $4.5 \times 109\ m^3$.

Assuming 0.75 efficiency in energy conversion for electricity production, the following equation describes the relationship between the volume of water (V, in cubic meters), the stored energy (E, in kWh), and the average head driving a turbine (h, in meters):

$$E(kWh) = \frac{V(m^3).h(m)}{490}$$

Using this relationship and having a minimum head of 35 m and an average one of 40 m, the energy storage capacity offered by this shallow basin would be 480 gigawatt-hours (GWh). This production is the equivalent of the Moroccan electricity demand for more than 1 week. The authors' research unit is currently studying a new model that could double the energy storage capacity of this shallow basin.

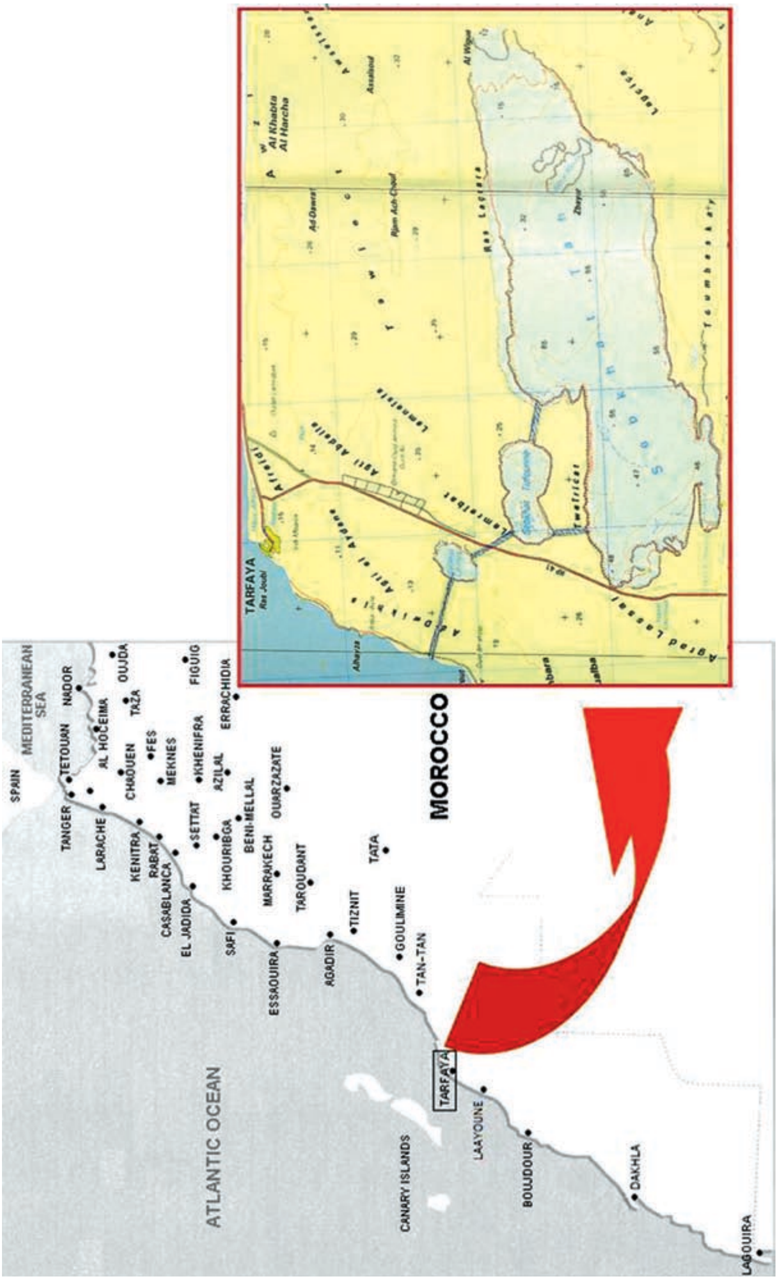

Figure 9.4. Geographical location of 'Sebkha Tah' and image picture of the wind park.

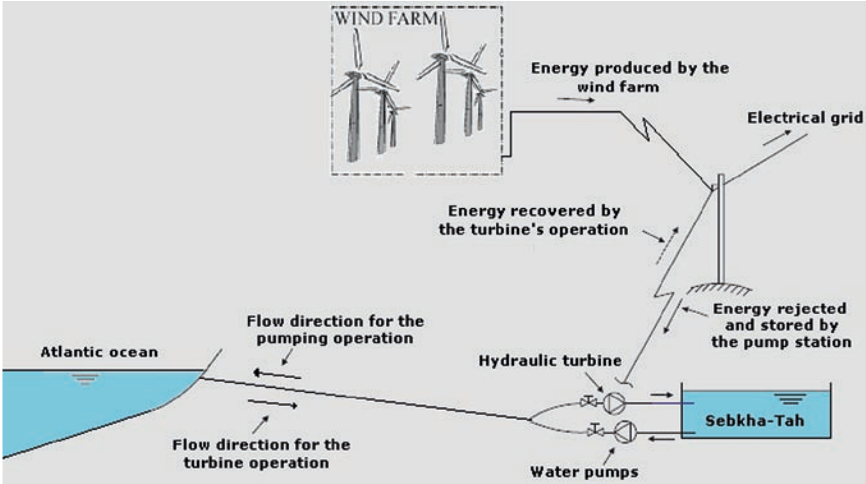

Figure 9.5. Schematic layout of the pumped hydro-storage system.

The use of this storage capacity in 1 day, for example during 5 h, needs a 95 GW hydraulic capacity and would require more than 70 GW wind capacity. That shows the huge potential that can offer this shallow basin in addition to other opportunities that are not the subject of this presentation like the salt production. The installation of only 10 GW will enable the use of wind energy to pump seawater from the basin to the sea and to inject the hydraulic electricity into the grid. This high quality electricity could be exported then to Europe through HVDC grid.

5.3. CHEMICAL STORAGE: INTEGRATED WIND HYDROGEN SYSTEMS

5.3.1. Introduction

Hydrogen has been identified as one of the most promising ways to store large amounts of wind energy for short and for long term, in accordance with the principle of sustainable development. It can be used as an alternative fuel as well as an energy carrier for the future energy supply. As electricity was the great energy carrier of the twentieth century, hydrogen is now emerging as the potential vehicle for a new energy transition (Scott 2004).

5.3.2. NATO Science for Peace Project (No. 982620)

In Morocco, to contribute to the start of long term thinking about the transition of the global energy system, a demonstration project on an integrated wind hydrogen system was submitted conjointly to NATO by a Moroccan private company (Sahara Wind Inc.), the University of Nouakchott (Mauritania), and the National Centre for Scientific and Technical Research of Morocco (CNRST) in collaboration with the following partners:

- United States Department of State (USA)
- Commissariat à l'Energie Atomique CEA (France)
- Ministry of Economic Affairs and Energy of the State of North Rhine-Westphalia (Germany)
- United Nations Industrial Development Organisation – International Centre for Hydrogen Energy Technologies UNIDO-ICHET (Turkey)

Titled *Sahara Trade Winds for Hydrogen,* this 3-year project (2007–2010), approved by NATO in 2007, aims at the installation of a combined wind power and hydrogen production facility, which is entitled the *Integrated Wind Hydrogen System* both in Morocco and in Mauritania. The challenge of the project is to demonstrate the viability of wind electricity integration through the development of energy storage mechanisms, specifically the use of wind-electrolysis to produce hydrogen. The specific aims are:

(a) To develop electrolyser prototypes dedicated to specific local conditions/ applications (Manufacturer agreements with patent protection under NATO IPR committee)

(b) To characterise electrolyser performance under variable input power conditions

(c) To expand knowledge-sharing opportunities where partnerships in research & development and learning demonstrations can be established

(d) To overcoming limits of wind energy utilisation in weak grids (investigating stabilisation through wind electrolysis, hydrogen and by-products integration)

(e) Providing Mauritania and Morocco with valuable experience in the operation and design of such integrated systems in order to increase the penetration and value of wind power in their power system

The NATO-funded project involves the development of two laboratory test beds in Morocco and Mauritania. The test beds will assess the energy storage and supply options for wind generated electricity. In Morocco, this project will be carried out at the Unit of Renewable Energy Economy and Technologies (TEER) of the Centre National pour la Recherche Scientifique et Technique (CNRST) in Rabat.

The test bench schematically represented in Figure 9.6 is made up of a wind turbine and a subsystem oriented to hydrogen production, its storage and reutilisation in order to provide a constant electrical power supply over long periods of time. The subsystem consists of a set of electrolysers to use the electricity produced by the wind turbine during periods of over-production,

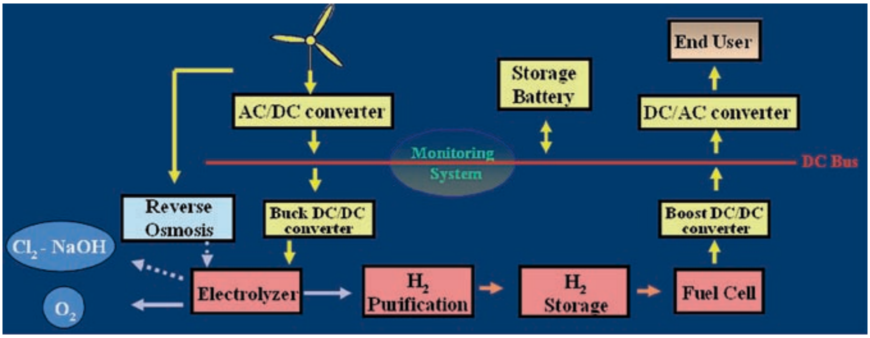

Figure 9.6. The test bench scheme.

converting it to hydrogen, which is stored and later reconverted into electrical energy by a fuel cell when extra power is needed, in order to maintain the power constant alongside the demand.

A Reverse Osmosis Unit (RO) will be included in this test bench to study the coupling of the wind turbine with RO and to study the interface problems that could occur between them. The use of RO could lead to the choice of a Chlor alkali electrolyser that uses brine instead of distillated water to produce hydrogen.

5.3.3. Alternative uses for hydrogen in Morocco

In addition to its use in the storage of electricity, hydrogen is an important input for the fertiliser and the petro-chemical industries. Fertiliser production is normally the largest hydrogen consumer, followed by oil refineries (Schenk et al. 2007). So there is a possibility to diversify hydrogen use in Morocco as it is introduced in the country. In Morocco, the production of nitrogen fertilisers by the Office Chérifien des Phosphates (OCP) involves the importation of 400,000 t of ammonia annually that also requires 70,588 t of hydrogen per year (Groupe Office Chérifien Des Phosphates 2005).

According to:

$$3H_2 + N_2 \rightarrow 2NH_3 \text{ (}N_2\text{ is from air)}$$

One kilogram of H_2: 141.9 MJ, approximately 40 kWh (higher heating value)

The annual production of 70,588 t of hydrogen would require about 3,500 GWh (assuming an electrolysis efficiency rate of 80%), which could be produced by a wind capacity of nearly 1 GW in the region of Dakhla in the south of Morocco. One kilogram of nitrogenous fertilisers $(NH_4)_2HPO_4$ requires 250 g ammonia.

5.3.4. Research project coordination

In conducting the NATO-funded project, the focus is on two research axes – wind electricity direct use and wind electricity storage. Further research and development under these axes is illustrated in Figure 9.7.

CNRST will coordinate the research programme on the test bench. For this reason it has set up a research network. This research network, presented in Figure 9.8, is made up of researchers from seven universities and engineering schools, as well as those representing end users, including Sahara-Wind Inc. The research network will be enlarged as and when nec-

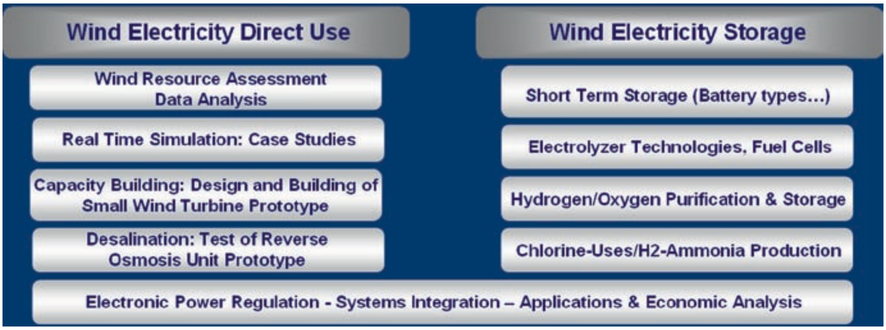

Figure 9.7. The R&D project themes.

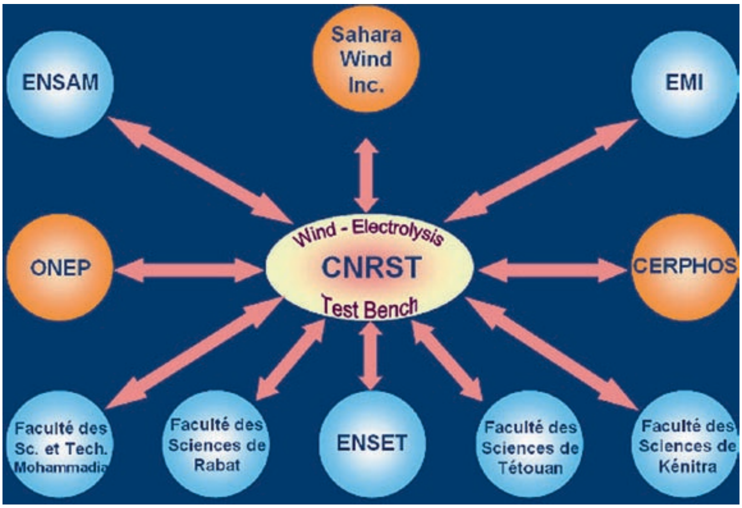

Figure 9.8. The R&D project network in Morocco.

essary. With 16 universities in Morocco, there is a potential pool of 15,000 researchers. Furthermore, the overall NATO-funded project, *Sahara Trade Winds for Hydrogen,* features 18 institutions from six countries (France, Germany, Mauritania, Morocco, United States and Turkey) with opportunities for effective cross-national research synergies.

6. Wind energy strategy analysis

6.1. INTRODUCTION

There is an urgent need for Morocco to find a technologically and economically optimal wind energy strategy. However, before establishing a national wind energy strategy, and in order to guarantee its success, it is necessary first to examine the development of wind energy technologies in other countries, highlighting why some have succeeded and why others have failed. This section will briefly provide such an overview.

6.2. GLOBAL WIND ENERGY UPTAKE

Wind energy has come of age. Its tremendous growth during the last 3 decades has pushed the technology beyond that of merely another 'alternative' (Gipe 1991). Wind power is now established as a commercial source of electricity in over 50 countries around the world (Golait et al. 2007). The annual market volume of wind turbines increases by 20–30% per year, reaching significant contributions to the national electricity supply in some countries (Denmark, Germany, and Spain). Wind turbines have increased in size more than tenfold in 20 years. Over the past 2 decades, global installed capacity has increased from 2.5 gigawatts (GW) in 1992 to almost 94 GW at the end of 2007.

Penetration levels in the electricity sector (percentage of wind energy in national electricity demand) have reached 20% in Denmark and about 6% in Germany and 8% in Spain. Wind turbine technology is now in good health: the operational availability of turbines is ~98%, which means that during 2% of the time they cannot produce due to maintenance or failures. The technology of wind turbines has evolved from robust and simple (the successful Danish concept) to turbines with a maximum controllability to produce kilowatt-hours according to the specifications of electric utilities (Van Kuik et al. 2006). However, further wind energy penetration in the electricity supply system will depend principally on efficient measures to integrate wind energy production in the electricity supply system.

6.3. WHY DO SOME COUNTRIES SUCCEED AND OTHERS FAIL IN DEVELOPING A WIND ENERGY INDUSTRY?

To answer this question, lessons can be drawn both from wind energy leaders and laggards around the world. A comparative review of these experiences will assist the identification of effective approaches for implementing wind technology in developing countries, including Morocco.

There are several studies that have compared approaches of various countries to wind industry development since the 1980s. On reviewing this international wind energy literature, there appear to be two main strands of thought (which often overlap) explaining successful wind energy development. The first strand tends to focus on the scientific and technological aspect of wind energy. The second one focuses on evaluating the national 'technology-punch' and 'demand-pull' policies put in place to support wind electricity production (Strachan and Lal 2004).

Here we will only give a very short introduction to the development of wind industry in six selected countries: Denmark, Germany, Netherlands, United Kingdom, Spain and India. If we start with the first four countries, all their governments gave active support to wind energy development. Furthermore, all these four countries have a comparable wind regime. However, the result of the development of wind energy in each country is very different. Nowadays, Germany and especially Denmark have a flourishing wind turbine industry that produces wind turbines for the world market. In the United Kingdom and Netherlands, wind turbine manufacturing and assembly remains modest. More recently, a number of latecomers have entered the global wind turbine industry, notably Spain and India. A rapid growth in global wind energy demand, led by the US and China, is spurring the expansion of wind turbine manufacturing: it is estimated that globally installed wind energy capacity will increase fivefold from 94 GW in 2007 to more than 576 GW by 2017 (Emerging Energy Research 2008).

