Opportunities for Renewable Energy in Tunisia: A Country Study

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Discussion Paper
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Disclamer

This paper was produced as a reference paper to inform the discussion paper "New Mechanisms for Financing Mitigation: Transforming economies sector by sector." The views expressed in this paper do not represent the views of WWF nor the agencies that committed financial support to carry out this project.

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An Introduction to the Global Financial Mechanism Supporting Studies Series

Beginning in mid-2008, at the request of several European governments, WWF led an analysis and dialogue on international financing arrangements to address climate change in developing countries. That meant, on the one hand, advancing a technically strong proposal capable of mobilizing the considerable public and private funds that may be needed to attain the below 2 degrees centigrade goal for climate change stabilization and, on the other hand, advancing an equitable proposal that could garner the support of the parties at COP15.

The work approach is designed (a) to bring a bottom-up perspective to the to the current top-down discussion, based on a suit of developing countries' sectoral studies that focus on what it would actually take to move whole economic sectors towards a low emission trajectory; (b) to focus on the operational requirements of an international financing scheme; (c) to engage leading experts on a critical review of relevant experiences and government proposals; (d) to convene experts and negotiators from South and North to discuss these issues; and (e) to present the project findings to key stakeholders and forums in the run-up to COP15.

The program's main conclusions and proposals are in the document: "Global Financial Mechanism. The Institutional Architecture for Financing a Global Climate Deal" that can be downloaded from
http://www.panda.org/what_we_do/how_we_work/policy/macro_economics/our_solutions/gfm/

In this Supporting Studies Series we are presenting a dozen reports that were used as inputs to the project. All these studies were commissioned to independent experts or institutions. Some are case studies of mitigation opportunities in different sectors of developing countries (e.g. cement and iron & steel in China and Mexico, coal based power generation in India, renewable energy opportunities in Morocco). Others are stock-taking reports focusing on critical issues for the global climate change financing (e.g. mapping new financing options for climate change, a review of sectoral mitigation proposals, a review of proposals to fund technology cooperation, etc.).

Some of the ideas and proposals in these support series have been carried over to the project recommendations and have been summarized in the main document (either as short summaries, theme boxes, or pull quotes). Still, these documents have much more to offer, and for that reason we present them here in full. As usual, opinions in each document are the sole responsibility of its author(s), and should in no way be considered representative of WWF positions.

Authors and titles in this GFM Supporting Studies Series include:

1. Michael Rock; (Bryn Mawr College) Using External Finance to Foster a Technology Transfer-Based CO_2 Reduction Strategy in the Cement and Iron and Steel Industries in China
2. Christine Woerlen (Arepo consult, Berlin) ; "Opportunities for renewable energy in Tunisia: A country Study
3. The Energy and Resources Institute (TERI, Delhi) "Strategies to reduce GHG emissions from India's coal-based power generation"
4. Britt Childs with Casey Freeman (WRI, Washington DC) "Tick Tech Tick Tech: Coming to Agreement on Technology in the Countdown to Copenhagen"
5. Energia, Tecnologia y Educacion, SC (ETE, Mexico DF) "Strategies to reduce Mexico's cement and iron & steel industry GHG emissions"
6. Charlotte Streck (Climate Focus, Brussels) "Sectoral Transformation Plans as Strategic Planning Tools"
7. Charlotte Streck (Climate Focus, Brussels) "Financing REDD a Review of Selected Policy Proposals

8. Charlotte Streck (Climate Focus, Brussels) "Financing Climate Change: Institutional Aspects of a Post-2012 Framework"
9. Silvia Magnoni "Review of the CDM and Other Existing and Proposed Financial Mechanisms to Transfer Funds from North to South for Mitigation and Adaptation Actions in Developing Countries"
10. Silvia Magnoni "Sectoral approaches to GHG mitigation and the post-2012 climate framework"
11. Weishuang Qu (Millennium Institute, Washington DC) "Using the T21 computing model to forecast production and emissions in China's cement and steel sectors"
12. Neil Bird et al (ODI, London) "New financing for climate change. And the environment in the developing world"