6.3.1. Denmark

In comparison to other countries, the history of the Danish wind energy industry is a remarkable success story. Since the late 1970s Denmark has led the development of a global wind energy industry (Kristinsson and Rao 2007). In 2004 wind energy supplied 20% of Denmark's electricity consumption. This is predicted to increase to 50% by 2025, featuring mostly offshore capacity (Golait et al. 2007). Today, Denmark is the world's largest manufacturer and exporter of wind turbines, with approximately 110 firms active in the sector (Kristinsson and Rao 2007). Between 1983 and 1998, Danish producers sold nearly 5,500 MW of capacity, of which approximately three-quarters was exported.

Danes have a cultural predisposition towards using wind energy. Danish wind technology grew out of the agricultural sector as a natural by-product of the Danish economy (Gipe 1991). The promotion of wind energy became important in Denmark in the mid-1970s. The installation of the first wind turbines coincided with a government-initiated technology competition for small scale wind turbines. The rapid increase in average production capacity just before 1980 was mainly a result of the Danish Wind Power Programme (Buen 2006). Already in 1991, wind turbines provided around 3% of the Danish electricity consumption (Klaassen et al. 2005). In Denmark, not only the private firms but also the universities and research centers, such as the Risoe National Laboratory, have been in the forefront of the technological development of wind turbines (Kristinsson and Rao 2007).

In general, policy instruments to stimulate wind power and wind industry development in Denmark have been gradually – if not always smoothly – removed in line with cost reductions and maturity of the industry (Buen 2006). From the mid-1980s, the Danish government provided another kind of incentive consisting of a partial refund for the energy and environmental taxes levied on electricity consumption in Denmark. This in effect consisted of the payment of a guaranteed tariff that was paid out to the wind farm operators by the energy supply companies for selling electricity to the latter, which helped in expanding overall capacity (Klaassen et al. 2005).

The Danish government has supported wind power through a mixture of technology-push and demand-pull policies. An additional focus has been on knowledge transfer between turbine producers, turbine owners and researchers (Ibenholt 2002).

6.3.2. Germany

Germany has encouraged the use of wind energy since the 1970s. The major government instruments that promoted the rapid diffusion of wind power capacity at the end of the 1980s consisted of the 100/250 MW program, the feed-in law, and tax breaks, as well as the provision of low-interest loans (Klaassen et al. 2005). Investments in wind turbines were subsidised by several programmes: at least 14 German suppliers of turbines received funding for 124 turbines in the period 1983–1991. This programme constituted an important part of the very small national market in the 1980s: total installed power was just 20 MW by the end of 1989. An early niche market was also found in ‘green’ demand from some utilities and from environmentally concerned farmers, reflecting the strength of the green movement (Jacobsson and Lauber 2006).

Regarding R&D support for wind energy, this was initiated in 1974 with the Growian project, which later ended in 1987. With a new focus on wind energy in the mid-1980s, R&D support was resumed again in Germany. This second wave included wind turbines with sizes of 640 to 1,200 kW as well as various projects concentrating on the development of small wind turbines.

In Germany, the first R&D programs (in the 1970s) to develop large-scale wind turbines (using aerospace knowledge) were regarded as a failure due to the considerable expenditures. The progress of small wind turbines proved to be more successful as they were developed on the basis of engineering and shipbuilding knowledge (Klaassen et al. 2005). Globally, Germany currently has the highest installed capacity of wind energy.

6.3.3. Netherlands

The Dutch Research Programme on Wind Energy started in 1976. Within this programme, subsidies were provided for R&D into the potential of wind energy in the Netherlands and into wind turbine building. The goal of this programme was to develop a significant wind turbine capacity in the Netherlands, consisting of a large number of large wind turbines. Among the results of this research programme, a large amount of theoretical knowledge on wind turbines was gained. This knowledge was based on aerodynamic knowledge from the aerospace industry (Kamp et al. 2004).

The Netherlands was very quick in installing its national wind industry in 1970–1980 by fostering principally vertical axis turbines while other wind energy industries in Europe developed horizontal axis turbines. In the 1990s Dutch wind energy targets was not met, partly due to restricted wind farm sites in a country with extensive areas of heavy population. Another problem that Dutch wind turbine manufacturers encountered was the small size of the domestic market. The Dutch market was and remains small because in the Netherlands no investment subsidies were available for wind turbine buyers (Kamp et al. 2004). Compared to Germany and England, the Dutch support system for wind power has been highly volatile (Breukers and Wolsink 2007). In the Netherlands, the early policy choice to focus on the energy sector and on large-scale applications resulted in less successful trajectories of development for the wind energy industry (Breukers and Wolsink 2007).

6.3.4. United Kingdom

Renewable energy policy in the United Kingdom (UK) has been anything but stable, resulting in unstable annual wind capacity additions. The UK is believed to have the best wind resources in Europe; however, until recently it was home to only one reasonably sized wind turbine manufacturer, DeWind, which was purchased from Germany in 2002 and still manufacturers its turbines there. Wind energy provides less than half a gigawatt of electricity generation.

The UK has employed few incentives so far to directly support local wind industry development (Lewis and Wiser 2005). However, with the two new offshore wind farms under construction, the UK will become the world's number one offshore wind generator (Asif and Muneer 2007). UK R&D expenditures for wind have been insufficiently geared towards the type of turbines being installed. More recently the UK Government has attempted to adopt a more coherent and coordinated stance towards wind energy, announcing plans in December 2007 to create up to 33 GW of offshore wind energy capacity by 2020.

6.3.5. Spain

A relative latecomer to the wind power scene, Spain has been able to increase installed wind capacity and simultaneously develop a local wind industry by actively supporting local manufacturing with policies that encourage foreign companies to shift manufacturing bases to Spain in return for access to domestic markets (Lewis and Wiser 2005). The national wind energy industry has started to export its wind generators since 1998 (Montes et al. 2007).

The Spanish Electricity Sector Law has provided the greatest support for the development of wind energy. Spanish Government agencies have long mandated the incorporation of local content in wind turbines installed on the Spanish soil; the creation of Gamesa in 1995 can be traced in part to these policies. The Spanish Government has clearly played a pro-active role in kick-starting a domestic wind industry, and the success of Gamesa and other manufacturers is very likely related to these policies. Gamesa is now the second largest wind turbine manufacturer in the world and is continuing to expand (Lewis and Wiser 2007).

The Spanish Government also provides some support for R&D in wind technology under the Research Centre for Energy, Environment and Technology (CIEMAT), the main public R&D organisation in wind energy. Spanish private wind companies invest heavily in R&D, estimated at about 11% of their gross value added, which is above average for other sectors and companies in Spain. Public R&D has been relatively consistent over time but small compared to the amount invested by countries like the US and Germany (Lewis and Wiser 2005).

6.3.6. India

Although some manufacturing of wind turbines was undertaken in India during the early 1980s, the actual thrust came in 1985 when the Indian Government started an initiative to give impetus to wind energy generation. Despite going through more than one turbulent political period during the development of the wind turbine industry, India is today the wind leader in Asia (Kristinsson and Rao 2007). And as far as wind power is concerned, a total of 1,840 MW of new capacity was commissioned during 2006 (Global Wind Energy Council 2007). It has secured fourth position in the world in wind power generation after Germany, Spain and USA (Golait et al. 2007; Global Wind Energy Council 2005).

In the beginning, India's knowledge base in wind energy generation as well as wind turbine manufacturing was weak and needed significant growth to be competitive at an international level. As a result the Indian Government embarked on a series of cooperation projects with leading actors to develop the knowledge needed. This policy was made easier by India's unique position as a market with a huge potential for the wind turbine industry as well as its status as a developing country. There was also interaction between the Indian and Danish governments concerning the development of several projects for the promotion of the wind power sector in India.

The current success of India in wind energy can be attributed to the 'interactive learning' undertaken by it (Kristinsson and Rao 2007). 'Interactive learning' means that interactions between the relevant actors – the research laboratories, industry, end-users and political decision-makers – enhance the diffusion of knowledge. Network relationships play a crucial role in achieving efficient product improvements and learning-by-interacting allows a firm to benefit from external sources of learning. It is positively associated with the increasing diffusion of technology (Kahouli-Brahmi 2008).

Interactive learning takes place not just by the transfer of technology between two firms in different countries, but more as a learning process where both sets of national actors are learning from each other. Nevertheless, the main beneficiary of this learning process is the country on the lower technological trajectory, which in this case is India. Danish firms were able to interact with the local firms in India by establishing subsidiaries in India and also by engaging in joint-venture with local firms (Kristinsson and Rao 2007). Indeed, Suzlon Energy, the largest Indian wind turbine manufacturer, has recently established its international headquarters in Denmark due to the presence of wind energy expertise and an extensive network of component suppliers (Kristinsson and Rao 2007). In June 2007 this Indian company acquired the German wind turbine manufacturer REpower (De Vries 2007).

7. Conclusion and policy recommendations

This chapter examined some of the difficulties involved with implementing a renewable energy policy based on wind power. We hope that we have provided a sound rationale for our endorsement of wind energy in

Morocco and conclude the chapter by calling for significant future research in this area. Indeed, there is a need for scientific and technical research programmes in addition to research programme into the national and regional economic benefits attributed to wind power expansion. Linked to this, there is also a need for more research into the economic impact of wind farms on other Moroccan sectors.

7.1. POLICY INSTRUMENTS FOR FOSTERING WIND POWER TECHNOLOGY LOCALISATION

The promotion of a local wind technology manufacturing industry requires the establishment of a large enough domestic demand for wind power. Local wind technology manufacturing may be driven further by the following support mechanisms:

- Political will is essential to establish a legal and financial framework to govern actions and activities of large-scale energy projects
- A high degree of interaction between the government, agencies, industries and the universities for more synergies
- Developing capacities to mobilise support
- Encouraging long-term thinking
- Enhancing the infrastructure of R&D institutions
- Building up local capacity and investment in knowledge-training
- Participating in international cooperation featuring exploring knowledge sharing
- Encouraging local industries to adopt renewable energy technologies
- Encouraging local industries to produce and use hydrogen-based process technologies

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INSTITUTIONAL ASPECTS OF REGIONAL ENERGY SYSTEMS

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Abstract. The chapter mainly addresses institutional aspects of regional renewable energy systems and cooperation in MENA (Middle East and North Africa) countries. The material presented here draws heavily on the deliberations of regional workshops on energy efficiency and renewable energy held at the American University of Beirut (AUB) in 2004 and 2005. In addition, the chapter discusses the importance of renewable energy as well as cooperation in renewable energy technologies in the Middle East where there exists a promising potential for utilising these resources. Furthermore, this chapter presents existing and proposed projects for regional cooperation, including the Al-Wehdah Dam, the Red-Dead Canal, regional electricity partnerships, and the Arab Gas Pipeline project. The chapter concludes that regional research collaboration on clean energy is a promising platform for developing institutional cooperation on renewable energy.

Keywords: Renewable energy, MENA region, energy cooperation, institutional aspects

1. Introduction

1.1. WHY RENEWABLE ENERGY?

World energy consumption witnessed a tenfold increase during the previous century of which fossil fuels provided more than 75% of the total. Estimates indicate that proven reserves of oil and gas will run out in the next 40 to 60 years if not earlier (Figure 10.1) regardless of the adverse environmental consequences of their use. Such consequences include, among other problems, air pollution and acid rain posing a serious threat to vital natural resources and the well-being of humans. Above all, the continued use and combustion

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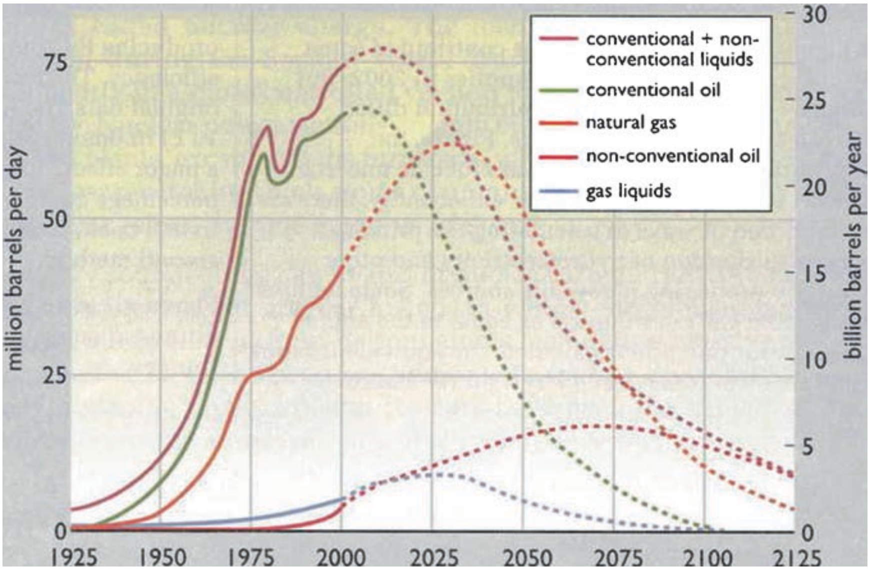

Figure 10.1. Global oil & gas production forecasts. Source: Boyle (2004); Laherrere (2001).

of fossil fuels that emit greenhouse gases (GHGs) pose a threat of particular global concern, namely human-induced climate change.

The phenomenon of global climate change has resulted in a significant rise in earth surface temperatures. According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the rise was 0.74°C during the twentieth century and is predicted to rise significantly higher this century if GHG emissions are not curbed – up to 4.0°C under the IPCC high emissions scenario (IPCC 2007). The projected consequences of such an average temperature rise include climatic extreme events like floods, droughts, serious sea level rises, and melting of the polar ice sheets. In order to alleviate the consequences cited above, substantial reductions in GHG emissions – ranging from 60% to 80% – may be necessary, which imply a major energy transition to clean energy sources, defined as increased energy efficiency and renewable energy. Renewable energy resources, as surveyed by Twidell et al. (1986) and Sorensen (2000), are those sources of energy generation which are naturally produced and replenished. The main renewable energy sources are solar power, wind power, hydroelectric power, biomass and biofuels. As well as preventing human-induced climate change, a major shift to renewable energy sources is needed to meet increasing global energy demands, particularly in developing countries.

1.2. WHY RENEWABLE ENERGY IN THE MIDDLE EAST?

As far as the MENA region is concerned, the general argument presented in the previous section applies as well, with the added concern that MENA countries are particularly reliant on oil and natural gas for domestic energy demands, with gas predicted to overtake oil as the key energy source for the region by 2020, partly because more oil is predicted to be freed up for exports. Primary energy demand is predicted to double between 2003 to 2030 to 1.2 billion tons of oil equivalent. This rapidly increasing energy demand is linked to demographic growth, industrialization and the growing use of electricity for desalinated water production (International Energy Agency 2005: 105–118). Outside the oil-rich Gulf states, many of the countries in the region lack domestic fossil fuel resources, and their fossil fuel dependency in an era of higher energy costs means an increasing fiscal burden with regard to growing energy imports.

In these circumstances there is a huge potential for unused domestic energy sources. As we will now explain, the promise of renewable energy in the Middle East rests on favourable physical conditions (especially for solar energy and wind energy), new sources of investment and growing regional collaboration on renewable energy technologies. However, there need to be appropriate institutional frameworks for such cooperation. The discussion of renewable energy resources focuses on the Arab countries of the eastern Mediterranean.

2. Middle East renewable energy resources

This section discusses some of the most important renewable energy sources in some of MENA countries to show the importance of utilising renewable energy in the region. The discussion covers the sources of solar, wind, biomass, and hydropower and presents summarized profiles of some renewable energy sources.

2.1. SOLAR ENERGY

Most renewable energy comes either directly or indirectly from the sun. Sunlight, or solar energy, can be used directly for heating and lighting, for generating electricity, and for hot water heating, solar cooling, and a variety of commercial and industrial uses. The sun's heat also drives the winds, whose energy is captured with wind turbines. In turn, wind and solar energy causes water to evaporate. When this water vapour turns into rain or snow and flows downhill into rivers or streams, its energy can be captured using hydroelectric power. Along with the precipitation, sunlight causes plants to grow. The organic matter that makes up those plants is known as biomass. Biomass as a source of renewable energy can be used to produce electricity, transportation fuels, or chemicals. Hydrogen also can be found in many organic compounds, as well as water. It is the most abundant element on the Earth, but it does not occur naturally as a gas. It is always combined with other elements such as with oxygen to make water. Once separated from another elements, hydrogen can be burned as a fuel or converted into electricity.