Contents

Abbreviations

a	ampere
ANME	Agence Nationale pour la Maitrise de l'Energie (National Agency for Energy Management)
CDM	Clean Development Mechanism
CERs	certified emission reduction
CO2	carbon dioxide
CO2eq	carbon dioxide equivalent
CSP	concentrating solar power
cts	cents
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DOE	Department of Energy
ETAP	Enterprise Tunisienne d´Activités Pétrolières
FDI	foreign direct investment
g	gram
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gas
GWh	gigawatt-hour
IEA	International Energy Agency
IFI	international financial institution
INC	Initial National Communication (to the UNFCCC)
IPP	independent power producer
IPR	intellectual property rights
KfW	Kreditanstalt für Wiederaufbau
kt	kilotonne
ktoe	kilotonne of oil equivalent
kV	kilovolt
kWh	kilowatt-hour
M	million
m^2	square meters
MENA	Middle East and North Africa
MENAREC	Middle East North Africa Renewable Energy Conference
Mt	megatonne
Mtoe	megatonne of oil equivalent
MUSD	Millions of USD

MW	megawatt
O&M	operation and maintenance
OECD	Organization for Economic Cooperation and Development
PES	primary energy supply
PPA	power purchase agreement
PPP	purchasing power parity
PV	photovoltaic
RE	renewable energy
STEG	Sociéte Tunisienne de l'Electricité et du Gaz
SWERA	Solar and Wind Energy Resource Assessment
t	tonne
TND	Tunisian dinar
TWh	terawatt-hour
UNDP	United Nations Development Programme
UNEP	United Nations Economic Program
UNFCCC	United Nations Framework Convention on Climate Change
USD	U.S. dollar

Foreword

WWF would like to contribute to the ongoing discussions in the runup to the United Nations Climate Change Conference in Copenhagen, Denmark, in December 2009. The idea is to have on the table by early 2009 a draft design for a new funding mechanism that would be incorporated into or parallel to some of the existing climate funds and clearinghouses. The purpose of this new fund would be to channel funds and technology from north to south and to accelerate the transition of developing countries toward low greenhouse gas (GHG) emissions, particularly in middle-income fast-growing countries. Together with the overall architecture of such a mechanism, WWF is interested in presenting case studies that show what it would take to move key sectors of developing countries to low GHG emissions. The intention is both to show that this is possible and to understand what it would entail in terms of funds and technology transfer activities. The Tunisia case study is one of these studies and focuses on substituting conventional power production with renewable sources of electricity.

The author would like to thank WWF for the opportunity to contribute to this discussion, and would like in particular to thank Pablo Gutman, David Reed, and Ingrid Timboe from the Washington, D.C., office of WWF-Macroeconomics for Sustainable Development Program Office. In addition, thanks goes to Dr. Hans-Joachim Ziesing and Andrea Kutter as well as all reviewers of early drafts.

Abstract

Tunisia is in many ways characteristic of a large number of small emitting countries, but comparatively progressive in terms of its energy-efficiency policies. This study analyzes how Tunisia could utilize much larger amounts of renewable energy for its energy supply.

Through an analysis of the current Tunisian energy sector, the study identifies two positive trends in the past: a trend of energy efficiency, as expressed in a decreasing energy intensity of a growing economy, and a trend of decarbonization, caused by a trend away from oil and toward natural gas as the main fuel. Both trends have been facilitated by consistent government policies toward more energy efficiency and toward the substitution of oil by gas in electricity and industrial heat provision.

The study describes an ambitious scenario for continuing the decarbonization trend by substituting the natural gas—which creates import dependence and budgetary problems—with two modern renewable energy technologies, that is, wind power and concentrating solar power. In theory, Tunisia could replace all of its generation capacity with renewable capacity by 2040–2050, thus having an electricity sector that is not only completely independent from energy imports but also completely emission-free. The incremental costs of this scenario are surprisingly low, even though large investments are required over a long period. The study discusses a variety of measures and activities that would be necessary to provide the grounds for this transformation, and analyzes how an international financial mechanism could help finance mitigation and technology transfer.

Keywords: Tunisia, fast-growing economies, renewable energy, energy efficiency, small middle-income countries, small emitters, technology transfer.

1 Why Tunisia?

Tunisia is a small middle-income country in Northern Africa. With respect to total greenhouse gas (GHG) emissions, Tunisia is the 100th biggest emitter worldwide, and in per capita GHG emissions it is number 125. So, why focus on a small middle-income country with a modest GHG footprint? Why go beyond the largest emitters? The answer is that Tunisia is an example of a large number of developing countries that are small players on their own, but as a group they are a significant source of GHG emissions and an important component of any global climate deal.