Figure 10.2 illustrates the geographical fact that the Middle East region enjoys one of the world's highest rates of solar radiation that extends over

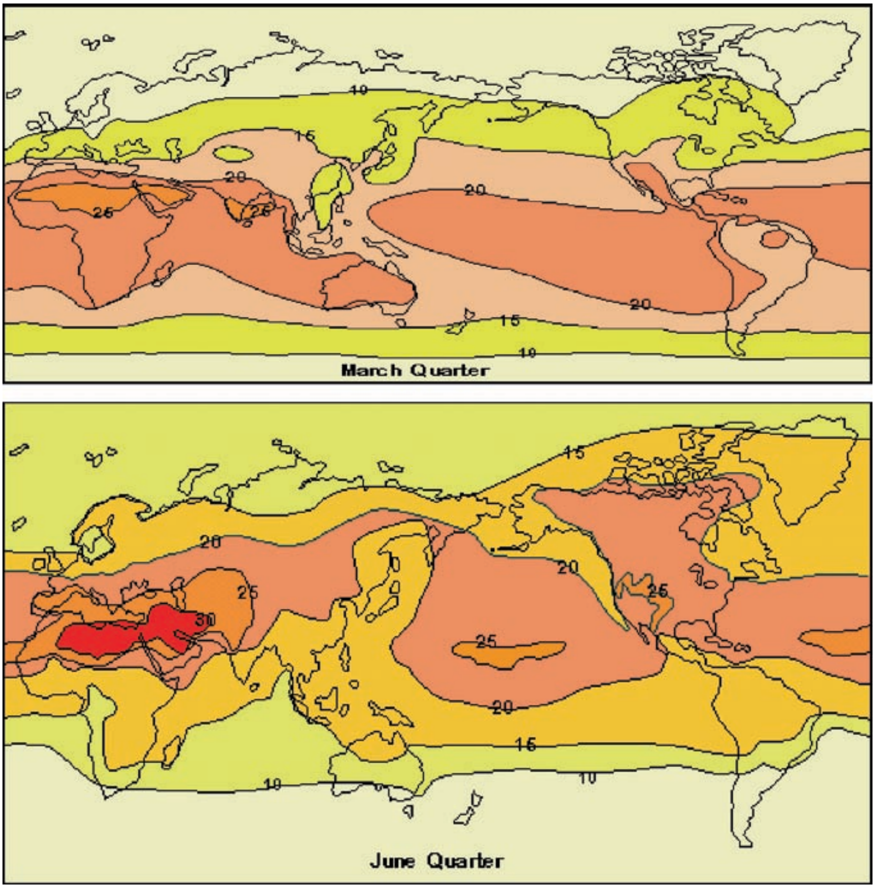

Figure 10.2. Average quarterly global isoflux contour plots February and July respectively. The units are in MJ/m^2 and give the solar insolation falling on a horizontal surface per day Source: Honsberg and Bowden (1999: 32).

TABLE 10.1. Solar radiation in $kWh/m^2/day$ for selected locations in Jordan.

Year	N/D	S/O	J/A	M/J	M/A	J/F	Station
5.3	3.1/4.9	5.6/4.4	7.3/6.6	7.0/7.5	4.9/6.1	2.9/3.5	Dair ala
5.1	2.9/2.3	5.7/4.4	7.3/6.7	7.0/7.5	5.1/6.2	3.0/3.7	Ghor safi
6.0	4.0/3.5	6.6/5.1	8.1/7.5	7.4/8.3	6.1/6.9	3.5/4.5	Aqaba airport
5.4	3.3/2.9	6.0/4.6	7.6/7.5	6.9/7.7	5.1/6.4	3.1/3.7	Irbid
5.6	3.3/2.9	6.0/4.5	8.1/7.4	7.1/8.3	5.4/6.8	3.2/4.1	Amman airport
5.8	3.3/2.9	6.5/4.9	8.3/7.7	7.5/8.4	5.5/6.8	3.2/4.1	Wadi Dhulail
5.0	3.5/2.9	5.5/4.4	6.6/6.3	6.3/6.8	5.0/5.9	3.3/3.9	Rwished
5.7	3.7/2.9	6.2/4.9	8.1/7.3	7.5/8.4	5.7/6.8	3.3/4.2	Azraq

Source: Al Husban (2006).

a large proportion of the year including both summer and winter months. Taking Jordan, for example, the data presented in Table 10.1 show that the average solar radiation is 5.5 $kWh/m^2/day$, which ranks among the highest in the world. It can also be seen that solar radiation in Jordan is abundant throughout the country, though insolation rates increase towards the south of the country. Comparable figures are recorded for neighbouring countries, including Syria and Lebanon (Hamzeh 2004; Green Line Association 2007). While the region is rich in solar energy, as yet a mere fraction of its full energy potential is utilised.

2.2. WIND ENERGY

Some of the region's countries have taken a few steps toward the utilisation of wind energy resources. For example, in Jordan, there are two operating wind farms producing electricity. The first windmill was established in 1988 in cooperation with a Danish firm and considered as a pilot project. It has a capacity of 320 kW (4 × 80 kW). The other and most recent wind energy project in Jordan has a capacity of 1.2 MW (5 × 225 kW). It was established in 1996 in cooperation with the German Government under a program called ELDORADO. The Government of Jordan has been offering many incentives for investment in wind energy in the country. Six projects have been declared feasible and are in various stages of tendering and commissioning by the Ministry of Energy and Mineral Resources (see Chapter 3).

There is also a promising potential for wind energy for Lebanon and Syria. In Lebanon two wind turbines have been built, though one of these at Khiam in south Lebanon was destroyed by Israeli military action during the 2006 war. The Government of Lebanon is currently preparing a detailed wind energy map to facilitate decision-making on wind turbine investment

(Saliba 1994; Green Line Association 2007). An evaluation of wind energy potential in Syria has demonstrated that a huge energy potential is available for direct exploitation and that as much as twice the current electricity consumption in Syria can be generated by the use of wind energy resources (Hamzeh 2004).

2.3. BIO-ENERGY

Some countries in the region have recognised the importance of implementing bioenergy projects. Relevant studies resulted in the implementation of the first biogas project (factory) in Jordan and the region. The current capacity of the project is 1.5 MW of electricity and it is connected to the national grid. This project at Rusaifa is owned, operated and maintained by the Jordan Biogas Company (JBCO), and will expand capacity up to 5.0 MW in the future (Figure 10.3). The factory, which is based on an abandoned landfill with Danish, German, and UN assistance, produces biogas from landfill wells and receives organic wastes from selected restaurants and hotels as well as slaughterhouses in Amman area (Al-Azam 2003). In order to facilitate dissemination of biogas technology in the country, a major UNDP study is underway, with awareness-raising and educational activities coordinated by the Jordan University of Science and Technology.

2.4. HYDROPOWER RESOURCES

In general, Middle Eastern countries lack significant hydropower sources mainly due to a lack of relevant water resources. In the eastern Mediterranean, Lebanon and Syria are the exceptions. In Lebanon the installed capacity of

Figure 10.3. Biogas plant in Rusaifa/Jordan. Source: Al Husban 2006.

its hydro power plants is distributed as follows (see also Chapter 3 of this volume):

- Litani plants: three power plants with a total capacity of 190 MW
- Ibrahim River: three plants with a total capacity of 32.5 MW
- Safa plant: with a capacity of 13 MW
- Bared plants: two plants with a total capacity of 17 MW
- Kadisha plants: three plants with a total capacity of 19 MW

In Syria the combined hydroelectric capacity is 1.9 GW, arising mainly from a large dam at Tabaqa on the Euphrates River. This capacity represents over 40% of the national generated electricity (Green Line Association 2007: 61).

3. Current regional cooperation projects

3.1. THE RED-DEAD CANAL

This project intends to bring Red Sea water into the Dead Sea in an attempt to alleviate the dire consequences of the diminishing water levels of the latter as a result of over-extraction from the Jordan River by Israel and Jordan. The Dead Sea is sinking more than a metre each year threatening to affect the unique ecology of the area and also harming economic development in the Dead Sea region, including the valuable tourist industry.

According to the 'Red-Dead Canal' proposal, the 400-m descent from Eilat/Aqaba to the Dead Sea could also be used to generate over 300 MW and power the world's biggest desalination plant. The project involves excavating a 180-km water channel to bring Red Sea water from the Gulf of Aqaba into the Dead Sea. The purpose is to recharge the shrinking Dead Sea with about 40 m/s flow velocity. This flow velocity can be utilised to generate an estimated 30% of the energy required to power the large-scale reverse osmosis desalination processes and associated water pumping (Beyth 2007).

Following a May 2005 cooperation agreement between Jordan, Israel and the Palestinian Authority, the Dead-Red project is currently the subject of a US$15 million feasibility study managed by the World Bank. While many have portrayed the project as a promising prospect for regional cooperation on renewable energy and water, it faces a number of serious few challenges concerning its environmental impact, the risk of earthquake damage to the canal, and the potential technical challenges of mixing canal water with Dead Sea water (stratification). There are also unresolved political issues between the parties concerning cost and benefit sharing.

3.2. THE AL-WIHDAH DAM

The Al-Wihdah Dam (Figure 10.4) marks a significant advance in Jordanian-Syrian cooperation on energy and water issues. The idea of bilateral cooperation on dam construction had been raised in the 1980s, but Syria's relations with Jordan had deteriorated after the signing of the Jordan-Israel Peace Treaty in 1994. Located on the Yarmouk River, which represents part of the northern boundaries of Jordan with Syria, the Al-Wihdah Dam was constructed between 2003 and 2005.

Initial construction of the dam had begun in the late 1990s but stalled when the World Bank discontinued funding. The construction of the dam was resumed in 2003 and continued until late 2005, funded by a US$113.4 million loan from the Abu Dhabi-based Arab Economic and Social Development Fund and a US$46.8 million loan from the Islamic Development Bank (Ministry of Planning 2000). A Turkish company, Ozaltin, led the construction with Jordanian and Syrian companies also employed. This dam type is Roller Compacted Concrete (RCC) and was constructed in two stages, successively raising the dam's crest from 116 m above sea level to 140 m. The total storage capacity is about 225 million cubic metres.

The annual water capacity of the dam is about 30 million cubic metres to irrigate 31,000 dunums of cultivated land (1.0 dunum = 1,000 m^2) and

Figure 10.4. Al-Wihdah Dam. Source Al Husban 2006.

50 million cubic metres of potable water to Amman and its vicinity. This is a significant contribution to addressing the problem of water scarcity in Jordan. Following completion of the second stage of the dam, the electricity generation capacity is about 18,800 MWh of hydroenergy per year. Three quarters of this power is exported to Syria. The dam is seen as a successful example of Jordanian-Syrian cooperation, which has contributed to better political relations between the two countries.

4. Regional energy networking

4.1. EGYPT–JORDAN–SYRIA ELECTRICAL INTERCONNECTION

The Al-Wihdah Dam development needs to be understood in the context of increasing interdependence of Arab electricity grids within the past decade. A Jordan–Egypt Electrical Interconnection Network was electrified in October 1998 and officially operational in March 1999, while a Jordan–Syria Electrical Interconnection Network was officially opened for operational use in March 2001.

The EIJLLST Electrical Interconnection Project (Figure 10.5) involves electricity grid connections across seven countries in the Middle East and North Africa:

1. 300 MW Egypt–Jordan–Syria interconnection (as mentioned above)
2. A 175 MW Egyptian–Libyan connection opened in 1998
3. A 300 MW Syrian–Turkish connection expected to be inaugurated in 2008
4. A 500 MW Syrian–Lebanese line connection opened at the end of 2007
5. A 200 MW Iraq–Turkish connection approved in March 2007 at a meeting of the International Reconstruction Fund Facility for Iraq
6. A 300 MW Syrian–Iraqi interconnection agreed by the two countries in 2008

It is anticipated that this increasing integration of electricity grids will lead to increased energy security for the participating countries and also may facilitate the transition to a European-MENA energy grid with an expanded role for renewable energy sources (see Conclusion of this volume).

4.2. THE ARAB GAS PIPELINE PROJECT

European energy security concerns prompted efforts in the 1970s to import natural gas from Algeria, in particular from Italy and Spain to meet expanding energy consumption in their countries This led, firstly, to the Transmed pipeline, which since 1983 has been transporting natural gas from Algeria, via Tunisia, to Sicily and then onto mainland Italy. Pipeline development was facilitated by the state-owned Italian energy company, Ente Nazionale Idrocarburi, as well as European Commission funding. A second sub-sea pipeline bringing Algerian gas to Spain and Portugal, via Morocco and Gibraltar, had a longer gestation; but this finally opened in 1996 as the Gaz Maghreb Europe pipeline (Hayes 2006).

Arab interest in developing a regional gas pipeline infrastructure is more recent. In 2001 The Governments of Egypt, Jordan, Syria and Lebanon signed a Memorandum of Understanding to establish the Arab Gas Pipeline network. They agreed that the route of the pipeline should be as follows: Al-Arish – Taba – Aqaba – Amman – Damascus – Hims, and then to Lebanon, Turkey and eventually to Europe. The 1,000 km pipeline will ultimately have a capacity of 10 billion cubic metres/year to facilitate the development of regional gas markets. The first stage of the pipeline (Al-Arish – Taba – Aqaba) was inaugurated in July 2003 by President Mobarak of Egypt and King Abdullah II of Jordan. By 2011, the gas pipeline network is expected to extend to Turkey (from Syria). A further expansion of the pipeline to Europe was agreed by the energy ministers of the participating countries at a meeting in Cairo in September 2008.

The Jordan Gas Transmission Pipeline Project (JGTP) is at the heart of this gas pipeline network, which has commercial support and which purports to offer significant benefits for all parties. For Jordan it promises (Al-Baka'in and Qudaisat 2005):

- A lowering of total energy costs
- Fiscal benefits from reduced oil imports and the elimination of fuel subsidies for more expensive domestic gas sources
- Increased energy security, with diversification of fuel supply away from a traditional dependence on oil and oil products

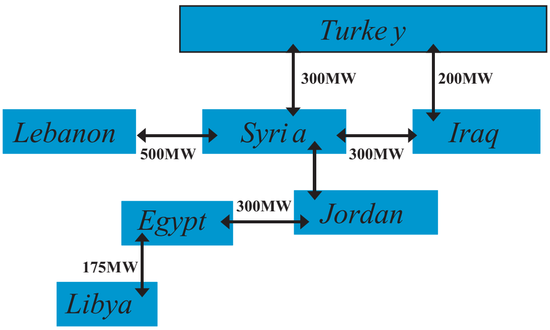

Figure 10.5. The interaction of electricity between MENA countries. Source: National Electric Power Company (2004: 10).

- The more advanced development of the electricity sector with the adoption of efficient combined cycle gas turbines
- Improved environmental performance from the reduced burning of high sulphur fuel oil

Similar benefits are predicted for Egypt, with an additional emphasis on the commercialisation of gas reserves in the country, as regional gas markets open up. Significantly, the Arab Gas Pipeline also includes an Egyptian connection to Israel (Al-Arish to Ashkelon), which became operational early in 2008. Should the Palestinians eventually be granted energy sovereignty over their significant natural gas reserves offshore from Gaza, connection to the Arab Gas Pipeline would facilitate immediate access to regional markets.

5. Institutional aspects of regional renewable energy systems

5.1. AMERICAN UNIVERSITY OF BEIRUT (AUB) REGIONAL WORKSHOPS

With support from the US Department of State and the United Nations Development Programme, regional collaboration and technical workshops on clean energy were held at the American University of Beirut (AUB) in Beirut, Lebanon in April 2004 and January 2005 (Figure 10.6). These workshops

Figure 10.6. Renewable energy workshop at American University of Beirut, Lebanon, January 2005.

focused on developing a US/Middle Eastern expert partnership for regional collaboration in energy efficiency and renewable energy technology (American University of Beirut: Energy Research Group 2005).

One of the main outcomes of the workshops was the establishment of a regional collaboration partnership and action plan among the participating universities to promote energy efficiency and renewable energy technologies for environmental sustainability and economic development.

5.1.1. Partnership mission

The key aim of the AUB workshops was "To enhance collaboration among universities and other stakeholders in order to promote energy efficiency and appropriate renewable energy technologies for environmental sustainability and economic development" (American University of Beirut: Energy Research Group 2005).

The institutional arrangement to carry out the mission involved the selection of a lead university to serve as a focal point in each country to coordinate activities among national universities and institutions including the following:

- American University of Beirut
- Jordan University of Science and Technology
- Palestinian Polytechnic University
- Damascus University
- King Fahd University of Petroleum and Minerals
- National Energy Education Institute
- Notre Dame University
- Lebanese American University
- Florida Solar Energy Center, University of Central Florida
- Northwest Energy Education Institute (NEEI), Eugene, Oregon
- PRD Consulting, Pleasanton, California

The setup of the AUB partnership Steering Committee as it relates to international organisations and national focal points is illustrated below in Figure 10.7.