Though it is obvious that all large emitters need to be on board with an agreement and implement mitigating measures, the large group of currently small emitters also has the power to influence the world's climate with their emissions. As table 1 shows, the aggregate emissions of the Non-Annex-I Countries without the "Big Five" in 2006 were of the same order of magnitude as the emissions from the United States or China, or six times as high as Germany's. They make up more than 17% of global energy-related carbon dioxide (CO2) emissions.[1]

Table 1. CO2 Emissions of Small Non-Annex I Countries

Source: IEA data, 2008.

2006		Tunisia	Northern Africa*	Medium and Small Non-Annex I countries*	World
Population	millions	10,1	611,50	2499,5	6536
Total GDP	billion, 2000 USD	78,60	790,70	10559,00	57564,50
CO2 eq emisisons from energy	Mt CO2eq	19,70	340,50	4876,10	28002,70
	% of World total	0,07%	1,22%	17,41%	

* Non-Annex I Countries minus China, India, Mexico, Brazil, South Africa

** Morocco, Algeria, Tunisia, Libya, Egypt

As table 1 and figure 1 demonstrate, about 60% of the energy-related emissions from Non-Annex I Parties come from five large emitters. The other 40% come from countries such as Tunisia. As a group, their emissions have grown from 2005 to 2006 by around 180 megatonnes (Mt) carbon dioxide equivalent (CO2eq), which is about equal to the 2006 emissions from the Netherlands. An exclusive focus on the large emitters cannot lead to a stable global climate.

[1] This study focuses only on CO2 emissions from energy. Factoring in emissions from land use and agriculture underlines the importance of this group even more.

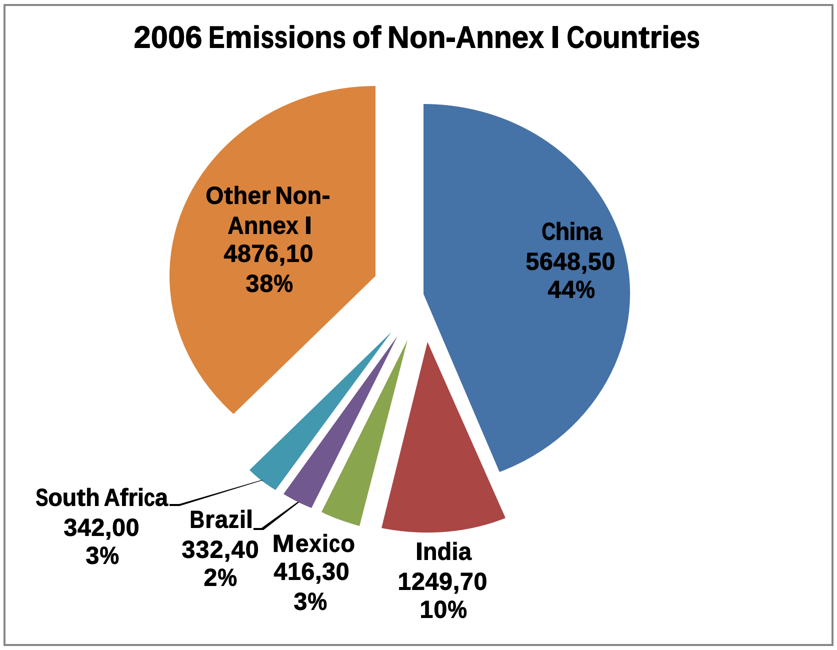

Figure 1. Energy-Related CO2eq Emissions of Non-Annex I Countries, 2006
Source: IEA 2008

Because they are small, these countries might require mitigation strategies and technology transfer measures that are tailored to their markets and their characteristics. These measures might include specific multicountry and regional initiatives on top of the local programs required in large countries. Tunisia is characteristic of this group in two ways: Like many of these countries, it has stable economic growth and has a comparatively small contribution of coal in its energy mix. If the economic growth trend and high energy prices on the world market[2] continue, a large-scale switch toward coal in many of these countries is likely and might increase their CO2 emissions significantly. This study analyzes Tunisia's situation in terms of emissions, emission reduction opportunities, and the use of renewable energy for a significant share of the Tunisian electricity. From this analysis, we infer what it would take to apply these strategies to the small emerging economies on a global scale, and what this might mean for a global financial mechanism for the United Nations Framework Convention on Climate Change (UNFCCC).

[2] At the time of this writing, energy prices have actually gone down. However, it is likely that they will pick up very fast when the economic recovery begins.

2 Tunisia's Energy Sector

2.1 Energy Trends in Tunisia

Tunisia's primary energy supply (PES) is dominated by oil (47%) and gas (40%) (figure 2). There is a very small component of renewable electricity generation technologies (mainly hydro) and no nuclear power.