5.1.2. Proposed initiatives

The partner institutions under the AUB initiative have proposed a series of initiatives to bolster the development of clean energy in the Middle East:

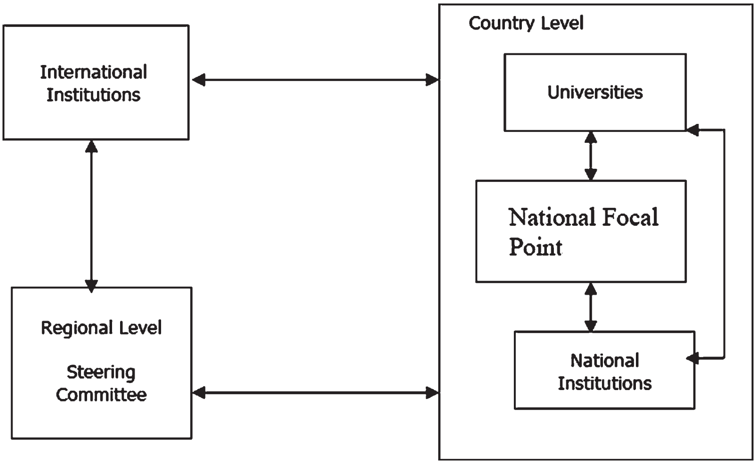

Figure 10.7. Institutional setup for regional collaboration on clean energy.

1. Development of a regional database for energy efficiency and renewable energy sources that includes collecting, refining, and publishing a database related to the energy aspects for solar and weather data.
2. Institutional strengthening and capacity building to become an important national/regional resource to support energy planning at the decision-maker level.
3. Participating universities to establish low-cost testing facilities on their campuses for educational and research purposes. The units would promote both research and capacity-building for human resources in the clean energy sector.
4. Universities should be active participants in determining certification standards for clean energy products and processes in the region. There should be unified rules and regulations for the design of A/C and heating systems and also unified thermal/ electrical standards that lead to energy conservation.
5. The AUB-facilitated regional university consortium should conduct a fresh evaluation of renewable energy technology and energy efficiency curricula and initiatives and consider developing a regional programme to train teachers and distribute energy-related curricula and other teaching resources as broadly as possible.
6. Technology transfer of products and processes related to the development of clean energy in the region. Participating universities would be expected

to define appropriate technology needs based on regional profiles, with a view to identifying ‘ready-to-install’ renewable energy technology. This proposed initiative aims to accelerate application of appropriate renewable technologies and also improve public awareness of the positive economic and environmental potential of renewable energy.

These objectives are ambitious and progress on them so far has been modest, limited by the absence of core programme funding. Nevertheless, the institutional focus for the programme remains a Steering Committee for Regional Collaboration on Energy Efficiency and Renewable Energy Technology. Priority areas identified by this Steering Committee in its include the development of an energy education programme proposal, the creation of a database on renewable energy and energy efficiency, Institutional capacity strengthening, the development of appropriate technology transfer, and the preparation of joint proposals for funding applications.

5.1.3. Development of an energy education programme proposal

Under the AUB-facilitated regional collaboration on clean energy, a major funding proposal has been developed on an Education and Research Programme for Applied Energy - Renewable Energy and Energy Efficiency in the Middle East. The objectives of this Energy Education Programme are summarised below:

- Curriculum development through interdisciplinary courses on clean energy at both undergraduate and graduate levels
- Enhancement of laboratory experience and the development of teaching aids and lab quality manuals
- Sharing and replicating best experience among the universities participating in the programme

The mechanical engineering department at the Jordan University of Science and Technology (JUST) was already participating in a TEMPUS (The Trans-European Mobility Scheme for University Studies) project focused on course development and improving teaching method improvements regarding energy education at the university level. To avoid duplication, preliminary work was done to collect background information on energy-related courses and programmes at other selected partner institutions: AUB, Notre Dame University and Kuwait University. The partner institutions identified complementary efforts needed to correct syllabus deficiencies in current university programmes on clean energy and also work on new course content designed to be attractive and relevant to students of the Middle

East. The key recommendations for higher education provision on energy efficiency and renewable energy were:

- Ensuring programme interdisciplinarity. A programme that can attract students from different disciplines will be an important contribution to energy education and research.
- Developing case studies from different countries to build up regional expertise on energy efficiency and renewable energy.
- Developing courses that have an impact on industrial practices and in building regional technologies (for example, applications of natural ventilation in the building industry, passive building designs, efficient industrial processes).
- Building laboratory experience on energy efficiency and renewable energy is essential for regional capacity-building on clean energy. Research seminars should be developed for professionals and for students on energy related issues.
- Transferring international Clean Development Mechanism (CDM) expertise to the region to enhance Sustainable Development projects in biogas-to-energy.
- Agreement on regional research priorities regarding renewable energy, notably: Integration of solar ponds in salinity mitigation schemes and power generation; brine disposal in inland desalination plants; advanced solar-based inverter systems.

5.1.4. Development of a regional database for renewable energy sources

At the second AUB renewable energy workshop in January 2005 (Figure 10.8), the development of the following regional data bases were agreed to be necessary to support coordination of renewable energy development in the Middle East:

1. Publications database
2. Weather database
3. Water resources database
4. Electricity generation and distribution database

It was also agreed that this information should be compiled in a single format accessible to member countries through a website. Database development was agreed to a priority for supporting institutional capacity-building and energy planning. It will also assist the development of educational courses in the region related to renewable and sustainable energies.

Figure 10.8. Renewable energy workshop at American University of Beirut, Lebanon, 2005.

5.1.5. Concluding remarks on the AUB clean energy workshops

The information shared during the AUB workshops on the energy situation in participating countries was valuable in identifying opportunities for collaboration on energy efficiency and renewable energy. 50% loss/waste of energy is commonly reported for energy produced in the region, most of which is generated from fossil fuels and therefore causes also environmental costs (regional air pollution and greenhouse gas emissions): the workshop participants therefore focused on energy efficiency as the first priority for the regional university consortium (American University of Beirut: Energy Research Group 2005). Since the workshop, a number of initiatives across the region have been launched to promote more efficient utilisation of energy, although high fossil fuel prices have been the overriding reason for these actions.

The regional university consortium formed through the AUB process decided to focus on clean energy actions within its realm of expertise; that is, a stress on education, technical workforce development, and public information outreach. It is important to stress that this covers more than higher education and research, encompassing capacity-building for key skills training in the participating countries and the development of mechanisms supporting technology transfer within different economic sectors.

The Steering Committee for Regional Collaboration on Energy Efficiency and Renewable Energy Technology is the institutional heart of the AUB process. It provides management, guidance and oversight for network activities between meetings of the academic partners. Consisting of representatives from member institutions and external academic advisors (mainly from US and Swedish universities), it has created a constitutional basis for the network in terms of a Partner General Assembly and agreed Partnership Bylaws. The core functions of the Steering Committee are to:

- Prepare rolling 2-year strategic plans and work programmes for discussion and approval at the Partner General Assembly
- Invite institutions meeting the membership criteria to become Members of the initiative
- Develop indicators for measuring the performance and success of the action plan
- Endorse themes and establishes Working Groups
- Identify funds under the broad directives of the Partner Assembly
- Disseminate information among partners
- Coordinate and structure activities including the Partner Assembly meetings
- Strengthen regional collaboration among universities
- Define major issues related to renewable energy and energy efficiency that affect sustainable development in the region
- Define and prioritise the research and development agenda for the participating universities
- Solicit potential sources for core funding

The Steering Committee is a promising vehicle for promoting renewable energy collaboration research and development among the participating countries, and could in principle be extended to North African universities, as well as Israeli ones (though that would of course be more difficult in view of current political sensitivities and differences). However, this committee still has to secure ongoing core funding. The current global interest in renewable energy technologies for reasons of energy security and climate change arguably increases the prospects of such financing coming forward.

6. Conclusions

This chapter discussed the importance of renewable energy in the future energy plans of the countries of the Middle East, highlighting particular renewable energy resources in the region which hold commercial promise. There exists a real potential for utilising renewable energy resources, particularly solar energy and wind energy, which can be harnessed to deliver economic growth and human development in the region. However, cooperation in renewable energy technologies in the Middle East (and North Africa) is vital to achieve the economics of scale and learning transfer necessary to their effective dissemination. This chapter gave examples of existing and proposed energy projects in which regional cooperation is shown to be essential (the Al-Wihdah Dam, the Red-Dead Canal, regional electricity partnerships, and the Arab Gas Pipeline project). The emergence of regional energy infrastructures for electricity and natural gas demonstrates the growing integration of energy markets in the Middle East, and this energy interdependence is conducive to the development and diffusion of renewable energy.

The AUB workshops on energy efficiency and renewable energy highlighted conditions for regional cooperation on renewable energy that still hold true. In summary, the key aims of the workshops involve:

- Forging a regional alliance for cooperation in regional energy issues with the support of key external actors (e.g. EU)
- Emphasizing the need for energy efficiency and energy audits, as well as developing and disseminating the expertise to undertake such audits
- Expanding the regional renewable energy alliance in the future to include experts in water and environmental protection
- Training the trainers for enhancing environmental sustainability through energy efficiency and renewable energy technology
- Promoting the enhancement and transfer throughout Middle East countries of climate change adaptation technologies
- Enhancing regional laboratory experience on renewable energy, including the development of teaching aids and laboratory quality manuals
- Sharing best experience among the universities participating in the regional cooperation programme on energy efficiency and renewable energy

There is no doubt that that the regional university consortium facilitated by the AUB meetings has put energy efficiency and renewable energy higher on the political agenda for Middle Eastern Arab countries. However, this is from a low base, where there has generally been very limited awareness among decision-makers about the potential benefits of clean energy technologies and also inadequate national institutions for developing clean energy technology (Chedid and Chaaban 2003). There has also been a lack of coordination with regional and international development and financial organisations. The challenge now is to find the regional political will and economic support (public and private investment) to ensure that these institutional conditions for technical learning and knowledge transfer are promoted and sustained in the long run.

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ENERGY AND WATER: INTERDEPENDENT PRODUCTION AND USE, THE REMEDIATION OF LOCAL SCARCITY AND THE MUTUALITY OF THE IMPACTS OF MISMANAGEMENT

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Abstract: Societies face major problems in managing their water and energy because Nature's processes and many of our economic systems are invisible to society individually and collectively but they determine environmental and economic outcomes. The purpose of the chapter will be to highlight some ways that the two strategically important natural resources – energy and water – are linked. These linkages will be analysed with respect to security and sustainable management. The analysis will also show that the two resources have a number of similarities vis-à-vis politics and management but many differences vis-à-vis their provenance and renewability. The analysis introduces the idea of 'three weddings and avoiding two funerals'. The three weddings are – water from energy; energy from water; and economic diversification and trade. It is argued that these weddings could help society to avoid the two funerals. The first funeral is the depletion and degradation of the environmental services of water. The second is the degradation of atmospheric services. Two main conclusions emerge. The first is the importance of shifting the production of energy to renewable and clean technologies to achieve energy, water and environmental security. The second is that the mindsets of consumers of energy and water determine whether we shall have secure water and energy futures. Both the big spending consumers in rich countries and the irrigating farmers in poor countries play key roles. The former need to want clean energy. The latter need to be helped to be more productive in their use of water.

Keywords: Water from energy, energy from water, trade, degradation of water services, degradation of atmospheric services, energy security, water security, environmental security

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1. Introduction

The purpose of the chapter is to provide a brief overview of the linkages that exist between the development and use of renewable and non-renewable water resources and of energy resources. The analysis will focus especially on the contentious political landscapes in which water and energy are allocated and mis-used. It will examine the engagement of globally significant national interests, of corporate interests and of the interests of the environment and its champions. The discussion will especially highlight the important role of the beliefs and the mindsets of the consumers of water and energy.

The analysis will review the nature of the water/energy linkages, their interdependence, their mutualities and their synergies. There are five issues. First, there are many differences and some synergies between the energy sector and the water sector. Secondly, there are dynamic narratives that have characterised – over the past century – the very different rates of increase in the use of water and energy. Thirdly, the co-production of energy and water from non-renewable energy will be examined; for example, solar energy for power production and for desalinated water production. The nature of the adaptation – again over the past century – that has occurred in water and energy policies, and in water and energy production in the global context, will be discussed. The dysfunctional politics and poorly evolved national and global governance in which the consumption and distribution of energy and water resources take place will be touched on. Fourthly, the technological possibilities of producing energy from water and water from energy will be reviewed. Finally, an analytical framework entitled 'Three weddings and avoiding two funerals' will be introduced. Emerging synergies in the production of clean energy, trade and avoiding the impairment of atmospheric services and the environmental services of water will be analysed.

2. The energy and water sectors: Asymmetries, many differences and some synergies

Selby (2005: 205) has provided an extremely useful summary of, first, the differences between the political economies of oil and of water and, secondly, between the two sectors with respect to security and armed conflict. In Table 11.1 his comparison of the two political economies is shown with some annotations highlighting the differences. The environmental and climate change impacts of the consumption and mismanagement of these two resources are also noted. In brief, oil – and the closely related fossil fuel natural gas – are high value economic resources that underpin the economic, social and political security of the 200 or so economies of the world.

TABLE 11.1. Oil and water in contemporary capitalism.

Political economy of oil	Political economy of water
Resource availability	
An inaccessible and unevenly distributed non-renewable resource	A plentiful and relatively widely distributed renewable resource
Strategic roles – in society and the economy	Not a strategic resource or a foreign policy concern for major capitalist powers
A ***key*** strategic commodity and a foreign policy concern for core capitalist powers	
Motor of industrial production for mass consumer capitalist societies	Key input into biological processes but much less important than oil as an input into industrial production and consumption
Oil and gas revenues are a ***key input*** into economic development and statebuilding in producer and consumer states	Water revenues ***unlikely*** to be a significant input into either economic development or state-building
Mode of organisation	Generally organised until recently through public monopolies; industry not conducive to international monopoly or high profit rates
Oligopolistically organised by multinational corporations which dominate an industry that generates ***extraordinary profits for companies and producer states***	
Relevance to human health and ecological health	Quantity and quality issues have become evident since about 1970. The Northern neo-liberal economies have become ***significantly. reflexive*** The Southern developing economies are still committed to developing climate water resources to meet demographic and new consumer preferences.
The associated advantages of wealth creation and economic advancement have outweighed the evident pollution (coal derived since the early nineteenth century and oil derived more recently) until the current climate change scare. ***Neither the advanced not the developing economies are being significantly reflexive***.	
A very dynamic industry. ***Major differences*** in the ways of framing the economic development versus human and ecological health nexus. The public (government) sector is in transition. Consumer behaviour very difficult to steer.	A very old industry trapped in the belief systems of consumers that insist that water services ***should be free***. As a consequence demand management polices are difficult to install in the South

Source: Adapted from Selby (2005: 204) with some additions on the human and ecological health issues in ***bold italics*** by the author

The distribution of these fossil energy resources is extremely asymmetric. Only 25% of the world's 200 economies have any oil production and reserves. Only 16 economies have significant production and reserves.[1] The most highly developed world economies in North America, Europe and East Asia are mainly, or almost totally, dependent on rentier economies in the Middle East or on other poorly developed economies for the oil and gas supplies that strategically underpin their energy security.

Table 11.2 indicates that oil and gas have long been highly political issues. They do cause international armed conflict. Commercial and interstate relations over hydrocarbons have been a high priority for over a century. They have become no less so in the past two decades when the demand for the most flexible of all energy resources – oil and gas – has continued to rise. This rising global demand is partly driven by the rapidly developing East and South Asian economies and other developing economies. At the same time the discovery of new reserves has slowed. Society and its political leaders are becoming painfully aware of the economic and political consequences of the phenomenon of peak oil.

The use and distribution of oil and water are both globalised systems. From soon after its beginning in the late nineteenth century the oil market has been globalised and asymmetric. About 69% of the world's 2,651 million tonnes of annual oil production is traded. For such a uniquely prime strategic resource this is an extraordinarily high figure. By comparison less than 5% of world rice production is traded. Currently most economies, including the most powerful, depend on a small number of oil suppliers. The US, Canada and the EU account for 35% of the imports plus 18% of the world's production,

TABLE 11.2. Oil, water and conflict.

Oil and Conflict	**Water and Conflict**
Key factor in the consolidation of state power and in the creation of authoritarian regimes; major source of civil conflicts	Local, ***sub-national*** violent domestic conflicts in the South increasingly ***commonplace***
Major cause of regional inter-state conflicts in oil-rich regions	Regional inter-state conflicts over water resources have never occurred and are increasingly unlikely
Major cause of inter-state conflicts between core capitalist powers and oil producers	Inter-state water wars involving core capitalist powers have never occurred and are ***extremely unlikely***

Source: After Selby (2005: 205).

[1]Throughout this chapter data relating to the oil and gas sector are based on the *BP Statistical Review of World Energy 2008* – www.bp.com.

while they only have 12% of the world's population. This energy footprint is an increasingly controversial issue as oil is a cheap but dirty source of energy.

Dependence is also the norm for water, but in the case of water many of the most powerful economies – in North America and Europe – are in water surplus or are not seriously in food and water deficit. Over 100 of the 200 or so economies of the world are also dependent on the global system for a significant proportion of their food and water security; such dependence is usual the more highly developed an economy and the more it engages in water intensive trade in food commodities (Fraiture et al. 2007a). Most economies cannot produce all the food they need. They have the land, but they do not have the necessary water resources or climatic conditions to produce all food products. Food production and consumption accounts for about 86% of water needed by an individual or a national economy. It was politically fortunate for the world's economies and their leaders that they entered their serious food deficits in the second half of the twentieth century. This was the era when the United States and Europe were experimenting with subsidised agriculture to see how much food they could produce, albeit with seriously distorting production and export subsidies.

The proportion of actual water traded is negligible. However, the *virtual water* 'traded' annually is substantial (Table 11.3). Virtual water is the water needed to produce a commodity such as wheat. It requires about 1,000 t (cubic metres) of water to produce a tonne of wheat. Chapagain and Hoekstra (2004) modelled virtual water 'trade' for the 1997–2001 period. They estimated that 1,625 billion cubic metres [22%] of water [freshwater and soil water] out of the 7,451 billion cubic metres [*tonnes*] of water needed by the global population were 'traded' virtually. The water included *freshwater and soil water* (80%) for agricultural products, and *freshwater* for industrial products (20%).

TABLE 11.3. International virtual water flow and global water use per sector, 1997–2001.

Gross water flows	**Agricultural products**	**Industrial products**	**Domestic water**	**Total**
Virtual water export related to export of locally production	957 80%	240 20%	0	1,197
Virtual water export related to re-export of imported products	306	122	0	425
Total virtual water exports	**1,262**	**362**	**0**	**1,625**
Water use per sector				
Gross water use – billion cubic metres/year	**6,391** 85%	**716** 10%	**344** 5%	**7,451**
Water in the world not used for local consumption but for export	15	34	0	16

Source: Chapagain and Hoekstra (2004: 46)

The most water scarce region, the Middle East and North Africa, moved into serious water deficit in the last quarter of the twentieth century. This period also experienced the outcomes of a number of extraordinary experiments in water resource productivity. In the temperate humid economies of Europe and North America, rainfed water productivity trebled from an already high level. The major tropical humid economies of China and India also increased the production of food staples by four and five times by increasing freshwater use and also by substantially increasing economic returns to water. Both the temperate and tropical zone experiments were dependent on high energy inputs. The increased energy inputs were associated first with nitrate fertiliser and pesticides in the temperate zone, secondly with the pumping of water in East and South Asia for irrigation and, thirdly, with new methods of cultivation and also with the increased use of fertilizers and pesticides everywhere.

If examined historically, the political economy of water resources has differed markedly from the political economy of oil and gas. Trade in staple foods has for millennia successfully remedied the water and food shortages of water scarce economies. Currently the 20 or so economies of the Middle East and North Africa have become very dependent on international ‘trade’ in virtual water. Most important the remedy has been economically invisible and politically silent (Allan 2001: 125ff. and 162ff.). The water scarce economies have not needed to find and develop water resources at unaffordable economic, and destabilising political, costs (Allan 2002). Water has been used productively in the water abundant economies which export food. There is also evidence that water has been saved as a consequence of raising food in regions where high water use efficiencies could be achieved. Food commodities have also been exported to places where water use efficiencies were lower (Chapagain and Hoekstra 2004; Chapagain 2006; Fraiture et al. 2007a). As a consequence as much as 350 km^3 of water per year have been saved (Chapagain 2006). This is enough to make 350 million people food and water secure; and equivalent to the needs of the whole population of the Middle East and North Africa. This volume of water would be enough for the total water needs of Europe or of the United States. In the last decades of the twentieth century these food staples were on the market at half their production costs because of US and EU production and trade subsidies. Food and virtual water ‘importers’ gained multiple benefits. Their water resource security problems were addressed with free water; their food security problems were solved with half cost food. Most important of all, the water security and food security issues were neither politicised nor securitised; that is, they did not become critical destabilising political issues for those managing national economies. Selby (2005: 205) summarises very helpfully the tendency for hydro-politics to be 'low politics' at the international level. He does emphasise, however, that they can be very conflictual and even violent at sub-national levels.

Both hydro-carbon resources and water resources are strategic for all economies. It is likely that the water resources will meet the needs of the future, assuming relatively modest increases in the world's population and its additional consumer preferences. The prospects for energy are less certain. Oil and gas will meet a decreasing proportion of the future energy needs of the world's population. Oil and gas will have to be augmented with numerous other energy sources. These energy resources will have to be clean in operation – unlike the current pivotal prime energy sources, namely coal, oil, gas and nuclear. The latter has unfathomable clean-up costs. Or there will have to be 'scrubbing technologies' that remove and store the excessive increments of carbon that currently degrade the atmosphere.

The main similarity between water resources and energy resources is that their sustainable use depends on the behaviour of *consumers* – individual and collective. The attitudes of consumers in society and the politics associated with consumption are fundamental. But the consumers causing the unsustainable outcomes in the two sectors are different. In the rich Northern economies the challenge is to get consumers – individually and collectively – to use clean energy and to use all energy more sustainably. Also they need to use water recognising the environmental services it provides. In non-industrialised economies the challenge is to provide incentives for their substantial irrigating communities to reduce the volumes of freshwater used in irrigation and to increase the productivity of such water. As important will be incentives to get the half billion or so farmers operating rainfed farms in poor countries to increase the productivity of their soil water alongside the continuation of a well paced urbanisation of their societies.

3. Dynamic narratives – using and trading water and energy

There are a number of other differences between the ways that society has used water and energy through history. Energy use has been transformed by industrialisation, water use much less so. Two millennia ago the most powerful individual in Europe, the Roman Emperor, could only mobilise a few horsepower per day and enjoyed some services based on wood burning. The Emperor of China was no different. These emperors were using more energy than available to pre-historic man but not much more than the ordinary nearby Roman or Chinese soldier. But this level of energy use was many orders of magnitude less than that which ordinary prosperous individuals utilise per day in contemporary industrialised economies. The water use of all these different individuals at different moments in history has changed very little. Today the difference in water use between people in the richest countries is only about four times that of the poorest. Not over 200 times. The reason is that we all need to eat and about 80% of the water we need is for food.

Since the industrial revolution both non-renewable energy and all types of water have been increasingly utilised. The most striking feature is that non-renewable energy use per person has increased by at least 200 times. Non-renewable and renewable water resources have not even doubled in use per person. It is the historically recent acceleration in the use of non-renewable energy that is the prime driving force in all highly developed economies and it is the main potential driving force in all other economies in our globalised futures. Figure 11.1 shows the two trends. The increase in the levels of energy use is dramatic, and significantly underpinned economic development and advances in human welfare. The use of water by society in per capita terms has not increased much since pre-historic times as our food consumption per head – accounting for over 90% of the water we need – has possibly only *doubled*. Energy consumption per head has increased in rich societies by *over*

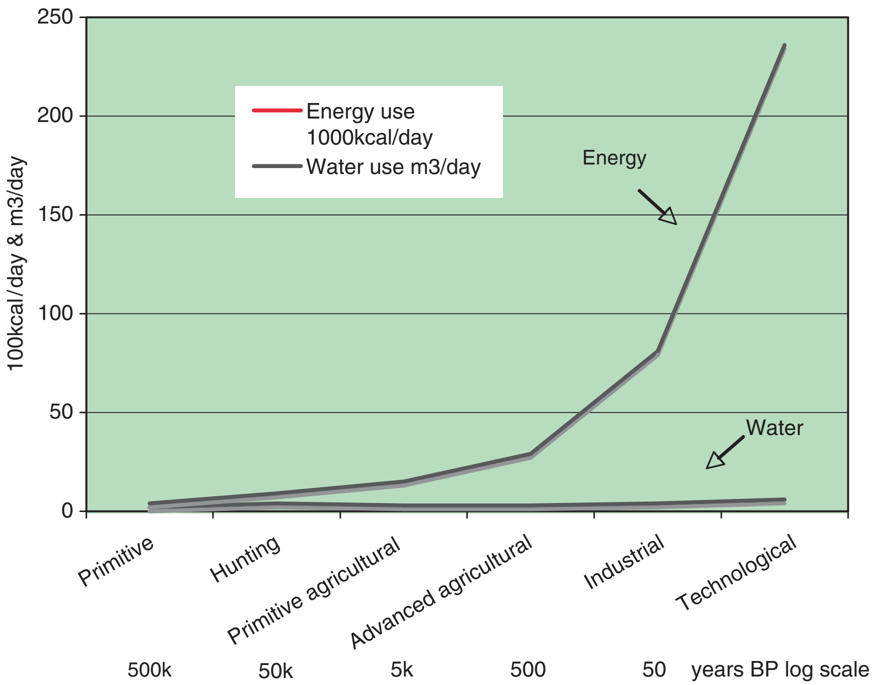

Figure 11.1. Estimates of the use of water – fresh and soil waters, and of energy – renewable and non-renewable. Source: Courtney (2005) and author's estimates.

three orders of magnitude. The figure also emphasises the hundred of thousands of years of human evolution during which we only appeared to need 4 l of [fresh] water per head per day and the only energy we could count on was that of the human frame. Human society lived over 400,000 years with primitive modes of natural resource use. We have been hard-wired to assume that we do not need much water. Processes of food production made the role of water in food provision invisible. Yet the total water use by primitive society is not much different from that in industrialised society. The use of freshwater is of course higher in industrialised society.

The allocative politics relating to water and energy are similar and dangerous. Secure access to both resources at the level of the nation and of the individual consumer are essential for human health. Interruptions to access lead to very conflictual politics in the case of oil. But not in the case of water. The stakes are very much higher in the energy sector. Virtual water 'trade' has remedied food and water scarcities. Access to both resources is achieved more by trade and related power relations and politics than by water and energy endowments. Diverse and powerful economies do not have problems managing water and energy except the self-imposed ones of managing them without significantly harming the environment. Highly developed human resources and trade are the basis of a secure diverse economy. Such economies can access their energy and water needs – providing the world is living peacefully. Singapore has only 5% of the water it needs for water and food self-sufficiency and it has no non-renewable energy. Through trade it is has access to both of these strategic resources. Is it secure? The importance of developing human resources cannot be over-emphasised. It is above all others the factor beyond the water sector that determines whether a society will be water and energy secure.

Energy and water differ in a number of ways. Water is delivered or accessed by society from only three sources – surface water, groundwater and soil water. Recently very small quantities have been manufactured and the utilisation of re-used water is increasing. Non-renewable water resources come from a single source, groundwater. Energy comes from many sources and currently 90% of energy use is from non-renewable sources. Sources of non-renewable energy have been multiplying for two centuries. To wood, coal, brown coal and peat in the nineteenth century have been added oil, gas, tar sands and uranium in the twentieth. For nearly a century, mighty industries and scores of multi-national companies have been either providers of non-renewable energy or totally dependent on its availability to power their products and services – such as trains, cars and planes. The providers of non-renewable energy – formerly coal companies and now the international oil and gas companies and the nuclear corporations – occupy the commanding heights of the global economy. Industries associated with land, sea and air

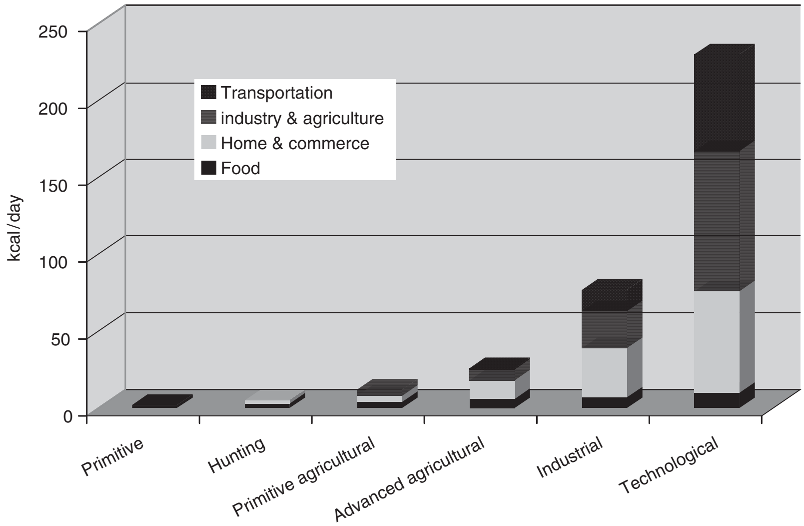

Figure 11.2. Estimates of historical consumption of energy per capita. Source: Courtney (2005) and author's estimates.

transport – all providing technologies that depend totally on non-renewable energy – are only a little less mighty. Figure 11.2 illustrates the substantial growth in historical energy consumption associated with advanced agriculture, industrialisation and technological development.

The role of trade in bringing security to political economies has also differed through history. For all of human evolution and deep even into the era of advanced agriculture, there was little trade in either water or energy. Water intensive food had to be produced close to the point of consumption as most food commodities were not durable. Increases in energy use only became globally significant well into the era of industrialisation. Water proper cannot easily be traded; however, the water embedded in commodities – virtual water – can be traded very easily. It has been traded since antiquity in that Rome was partly fed from Egypt and North Africa. The energy trade is very recent. The technologies of mining coal and the invention of the steam engine in the nineteenth century initiated trade in energy. The difference between water and energy is that only 22% of water is 'traded' virtually compared with about 80% of real oil and gas.[2] The proportions traded of other

[2]The amount of embedded energy 'traded' internationally is considerable. The author was initially deterred from modelling virtual water and virtual water trade because an army of economists attempted to estimate what would now be called virtual energy 'trade' at the height of the oil prices spikes of the 1970s. They emerged from the endeavour defeated as the production and international trade in oil is very complicated indeed as a consequence of the

energy sources such as coal, hydro-power and nuclear is much less as there are substantial domestic markets for all of these much more widely available energy resources. Trade in water itself – except in the small quantities of high value bottled water – remains negligible, and 'trade' in virtual water, while substantial at over 20% of the total water used in the world's economies is still small in comparison to the accelerating international trade in energy.

There is a very dangerous nexus of interests driving the use of energy. The incoherent energy policies of states have deceived voters, and corporations have marketed energy to these same voter/consumers so that they have unsustainable expectations. Political leaders and the very influential leaders of the transnational corporations that provide energy and sell wondrous energy-intensive technologies have pursued policies that have brought unintended consequences. Consumers have become addicted to levels of energy consumption that are environmentally toxic. Voters and consumers in the neo-liberal rich economies are locked in a mindset that is potentially apocalyptic for both the rich and the poor everywhere. The impairment of atmospheric services will also affect the availability of water resources for most people in the world. Whether we will be able to trade ourselves out of the predicament during the transition in which we change behaviour and develop clean technologies is not clear.

The nexus driving the environmentally unsustainable use of water is very different. The accelerating use of energy is more associated with the extraordinary capacity of individuals and society to increase their uses of energy – by many hundreds of times – as their living standards increase. While food consumption – the major user of water – does increase as standards of living rise: the increase is a mere doubling. At the same time, the vast array of interests associated with the global political economy of energy is not replicated in commodity related international 'trade' in virtual water. In poor countries depending on rural economies, the intense and inflexible politics come from farmers and their families. Their livelihoods and survival depend on them doing the same as in the past and more of the same if their communities are expanding. They have no alternative livelihood options.

This analysis of the role of consumers in the water and in the energy sectors shows that it is in some ways easier, although not easy, to get over-consuming energy users in rich economies – responsible for the past and current destruction of atmospheric services – to change behaviour. Rich consumers

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myriad of complex production agreements and especially because of dynamic tax regimes at all stage of the production and trade including retailing. Their results would have been useful for this analysis. The current entry in Wikipedia on embodied energy confirms that the debate is still about methodology rather than operating an effective approach. Happily, Arjen Hoekstra's team were not deterred and have provided a useful methodology for estimating virtual water use and of water footprints (Hoekstra and Chapagain 2007).

have options in consuming energy even if they are slow to take them. Poor consumers do not have water managing options to turn to in the absence of other resources. Nor do they have access to finance or alternative livelihoods. A major finding of the analysis is that the essential priority of getting consumers to change behaviour is different in the two sectors. The behaviour of individual consumers of energy, especially in diverse and strong economies, could have a strategically important impact on global energy consumption. For water resources the key consumers are the users of freshwater and soil water in poor economies. Neither their local environments and markets nor international trade relations are conducive to qualitative transformation in poor economies. They could be assisted materially by improved prices for the commodities they produce and by other measures to improve the returns they get from the large volumes of water which they utilise. Outside agencies could play an important role in accelerating economic change. Reforming the terms of international trade is an even more important priority if poor farmers are to consume water more efficiently.

The emerging challenges in the changing circumstances facing society in managing its water and energy resources require that we abandon the notion that the future will be a version of the past where proven technologies will always be preferred to alternative technologies. We need the sort of technological breakthroughs as major as those that made it possible to revolutionise transportation between 150 and 100 years ago, but without being blind to the environmental health of the planet that such changes of direction can bring. We need to do the right thing even a little badly rather than the wrong thing extremely well. What the industrialised societies did in 1980 is an extreme example of doing the wrong thing extremely well. Massive investment in the North Sea and North Slope oil and gas resources in the 1980s has proved to be a seriously non-sustainable approach. Existing energy technologies will be needed to ease the transition to the adoption of a sustainable mix of clean energy sources. But the aim must be to make them minor elements in that mix.

Any breakthroughs in this next technological transition must be mediated by awareness of the importance of global ecological health and not just the consumer's health and convenience. The neo-liberal capitalist priorities of a sound bottom-line and satisfied customer/voters are being shown – not for the first time – to be a recipe for allocative and market politics that bring unsustainable outcomes. The first failure of capitalism was over labour. This failure occurred in the mid-nineteenth century and its political origins were revealed by political economists of the time. The second failure – over the environment – which affected both neo-liberal capitalist and the socialist political economies made itself evident a century later in the second half of the twentieth century. Marx revealed the first failure, environmental activists revealed the second. Governments and corporations did not spot the need to take new directions in both cases. Political activists and environmentalists did.

The diverse economies and societies of the world are in the middle of adjusting to this second elemental shift in social and economic perspectives. The early phase of environmental awareness in the 1960s and 1970s focused on the depletion of water resources and of biodiversity. The current phase is a consequence of the hiatus over energy and the impact of our mis-use of energy on the atmosphere. Past technological breakthroughs addressing economic and social problems have usually made things worse for global ecological health and especially for atmospheric services. A responsible approach to the development of renewable energy resources such as, for example, solar thermal energy generation would meet global energy demands as well as minimising environmental impacts.

Writing this chapter has been a very unusual experience in that unprecedented and very intense political, policy and media discourses have revealed social and political turmoil. Notions that were unspeakable 6 months ago are now in popular currency. Unexpected engagement is reported daily between financial and corporate interests and those of state governments, as well as between international agencies and countless prominent and less prominent environmental activists. At the same time there is evident an inertia on the part of powerful capitalist forces that want to profit from past and current investments in familiar and tested technologies. In addition, unwilling governments – especially the elected ones – do not want to frighten their voters. But there are mighty forces in train that will make the management of energy, if not water, much more sustainable – provided the price of energy remains high.

In the current fervent to re-examine some of our economic and social priorities, a number of water and energy linkages have become evident. Most significant is the realisation that water and energy must be provided by clean technologies. The clean energy issue is the main focus of the chapters in this book, with some of the contributors discussing the linkages with water provision (notably in Chapter 8). Next there will be a brief description of the types of water and energy available and how they are utilised by society. In addition, the links between energy and water in agriculture, in hydropower production, in biofuel production and in the technologies of solar thermal energy production and desalination will be highlighted.

4. Some synergies in the use of hydrocarbons and water resources

Hydrocarbon resources and water resources have been shown in the analysis to occupy different positions in the global political economy. They differ in their distribution across the world's economies, in the extent to which they are renewable or not, in the proportions traded, and especially in the role of the consumers in industrialised and non- or less-industrialised economies. Water and energy are also very different in the number of their sources.

Water resources are limited to three main and two secondary sources. Water is found at the *surface* in river channels, lakes, reservoirs and wetlands. Secondly, it is found at depth in the ground in aquifers. About 40% of the water used in human economic systems comes from these *freshwater resources*, sometimes called *blue water* resources (Falkenmark 2000). Usable water is also present in soil profiles for vegetation and crops. Over 60% of the water used in human economic systems is derived from *water in soil profiles*. This water is sometimes called *green water*. The volumes of water used by the world's agricultural economies are estimated from the calculated evapo-transpiration of crops (FAO 2006). The water in the environment and uses in the natural biosphere includes the vast majority of the world's non-saline freshwaters and soil waters. These last sources are not the concern of this analysis except insofar as they should not be impaired to the point at which they no longer provide particular environmental services. These naturally occurring waters available for development are supplemented, first, by waters that are used and re-used in irrigation systems and to a lesser extent by re-used water from urban and industrial activities and, secondly, by manufactured water; for example, water can be manufactured in desalination plants.

In the economic and technological processes that take place in the world's economies there exist two major water and energy synergies. By synergy we here mean that one resource can be produced by using the other. First, water can be used to produce energy in two ways. Hydropower can produce electrical power which can be transmitted over long distances.[3] Energy can also be produced from water (and land) via the conversion of vegetation and crops into bio-fuel.

Water can also be manufactured by desalination technologies using a potentially wide range of energy sources. Currently almost all desalinated water is produced using oil and gas by a variety of technologies which use different amounts of energy per cubic metre. In future there is scope for the production of significant volumes of electrical energy via solar thermal technologies and strategically significant amounts via solar-voltaic technologies.

Energy is also intimately associated with water in two other major ways. Water systems depend on energy for their operation. Electrical energy production is often dependent on water for cooling. Energy producers use a mix of clean and dirty technologies to produce energy.

The lifting and distribution of water from groundwater aquifers and all waters distributed at the land surface require energy – much of it from

[3]The transmission of electrical energy is not efficient over long distances using the AC mode. High-Voltage DC energy can be transmitted economically over long distances but the technology is not yet widely installed.

hydrocarbons. Almost all water needs to be pumped to make it available for use. The agricultural sector in industrialised economies uses about 1% of total national energy use. In non-industrialised economies with extensive irrigated tracts it can be much higher. Energy is needed for cultivation, pumping water, to produce fertilizer and other energy intensive inputs including pesticides and fertilizers, as well as for transportation. Data for the United States show that energy inputs for field crops approaches 30% of total production costs though only about 10% of all farm costs including land, financial costs, labour and marketing. For livestock production energy use accounts ranges for between 2% and 10% of total production costs. It is not well known that the agricultural sectors of industrialised countries responded to the oil price shocks of the 1970s by increasing their energy efficiency. They have reduced the levels of energy inputs by 25%. Improved technologies, switches to diesel, adopting low till methods and the reduction of fertilizer and pesticide inputs enabled these reductions in energy use (Schnepf 2004). Agriculture in non-industrialised countries is characterised by very low prime energy inputs except for irrigation. They do use very significant amounts of human energy, as did farmers in pre-industrial Europe and the United States.

Trends in energy use in the high water-using natural resource sector – agriculture – has been increasing much more rapidly in the rest of the world. World energy use in agriculture doubled in the 25 years between 1971 and 1995, although the rate of increase declined significantly during the period (see Table 11.4).

4.1. THREE WEDDINGS

The purpose of the next two sections is to weave some of the most important water and energy issues into an analysis that emphasises the synergies and mutualities that exist between water and energy in an increasingly technological

TABLE 11.4. Global primary energy use by sector 1971 to 2005.

									Annual average growth rate	
Sector	**1971**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**	**1971–1990**	**1990–2005**
Industrial	91	101	120	120	131	132	140	175	2.0%	1.1%
Buildings	89	100	111	121	134	137	149	169	2.2%	0.9%
Residential	69	77	85	94	101	101	108	118	2.0%	0.6%
Commercial	20	23	26	27	33	36	41	51	2.7%	1.8%
Transport	42	49	54	59	69	78	87	98	2.7%	1.4%
Agriculture	6	7	9	10	11	11	11	12	3.6%	0.4%
Total	227	257	294	309	346	358	387	454	2.2%	1.1%

Source: de la Rue du Can and Price (2008) and globalised world. One synergy is technological, the other is economic – trade. The term wedding here is used to signify an arrangement which leads to a mutually beneficial outcome in terms of securing the future of more than one partner by synergising the mobilisation of their strategic water and energy resources. The first two weddings are the *production of energy from water* and the *manufacture of water with energy*. The third synergising process is *economic diversification and trade*.

In the next section the focus will be on *avoiding the two funerals* of water and energy respectively. These funerals are inevitable with a business as usual approach. The two funerals are, firstly, *the degradation of the environmental services of water resources* through the mismanagement of freshwater and, secondly, the *degradation of atmospheric services* through the mismanagement of energy.

It will be shown that this helpful framework is not complete. It will also be necessary to highlight the role of *consumers* and their mindsets. The big *users of irrigation water* in non-industrialised countries and the *big spenders on energy* in highly industrialised economies both have a big part to play in achieving the sustainable management of water and energy. The discussion will be skeletal, as the other chapters in the book have provided relevant scientific and technical information and analysis on the synergies and the technologies.

Energy can be produced with water. Hydropower is a long established source of hydraulic power and more recently of electrical power. The volumes of energy produced rose steadily through the twentieth century until hydropower was producing about 6% of the world's energy by the millennium. Construction of hydro-dams slowed in the global North in the last 2 decades of the twentieth century by which time all of the dam sites had been used, such as in the United States. But dams for hydropower are still being installed in many of the most rapidly expanding economies, such as China and Turkey. Global and local environmental activists mobilised opinion against the social impact of hydro-dams in the 1980s and 1990s. They especially exposed the disruptive displacement of poor communities with limited livelihood options. Hydro-dams can be appropriate if they are constructed according the guidelines of the World Commission on Dams (2000).

The other renewable energy sources – geothermal, solar, wind, wood and bioenergy – account for only about 1% of energy consumption. These are the sources that will provide the clean energy of the future. The mobilisation of clean energy is the main environmental priority for a transition to sustainability. Further impairment of atmospheric services is not an option for society facing significant human-induced climate change. Awareness of peak oil and the 2008 near doubling of the price of oil have uniquely focused the attention of the media, politicians, local communities, as well as of many corporations, on the importance of clean energy (McCornick et al. 2007: 23). Environmental and climate change activism, good journalism and even activist science can achieve a great deal to bring about this wedding of technologies. But the experience of the extraordinarily intense discursive processes of 2008 show that the price of oil is the main agent that changes minds and behaviour. It remains to be seen whether corporate interests have been persuaded that they must provide cheap clean energy and products that make use of clean – possibly more expensive – energy. The debates have been complex and controversial. In addition the role of bio-energy has been tested. It has been shown to be useful in very water rich economies such as Brazil. But elsewhere the commercial exploitation of biofuels is an irrational approach as it exacerbates the already dangerous competition between food production from soil water and the environmental services of soil water environments (Rajagopal and Zilberman 2007: Fraiture et al. 2007b: 77). Bioenergy has been produced almost exclusively from soil water to date and it will be mainly produced from soil water in future (Aldaya et al. 2009). Gerbens-Leenes et al. (2008: 24) show that the water footprint of different types of bio-energy produced in different environments – the Netherlands, the United States, Brazil and Zimbabwe – are between 24 and 160 times greater than the water footprint of oil (the average was 72 times greater). The water footprint case against bio-energy is total for all except the exceptionally soil water rich economies in South America.

The role of the manufacture of water from energy has changed dramatically in the past decade. Ten years ago the desalination of water cost about US$2.5 per cubic metre. The desalination industry had lacked the incentive to produce desalination more cheaply as the main customers were conservative oil-rich Gulf states. When some drought related emergencies occurred in California, Florida and Israel in the late 1990s, the desalination industry revealed that the reverse-osmosis process could produce water at about US$0.56 per cubic metre. This is a price that most people pay for drinking quality water in their homes in both rich and poor countries. Even the doubling of the cost of oil does not move desalination costs beyond affordability. At the same time the production of clean water with dirty energy is not a sound water or energy policy. This clean *renewable energy/desalinated water wedding* has immense potential as it addresses the strategic issue of providing enough high quality water for households, industry and services for any populations living near a coast, a river or brackish groundwater. 70%, possibly 80% of the world's populations, live close to such sources. Supplementary desalinated water will also underpin non-agricultural livelihoods. It will not provide food security except insofar as a livelihood will enable access to secure food supplies in a peaceful world. The food will have to come from richer water environments via trade.

Desalinated water production cannot solve the problem of irrigators in poor countries running out of water: their water must be free or nearly free. There is not yet a wedding of technologies that addresses the problem of poor irrigators having enduring and affordable access to water. The problems of irrigators in the economies of poor countries will be solved partly by global forces such as terms of trade, but mainly by the processes of economic diversification and urbanisation. Improvements in farming techniques are associated with the nexus of economic diversification and improved internal and external markets in these poor countries.

The discussion in this section has led naturally to the third wedding – namely *economic diversification and trade*. It has been shown how invisibly and spectacularly virtual water 'trade' has enabled the seriously water poor to be food and water secure (Allan 2001). The successful wedding requires that the water-scarce be rich and preferably living in wealthy economies. They may be rich either through having developed their human resources to a high level or by earning rent from other natural resources such as oil and gas. The same rich economies have been able to command a disproportionate share of the world's unequally distributed non-renewable energy resources. Trade currently solves the water and energy problems of the rich very effectively with the downside that the way they use energy will destroy the environment in the medium to long term. Trade has the potential to solve the problems of poor economies but only after they diversify and strengthen their economies. These socio-economic processes beyond the water and energy sectors need to be understood by all of those trying to bring about the first two weddings of water and clean energy production.

4.2. AVOIDING TWO FUNERALS

Degraded and depleted water and energy resources define two funerals for humanity. The funeral of impaired freshwater and soil water resources would ultimately bring starvation and armed conflict. We have learned that we must not push the use of water in the global hydrological system beyond its capacity to meet human and environmental needs. To date we have been able to trade our way to water security. But we have achieved this by seriously over-using freshwater resources. Surface waters in rivers such as the Yellow River in China, the Indus in Pakistan, the Nile in Egypt and the Colorado in the United States have been used to the point that natural flows occasionally cease or the quality of water discharged is toxic or environmentally dead. Freshwater in groundwater resources has even more often been driven to exhaustion in all the continents.

The analysis here has shown that immense increases in water productivity have been achieved in the second half of the twentieth century, especially from soil water. It is not clear what the potential increased returns to soil water are for the places in the world where soil water productivity is extremely low; for example, in tropical Africa. The challenges are not just technological. But they are certainly partly technological, including improved irrigation techniques and agronomic practices more generally. The role of another 10, sometimes 20, inputs usually associated with proximity of the farms to urban markets and a diversifying economy are not well understood. But they are certainly very important indeed. Studies have shown that the productivity of tracts of rainfed land in tropical Africa can be ten times more productive if they are located close to an urban centre and linked by decent transport to urban markets (Daroush 2008).

The experience of humanity in responding to the increases in demand for water and food following the unprecedented trebling of population in the last half the twentieth century has been conflictual but not violent. Countries do not go to war over water although individual farmers and villages have. The pressures from increased demands for food and water have not and will not have apocalyptic outcomes. Energy is different. It has been shown how the demand for non-renewable energy has increased at orders of magnitude higher than the rate of increase in the demand for water. Oil is a resource that causes wars. Further increases in the demand for energy are predictable and certain. The ingenuity of society and its technologies to respond to future demand will probably be adequate. But we are by no means certain. It is especially uncertain whether we shall be ingenious in time. Nor is it certain that we can modify our demand for energy and produce the majority of our needs with clean technologies.

The form and consequences of the energy funeral caused by our not being able to produce clean energy and consume it ethically are stark and very much more easy to predict. A collapse in the supply of energy would bring economic chaos and social and political violence. Transport, heating, cooling, communication and IT systems would cease to function. And trading systems that solve so many geographically asymmetric natural resource endowments – especially those of water – would not be able to operate. The cataclysmic energy supply funeral and the incremental funeral being brought about by the unethical use of dirty energy impairing atmospheric services are mighty challenges. To get attention from society requires huge oil price shocks such as those experienced in 2008. The price must be pointing at US$200 per barrel to be certain to get the big spending rich country energy users to behave responsibly and ethically. Otherwise we shall not avoid the funeral of our atmospheric services.

5. Concluding comments

Water and energy are strategic resources which underpin the sustainable future of existing industrialised economies. They are also pivotal for a much more comprehensively industrialised world in future. It has been noted that consumers in industrialised countries must be less greedy and more ethical to reverse the impairment of atmospheric services. In poor countries we need the consumers of irrigation water to change behaviour and gain higher returns to freshwater. Those using only soil water must also gain much higher returns to their soil water.

It has also been shown that water and energy are very different in many ways. Levels of use of water reflect increases of population quite closely. Water use per head including water for food is not very different between non-industrialised and industrialised economies. The use of energy, however, reflects the propensity of consumers to consume it. People in industrialised economies have a very high propensity to consume energy. They have been misled by price signals in markets and by public policy to believe that energy is limitless and is very cheap. There is an intense public discourse in industrialised countries at the time of writing in which the need for ethical and sustainable energy policies is becoming increasingly prominent.

People in many poor economies have little propensity to consume more energy. They have no control, however, over the increase in demand for water brought about by rises in population. Each new mouth in a poor country needs almost as much water as each new mouth in a rich country. It is the rise in the number of consumers in poor countries that brings globally significant destabilising water demands and the possible funeral which we have referred to in this study as the funeral of degraded water resources. The increase of water use in political economies where people are poor is a serious issue. It is the food production deficit facing these people and their governments that is most worrying. They do not find it economically or politically easy to introduce more sustainable practices in food production or measures to protect the water environment.

It is the consumers in rich countries who bring the destabilising demands for energy that have been accelerating the world and its peoples towards the potential funeral of atmospheric services through the poisoning the atmosphere.

Three processes play a very significant role in enabling society to avoid the two environmental resource funerals. Part of the water depletion and degradation problem will be addressed by producing clean energy to produce desalinated water. This approach will only address the small volumes of high quality and high value water. There is a ready demand in most economies for desalinated water as its price has fallen so much in the past decade.

The production of clean solar energy will also reverse the impairment of atmospheric services. Water for food, especially for the increasing number of consumers in poor countries, is the main challenge for water resources managers. It has been argued that the third wedding – that is socio-economic development, economic diversification and international trade – has the capacity to address this challenge. The universal prominence given to poverty reduction shows that many professionals and activists have the same idea in mind. Finally, it has been shown that while the sustainable and ethical management of water is an urgent issue, it is the unsustainable and unethical allocation and use of energy that would bring about the collapse of the world's systems.

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CONCLUSION: TOWARDS A RENEWABLE ENERGY TRANSITION IN THE MIDDLE EAST AND NORTH AFRICA?

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Abstract. For the Middle East and North Africa the notion of a renewable energy transition is no longer beyond the limits of technical possibility. This conclusion examines one proposed sustainability transition – the DESERTEC energy community – that has received high-level political support in Europe and also has influential champions in the Middle East. The DESERTEC vision anticipates an unprecedented level of regional cooperation and regional investment in renewable energy. There are significant but not insuperable obstacles to such an energy transition in the Middle East and North Africa: a necessary condition for overcoming them is the 'descuritisation' of energy governance, such that energy sustainability, climate change governance and human security are recognised as mutually reinforcing development paths.

Keywords: Renewable energy, transition management, Middle East, North Africa, renewable energy governance, energy security, climate change.

1. A renewable energy transition for the Middle East and North Africa

The chapters of this volume have examined various facets of the energy/security nexus in the Middle East and North Africa (MENA). After an initial outline of the regional security context, there were reviews of renewable energy policy and practices within Israel and neighbouring Arab Mashreq countries (including the Occupied Palestinian Territory). Chapters addressing various policy proposals and pilot projects for renewable energy use followed: the initiatives discussed encompassed renewable energy finance (Morocco), energy-efficient rural communities (Israel), solar energy for desalination (Tunisia), and wind energy (Morocco). While there was wide variation in renewable energy interests and practices reported in the review and thematic chapters, it is clear that there is significant potential for an increase in the uptake of renewable energy technologies in the region. Several contributors concurred in attributing this window of opportunity to high oil and gas prices, an increased political significance afforded to energy security, new energy infrastructure investments, and the UN climate change regime (notably the Clean Development Mechanism).

Ironically, within MENA it is the oil-rich Gulf States that have expressed the greatest interest in renewable energy, though this is explicable in terms of their need to recycle huge financial surpluses from oil production, as they seek vehicles for economic diversification. Abu Dhabi has taken the lead investing in renewable energy technology both regionally and globally: the Abu Dhabi Future Energy Company (owned by the state-run Mubadala Development Company) is investing US$2 billion in thin-film photovoltaic (PV) manufacturing, including a US$230 million production plant in Ichtershausen, Germany and domestic PV production capacity within Masdar City – a planned zero-carbon, zero-waste settlement generating 100% of its energy from renewable sources (Masdar Initiative 2008). Beyond the Gulf States, regional organisations – from the United Nations Economic and Social Commission for Western Asia to the Arab Maghreb Union – have periodically called for greater utilisation of renewable energy resources within MENA but, as will be argued below, regional cooperative capacity on energy remains weak.

Academics have begun to conceptualise the transition to renewable energy in terms of a wider transformation of 'socio-technical systems' in line with norms of sustainability. On the basis of historical studies of previous societal transitions and the modelling of complex system dynamics, there are argued to be lessons for effectively steering both trajectories of technological innovation and institutional infrastructures in support of renewable energy (van den Bergh and Bruinsma 2008). Arguably the most influential strand of this 'transition management' literature is the multilevel perspective on system transitions, which posits that, in order to stand a chance of adoption, novel technologies and practices initially require micro-level experimental spaces or *niches* protected from the dominant technological regime. Should these technological niches stabilise and develop, they can break through to more widespread adoption as they both adapt to and shape wider social mechanisms and institutions at the meso-level *regime* (e.g. market choices, policy-making, scientific research). Finally, they can be entrenched or blocked by macro-scaled economic and political structures at the so-called *landscape* level (Rip and Kemp 1998; Grin 2008). Importantly, the co-dynamics between these three levels places a heavy burden on governing forms in support of a transition, which have to network and coordinate at different scales. Any transition to renewable energy, therefore, has to accommodate plural constituencies, bypass or head off opposing interests and facilitate social learning on clean energy choices. This is a tall order.

In the next section I consider the most developed, recent vision of a renewable energy transition for the Middle East and North Africa – the DESERTEC energy community. I outline the genesis and key components of this ambitious plan, which has attracted high-level political support in Europe and also has influential advocates in the Middle East. The DESERTEC vision anticipates an unprecedented level of regional collaboration and coordinated energy financing: both regional cooperation capacity and renewable energy investment in MENA are therefore examined. Ultimately, a renewable energy transition implies far more than the application of particular energy technologies, and it is their social impacts (intended or unintended) that may well unsettle political and institutional orders in the eastern and southern Mediterranean states. That is to say, there are likely to be significant security consequences from a technologically-driven energy transition. It is argued, finally, that such a transition needs therefore to be transparent and reflexive in its design and transformative practice.

2. The DESERTEC energy community

The DESERTEC (DESERts-TEChnology) concept has been developed and popularised by the Trans-Mediterranean Renewable Energy Cooperation (TREC) network, which was founded in 2003 as a partnership of the Club of Rome, the Hamburg Climate Protection Foundation and the National Energy Research Centre of Jordan. Its philosophical inspiration is a geographical imagining of the European Union, the Middle East and North Africa (EUMENA) as a community of shared energy, water and climate security interests. The original idea can be traced back to His Royal Highness Prince Hassan bin-Talal of Jordan and Dr Munther Haddadin, former Jordanian Minister of Water and Irrigation and one of the Jordanian negotiators of the 1994 Peace Treaty with Israel (Haddadin 2006). In his unofficial diplomatic work as, amongst other roles, President of the Club of Rome, Chairman of the Arab Thought Forum and Moderator of the World Conference on Religion and Peace, Prince Hassan has long promoted the idea of supranational decision-making in MENA to address the "human dignity deficit" caused by the narrow and divisive pursuit of national interests in the region (El Hassan Bin Talal 2006). From an awareness of the triple threats of energy insecurity, water scarcity and climate change, Prince Hassan has proposed a EUMENA community of energy, water and climate security in which the harnessing of solar energy in the MENA 'sunbelt' region is coupled with European technology and expertise is a clean energy supergrid (El Hassan Bin Talal 2007).

To be sure, since the mid-1990s there had already been interest by European renewable energy experts and companies in the technical and economic feasibility of bulk electricity transmission from solar thermal power plants in MENA to European centres of high energy demand. The increasing interconnectedness of North African electrical grids had improved prospects for a Mediterranean Transmission Line Ring (originally proposed in 1987 by Maher Abaza, former Egyptian Minister of Electricity and Energy). At a meeting in Rome in 2003, Mediterranean energy ministers endorsed the idea of three south–north marine cables connecting the North African grid to locations in Greece, Italy and Spain, though these have yet to be commissioned (El Nokrashy 2004). However, the technical feasibility of such long-distance electricity transmission has been established, which in the case of the Mediterranean crossings would require High Voltage Direct Current (HVDC) technology. For proponents of renewable energy within the EUMENA region, HVDC would facilitate transmission of solar power from MENA, wind power from Europe's western periphery and hydropower from Scandinavia and the Alps (Asplund 2004; Suraci and Giovanni 1999).

DESERTEC is the most developed formulation of a EUMENA community of clean energy. In terms of transition management, its vision of a low-carbon regional energy regime articulates a 'purposive transition' (Berkhout et al. 2004) – a concerted effort to overturn the prevailing high-carbon energy infrastructure. Figure C.1 is the geographical representation of the 'EUMENA Supergrid' contained in a Club of Rome/TREC White Paper, *Clean Power from the Deserts* (Knies et al. 2007), sketching out indicative locations for power sources and HVDC transmission lines.

The purposive energy transition promoted by the Club or Rome/TREC focuses on switching the primary energy source for EUMENA electricity generation from non-renewable to renewable sources, though fossil fuels retain an important secondary role for balancing power and grid stabilisation. Similarly, the up-scaling of the electricity grid infrastructure facilitated by HVDC technology feeds into more localised alternating current (AC) power grids and decentralised micro-generation units (Trieb and Müller-Steinhagen 2007a, b).

For its proponents, a DESERTEC renewable energy transition would bring multiple benefits for the region in the face of major challenges testing the adaptive capacity of the existing carbon-intensive energy regime – rising energy demand in EUMENA, energy insecurity, economic and human development priorities for MENA (including water desalination needs), and the costs of climate change. Against each of these challenges, the DESERTEC energy regime is argued to be superior to the incumbent one (Trieb and Müller-Steinhagen 2007a, b). Yet while it is associated with a 'new development paradigm' for MENA, with clear and realisable benefits for those countries, it has largely been framed in accordance with future European energy

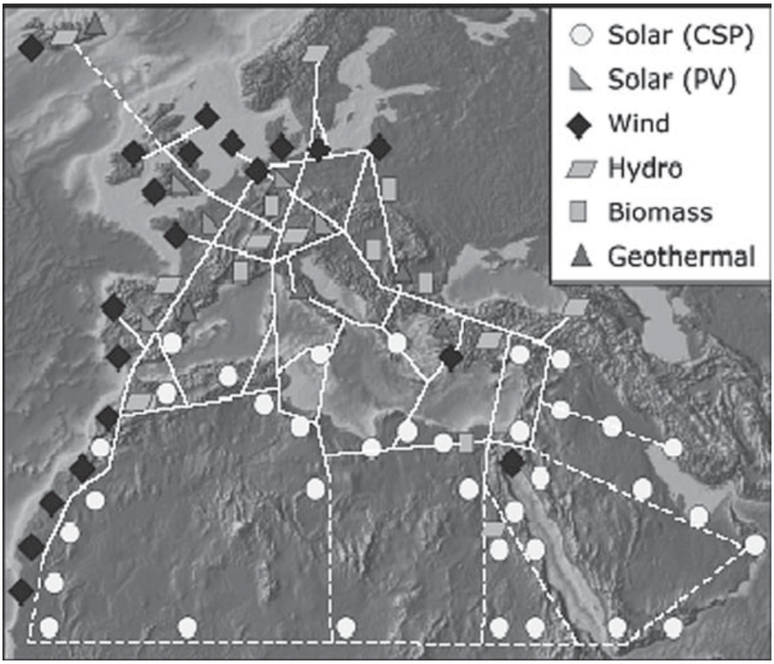

Figure C.1 EUMENA Supergrid
Source: Adapted from Trieb and Müller-Steinhagen (2007b: 33)

needs and in line also with a European economic ideology of energy sector liberalisation. The regional patterning of clean energy technologies mapped out in Figure C.1 (most obviously the specialisation on solar in MENA countries and the clustering of wind energy along exposed western coasts) represents the comparative renewable energy advantage available to countries within an anticipated EUMENA free trade area for power generation and transmission. In this way, Europe is assisted in a transition to renewable energy with, it is forecast, 15% of European electricity demand in 2050 provided by solar imports of about 700 terrawatt hours (TWh)/year from 20–40 different locations in MENA countries (Trieb and Müller-Steinhagen 2007a: 213–214, 2007b: 33–34).

At the same time, the DESERTEC proposal is informed by a technocentric, European framing of a sustainable energy system transition: this is consistent with MLP, although the implicit assumptions about social and political change are not spelt out. The Club of Rome/TREC White Paper relies heavily on two studies undertaken by the German Aerospace Centre (DLR) at the Institute of Technical Thermodynamics, Systems Analysis and Technology Assessment, located in Stuttgart (DLR 2005, 2006). These reports prioritise concentrating solar power (CSP) as the technological niche most deserving of regional political sponsorship in terms of its availability and competitive cost advantage for MENA countries exporting energy to Europe. That this is justified in terms of a commitment to least cost supply reveals an economic understanding of the drivers of innovation and technology selection, where market energy prices, suitably corrected to reflect the external costs of climate change, induce a switch to renewable sources. Yet the efficient realignment of supply and demand towards this energy transition requires also meso-level institutional changes to support the effective diffusion of renewable energy, as indeed is prescribed by innovation theory (Jacobsson and Johnson 2000; Berkhout 2008). In the case of the DLR reports, this includes a regional renewable energy agreement, capital investment subsidies or rebates, and long-term power-purchase agreements modelled on the Spanish and German Renewable Energy Acts (DLR 2005: 175–195, 2006: 92–105).

Significantly, both DLR reports were financed by the German Ministry of Environment, Nature Conservation and Nuclear Safety (BMU), which also commissioned a third study examining the potential of CSP for seawater desalination. The German Government has taken on political sponsorship of the DESERTEC proposal within the European Union, promoting it during the German Presidency of the EU (January–June 2007). There are of course clear economic and political incentives for a German solar energy agenda for EUMENA: German firms are at the forefront of renewable energy technology, with a $24.6 billion turnover in 2007. This includes firms with expertise in CSP (e.g. Solar Millennium AG), though Spanish firms (e.g. Cobra and Abener) have so far made more progress in winning CSP tenders in MENA countries, notably Morocco and Tunisia. Domestic political support in Germany for renewable energy encompasses Chancellor Merkel's Grand Coalition of governing parties as well as the Greens – the first political party to champion DESERTEC. The influence of this powerful national constituency in favour of DESERTEC extends beyond the EU. As the price for German support of his Union for the Mediterranean initiative launched in Paris in July 2008 (a forum for 43 European and MENA countries co-chaired by France and Egypt), French President Nicolas Sarkozy included in the Joint Declaration a commitment to develop a *Mediterranean Solar Plan*. While the DESERTEC proposal has unofficial support from energy experts and officials in a number of MENA countries – including Algeria, Egypt, Jordan, Morocco and Tunisia (Knies et al. 2007: 45–55) – there is as yet no high-level state sponsorship. This begs the question as to the capacity of regional MENA organisations to cultivate interest in renewable energy across the southern and eastern Mediterranean states.

3. Regional cooperation capacity for renewable energy

According to the multilevel perspective on the transition of socio-technical regimes, the dynamics of change are explained by a quasi-evolutionary account of competitive pressures within and between different scale levels (Grin 2008: 49–57). Interested social actors come together to protect and promote a particular technical innovation (e.g. CSP). Insofar as this niche then finds wider political and economic support, it gains traction within a socio-technical regime, prompting adjustments in its favour (e.g. increased research & development budgets, renewable energy feed-in tariffs in bulk purchasing of electricity), which it can then benefit from. More radical changes are seen to be more likely if they resonate with landscape-level shifts (e.g. an international climate change protocol prescribing stricter targets for reductions in greenhouse gas emissions).

However, prevailing regimes of energy production and consumption around the world demonstrate also a great inertia that tends to channel any socio-technical innovation regarding energy along established institutional pathways. Fossil fuel energy infrastructures have huge sunk capital investments (both political and economic capital), close alignments with international energy markets, and still only modest regulatory accountability for their external environmental costs. In recent years, high oil and gas prices (energy insecurity), combined with a rising cultural awareness of the potentially grave consequences of human-induced climate change (climate insecurity) have arguably been the most significant landscape-level changes to re-ignite, across many countries, political and economic interest in renewable energy.

Here the transition management literature makes explicit its claim that a successful regime change rests on a high level of coordinated pressure from proponents of the new technological practices. Guided by a purposive vision, these supporters engage in intense negotiations with other social actors to legitimise and rollout their chosen socio-technical configurations. This intentional political and economic steering has been described as 'reflexive governance' in the sense that any socio-technical transition is seen as an iterative, problem-solving process in which system-wide questions of complexity and adaptive capacity are directly confronted (Kemp and Loorbach 2006). There remain unresolved questions about the empirical validity of this bottom-up, niche-based model of normatively guided transition, which seems to clash with the historical reality of many technological innovations where processes of transformation were more dispersed and autonomous (Berkhout et al. 2004: 57–63). Nevertheless, given the DESERTEC vision for MENA is framed by a transition management paradigm, it is necessary briefly to examine the coordinated steering capacity of regional organisations.

In the first place, there is no question that regional cooperation in the Middle East is necessary for any successful transition to a renewable energy future. As the chapters in this book have shown, there are both low levels of renewable energy use in the countries of the eastern Mediterranean and also significant barriers to the increased uptake of renewable energy technologies: these include the low political priority accorded to such technologies by national governments, outdated power sector infrastructures, insufficient public or private investment in non-fossil fuel electricity production capacity, low public awareness of the benefits of renewable energy, and a lack of coordination on renewable sources between energy planning offices and international donors/development banks (cf. Chedid and Chaaban 2003). At the same time, there are increasing energy interdependencies within the region that are locking countries into non-renewable energy paths; for example, both Israel and Lebanon have power plants which import natural gas from Egypt (and in 2008 both countries experienced threats to electricity production because of irregular or delayed Egyptian gas supplies). The interlinking of regional electricity and gas networks, which nevertheless still feed into – and out from – heavily centralised national grids, justifies the notion of a regional energy production and distribution regime. Thus, niches of renewable energy innovation will only expand out and become institutionally embedded if there is coordinated political and policy support from across the region.

However, there remains a substantial deficit in regional cooperation capacity for renewable energy development. On the surface, this seems not to be the case: at least for the Arab states, renewable energy has been actively promoted in the main regional organisations representing the Middle East – the Arab League and the Economic and Social Council of Western Asia (ESCWA, one of the five UN regional commissions). Indeed, support for renewable energy within the former can be traced back to 1976 with the formation an Arab committee on renewable energy, although most of the research sponsorship and technical capacity-building has been undertaken since then by the Arab League Education, Culture and Scientific Organisation (Alnaser et al. 1995). Within ESCWA, renewable energy promotion was one of the commitments made by the Council of Arab Ministers Responsible for the Environment at a special session in Abu Dhabi in February 2001. Since this Abu-Dhabi Declaration, ESCWA and the United Nations Environment Programme have facilitated a number of high-profile meetings as the Middle East and North Africa Renewable Energy Conference (MENAREC) series; for example MENAREC 4 in Syria in June 2007 featured 500 participants from governments, the private sector and civil society. Recommendations from MENAREC 4 – the Damascus Declaration – included a call on participating countries to set national targets for renewable energy deployment and energy efficiency, as well as expressing support for large-scale renewable energy systems – including solar thermal and wind for domestic electricity generation and export to Europe (interestingly, MENAREC received significant financial support from the German Ministry of Environment).

Yet this flurry of activity disguises the fact that the regional organisations are too weak to introduce policy harmonisation measures for the effective promotion of renewable energy. In part, this is a matter of structural design: the Arab League is prohibited from engaging in political integration measures – such as the introduction of regionally binding renewable energy targets – that would constrain the sovereign authority of member states. Similarly, the renewable energy commitments issuing from the MENAREC process under ESCWA are declarative rather than prescriptive. These expressions of shared energy aspirations attest to the largely symbolic character of Arab regional cooperation in the Middle East, where the autonomous, often divergent, interests of ruling elites are the dominant drivers of inter-state relations (Tripp 1995; Barnett and Solingen 2007). Even more starkly, Ehtshami identifies an "integration paralysis" (2007: 59) for the wider MENA network that is accentuated by the creation of sub-regional organisations with very different agendas – notably the Gulf Cooperation Council (GCC) representing the oil-rich Arabian Peninsula states and the Arab Maghreb Union representing the North African Arab states. Of the two, the Arab Maghreb Union has issued the strongest statement on regional energy cooperation and market integration, including in the field of renewable energy (Union of the Arab Maghreb 2008), but this agreement has not yet progressed beyond technical and legal discussions.

Cooperation on renewable energy by Middle Eastern states has been encouraged by the US and EU. Chapter 10 examined the regional collaboration and technical workshops on clean energy that took place in Beirut in 2004–2005, supported financially by the US State Department. However, these meetings failed to set in motion ongoing cooperation, and the only formal US involvement in renewable energy development since has been a bilateral energy research agreement between the US Department of Energy and Israeli Ministry of National Infrastructure. European initiatives have been launched at a higher political level on account of a converging EU external energy, economic cooperation and security agenda for MENA – particularly those north African and eastern Mediterranean states falling within the scope of the European Neighbourhood Policy. To be sure, European energy security anxieties are accelerating cooperation over fossil fuel supplies, such as moves to integrate the Mashreq and European markets for natural gas in anticipation of Turkey joining the Arab Gas Pipeline. Yet there are also efforts to promote renewable energy generation in response to the EU target that renewable energy sources supply 20% of total European energy consumption by 2020. An EU–Africa–Middle East Conference held in November 2007 in Sharm El Sheikh, Egypt, brought together senior political representatives to discuss energy cooperation, and has generated technical collaboration on the development of clean energy technologies. This cooperation led to the creation in June 2008 of a Regional Centre of Excellence for Renewable Energy and Energy Efficiency, located in Cairo and supported by over $23 million of European grants.

The significant European technical support for regional energy cooperation in MENA is part of a wider Euro-Mediterranean Partnership (the Barcelona Process) prioritising economic reform and democratisation in MENA in order to maintain security in Europe. It remains the case that international security concerns still dominate European and American dealings with the region, from the long-running Israeli–Palestinian conflict to the more recent rise of radical Islamist parties and political movements. In the past few decades, numerous international diplomatic efforts (official and unofficial) have attempted, and failed, to secure lasting peace in the Middle East. There remain acute Arab grievances arising from the continued Israeli occupation of Palestinian territory (which feeds Islamist radicalism), while Israeli perceptions of state insecurity underlie its dismemberment of the West Bank and military isolation of Gaza. The resultant political impasse has prevented the 'desecuritised' Israeli–Arab state relations necessary for effective regional cooperation over a clean energy transition. Shared concerns over energy security and environmental sustainability are offset by the countervailing weight of divergent geopolitical interests.

In this context it is also not surprising that international efforts at promoting democracy and 'good governance' in the Middle East have met with limited success, though these are conditions that transition management proponents posit as necessary for regime change. Unrealistically detached from the need to solve the Israeli–Palestinian problem, European and American democracy promotion in the region has suffered from a lack of coordination and credibility (Brown and Shahin 2009): Arab states allege double standards, pointing to instances where democratically expressed preferences have simply been discounted by Western states and international donors (e.g. the 2006 Palestinian elections which brought Hamas to power). The representation of political consensus-formation as unproblematic in the transition management literature is also directly challenged by the Middle Eastern regional context, where most states possess centralised, clientistic structures and where civil society organisations struggle to be independent of governing authorities (Tripp 2001; Jamal 2007). This suggests that enduring regional cooperation on new technologies and development paths is likely to depend on a close overlapping of interests as identified by ruling state elites.

4. Regional investment in clean energy

There is a careful avoidance of democratic governance prescriptions in the DESERTEC vision of a clean energy future for the MENA region. Instead there is direct appeal to MENA governments to support the large-scale deployment of solar power plants on the basis of energy security, economic development and the production of desalinated water. The DESERTEC programme is represented above all as a major technical-engineering challenge – similar in ambition to the Apollo space programme – which manifestly meets the needs of present and future generations (Knies et al. 2007: 56–58). This neatly bypasses political issues of interest representation and negotiation in the MENA countries, but at the same it is stressed that “adequate” (i.e. market liberal) legal and regulatory frameworks need to be in place to facilitate the massive financial investment needed for a successful renewable energy transition. In other words, there is an expectation that market-led steering can achieve much of the strategic coordination on renewable energy uptake so conspicuously lacking in regional political organisations.

The DESERTEC proposal emphasises that the mass production of solar thermal power plants in MENA requires new forms of North–South investment, which can be jump-started by an infusion of €10 billion from the EU and European industry (Knies et al. 2007: 56). There is an assumption that, within MENA, there is insufficient investment capital available in non-Gulf states to effect a transformation to a low-carbon energy path even if political leaders in the region embrace this scenario. This has significant implications for the nature of the energy transformation: according to the transition management literature, the more a regime relies on external resources for innovation and adaptation, the more the opportunity for major structural change exists (Berkhout et al. 2004: 66). In these terms, the liberalisation of European energy markets is a landscape-level change favouring suppliers making large investments in power generation and distribution – including North Africa and the Middle East – but this does not, by itself, favour renewable energy investment in a situation where carbon emissions have been under-priced by regulators (e.g. the European Emissions Trading Scheme). However, if the EU endorses a recent recommendation by its Commission that a Mediterranean Solar Plan merits high-level political and financial support as part of European efforts to increase energy and climate security (Commission of the European Communities 2008: 6), this may trigger the type of co-ordinated clean energy investment invited by the proponents of DESERTEC.

In order to mobilise large-scale financing for clean energy development in North Africa and the Middle East, the European Commission envisages the creation of a Sustainable Energy Financing Initiative jointly managed with the European Investment Bank. This would combine public and private sector sources of funding in a strategic investment vehicle optimistically portrayed as a key element in the response of the EU to the global financial crisis (Commission of the European Communities 2008: 19). To be sure, this presumes a EU external energy policy far more coherent than current practice: the EU single energy market that would purchase 'green' electricity from southern Mediterranean countries is still not complete, even though there is already a European pressure on these countries to liberalise their own energy markets. Moreover, the inability of the EU to wrest energy security policy away from the its Member States – which cling to state-centred positions on energy sovereignty (Belyi 2008) – means that, at least for reasons of energy security, there is not yet a unified EU political platform for supporting substantial investment in renewable energy in MENA countries.

Nevertheless, major external financing is already available. In 2007 the European Investment Bank (EIB) was the largest global investor in clean energy – investing \$3.2 billion – followed by the World Bank Group at \$1.43 billion (United Nations Environment Programme 2008: 50); and both these international development banks already provide significant public financing for renewable energy in the MENA region. Since 2002, under the Facility for Euro-Mediterranean Investment and Partnership, EIB has provided over \$2.8 billion of finance to Mediterranean partner countries. Its remit explicitly includes integration of Euro-Mediterranean energy markets and renewable energy investment (European Investment Bank 2008: 51–53). The World Bank Group has stepped up clean energy investment since developing in 2006/2007 a Clean Energy and Development Investment Framework, which supports low-carbon development paths and climate change adaptation programmes with also a regional focus on improving energy access in sub-Saharan Africa. In 2007 the MENA region received \$65 million of World Bank investment in renewable energy (excluding \$40 million support for hydroelectricity development), with \$43.2 million of this channelled via the Global Environment Facility into the development of an integrated solar combined cycle power plant in Morocco (World Bank Group 2007: 54–56). If realised, World Bank plans for a Clean Technology Fund to finance climate change mitigation activities in developing countries would create additional opportunities for clean energy investments in MENA.

The development banks – of which EIB and the World Bank Group are biggest international players in MENA – typically aim through their activities to leverage private finance. This goal relates more to the direction than availability of private finance, which dwarfs multilateral and bilateral development bank funds. Of the \$490 billion total of planned energy capital investment within MENA between 2008 and 2012, oil supply chain investments comprise 41% of the total, gas supply chain investments comprise

45%, and most of the rest is anticipated to go to oil- or gas-fuelled power generation (Aissaoui 2007: 2): renewable energy investment is still negligible. Despite new investments in renewable energy technology manufacturing by several Gulf state sovereign wealth funds (as mentioned at the start of this essay), there is no immediate prospect of significant moves away from this sectoral bias in favour of fossil fuel financing, which is entrenching high-carbon energy infrastructures in the region. This contrasts both with the global expansion of clean energy financing – $148.8 billion raised in 2007, up 60% from 2006 (United Nations Environment Programme 2008: 1) – and also rapidly growing Research & Development (R&D) spending on clean energy in the Middle East, notably in Israel (New Energy Finance 2006).

Indeed, renewable energy investment in MENA is devoted more to export-based manufacturing and R&D than to new power generation capacity – a different investment trajectory for the region than envisaged in the DESERTEC proposal. Unless governing elites and national power utilities perceive renewable energy to be a reliable, cost-competitive alternative, or major supplement to, fossil-fuel generating capacity, then there will be insufficient momentum for a transition to a clean energy socio-technical regime. The barriers here are not financial: even during the global credit crunch, the main driver for clean energy investment has been *asset finance* (i.e. funding power generation capacity) from a variety of sources – private and public equity, debt markets and the growing carbon finance market. Harnessing these substantial capital resources at a regional scale requires some harmonisation of regulatory frameworks between MENA countries in order to remove barriers to the increased utilisation of renewable energy; for example, lack of information and technical experience, high import duties on the import of relevant technologies, and subsidised tariffs for electricity from fossil fuel power plants. To be sure, there is evidence of convergence in energy law reforms underway in several MENA countries (Egypt, Jordan, Morocco), which feature regulatory incentives favoured in the DESERTEC energy regime, notably long-term power purchase agreements or feed-in tariffs for renewable electricity and income tax exemptions on capital investment in renewable energy plants (Trieb and Müller-Steinhagen 2007b: 42). Interestingly, some of these measures are more interventionist than the market-oriented policy measures promoted by the Global Environment Facility and other multilateral financial mechanisms.

This last point highlights perhaps the key economic barrier facing efforts to open up the Arab MENA countries to substantial private capital investment in renewable energy generation projects – the absence of a coherent free market. There is only a narrow range of tradable goods produced in the region, while the oil-rich Gulf states are integrated more with the global economy than MENA trading networks (Ehteshami 2007: 52–53). The lack of regional market cooperation is accentuated by economic protectionism, as most Arab states accrue substantial revenue from import tariffs and duties. Furthermore, there is still no regional endorsement of liberal economic values despite efforts by Western countries and international economic organisations to implant these (Barnett and Solingen 2007: 184–185). From the perspective of these global representatives of economic liberalism, the weaknesses in market development in the Middle East and North Africa compound, and are compounded by, geopolitical fragmentation and insecurity.

5. Conclusion

There is, at most, a nascent clean energy transition in MENA. The evidence for this is the modest but growing uptake of renewable energy technologies described in this volume, accompanied by favourable regime-level changes – e.g. energy policy reforms, sharing of scientific knowledge/expertise, and new clean energy investment opportunities. However, these developments fall far short of the 'purposive transition' – the planned, concerted shift to a low-carbon regional energy system – called for in the DESERTEC vision. Indeed, I have argued that the prevailing political and economic context is currently not conducive to such a transition. Even if substantial energy capital investment can be diverted from the existing regional fossil fuel infrastructure (with its long-term technological imprint and environmental legacy) to renewable energy power generation and distribution, the low level of political coordination available between MENA countries suggests a more messy transition. This would be one that corresponds closest to an 'emergent transformation' as identified in the transition management literature; that is, an energy regime transformation riding on largely uncoordinated, contingent social choices (Berkhout et al. 2004: 66–70). It is also a transition away from hydrocarbons that will have to compete with, and likely accommodate, rising interest in nuclear power amongst MENA states.

The preoccupation of the DESERTEC vision with technologically-driven changes to energy use leaves little space for considering the significant social impacts (intended or unintended) that would accompany a transition to renewable energy in MENA. Imagining that such an energy transition would have positive impacts on regional security presupposes the acquiescence of ruling political elites and also papers over the geopolitical fault-line that is the Israeli–Palestinian conflict. Social cooperation within and between states is presumed to co-evolve with the diffusion of new energy technologies, but this underestimates the potential for disruption and opposition from those groups with a vested interest in the status quo. The displacement of politics from the DESERTEC vision is understandable, but disingenuous: it is a normative oversight characteristic of the wider transition management literature, which construes political agency according to a consensual – arguably European – notion of social deliberation and agreement (Berkhout et al. 2004: 56–59; Walker and Shove 2007). It might also be suggested that DESERTEC energy regime uncritically accepts European ideas of sustainability by not questioning, for example, the underlying consumption patterns that necessitate a massive importation of electricity (however clean) to the EU from MENA countries. That would judge too harshly, perhaps, a proposal crafted to mobilise wide-ranging political support for a green energy transition. But a more reflexive understanding of the contending interests and antagonisms at play both in MENA and Europe could make the DESERTEC vision more persuasive.

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