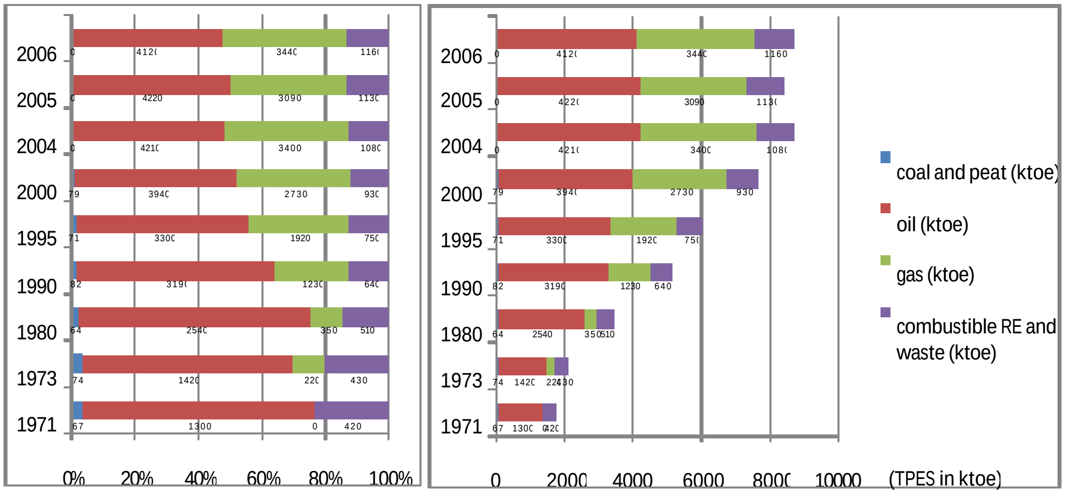

Figure 2. Total Primary Energy Supply in Tunisia 1970–2008
Source: IEA Energy Balances 2008

Tunisia's economy is service-oriented. According to information from the World Bank (2009)[3] 59% of its gross domestic product (GDP) is generated in the service sector. Telecommunications, transport, and commerce have been the engine of a 7% average growth rate from 2000 to 2007, while growth in tourism has remained modest. Seventeen percent of GDP comes from the manufacturing sector, where the mechanical and electrical sectors have experienced double-digit growth in investments and export.

Because of this stable economic development, Tunisia's energy consumption as well as its electricity consumption has risen steadily over the past decades. As figure 2 demonstrates, total PES increased by 250% between 1980 and 2006. Oil consumption has doubled, electricity consumption has grown by a factor of 5, and natural gas consumption has grown more than tenfold. Industrial energy consumption has grown in line with economic activity. The fact that oil consumption grew slower than did gas and electricity consumption indicates a decarbonization trend of industrial activity. In fact, though oil was the main fuel in both industry and power generation at the beginning of the period, it is now relegated to transportation and a small share of power generation. In light of dwindling oil reserves and the switch to a negative energy export balance in 2003, Tunisia, through its oil company ETAP (Enterprise Tunisienne d´Activités Pétrolières), has striven to enhance its effectiveness in exploring and producing oil through cooperation with 42 national and international companies (EIA 2006). Still, Tunisia nowadays imports 16% of its oil.[4] Increasingly, gas is used to cover Tunisia's rising energy needs. In 2003, 14% of primary energy consumption was covered by natural gas, but by 2005, the figure was already 44%, and in 2006, 45% (ETAP 2007). An incentive

[4] In fact, because of severe shortages in refining capacity, crude is exported and reimported as refined petroleum products.

system encourages the use of natural gas to replace oil. But for natural gas, too, Tunisia changed from an exporter into an importer. In 2005, Tunisia imported 36% of its natural gas consumption.

For the provision of electricity and downstream gas, Tunisia relies on its national utility, STEG (Sociéte Tunisienne de l`Electricité et du Gaz). Some large industries (e.g., cement) produce their own electricity. For electricity production, Tunisia relies on natural gas for about 60% of its installed capacity. Most of the rest still comes from oil. Sixty-two megawatts (MW) or 2% of installed capacity comes from hydro power. More than half (36 MW) of this is installed at the Sidi-Salem dam. There have been very few attempts to use biomass for power generation. In 2000, the Tunisian-Chinese cooperation put into operation a pilot plant to generate power from poultry waste. With three tonnes of poultry waste per day, the plant generates about 200 m³ biogas, which provides 300 watt-hours of electricity (GTZ 2007).

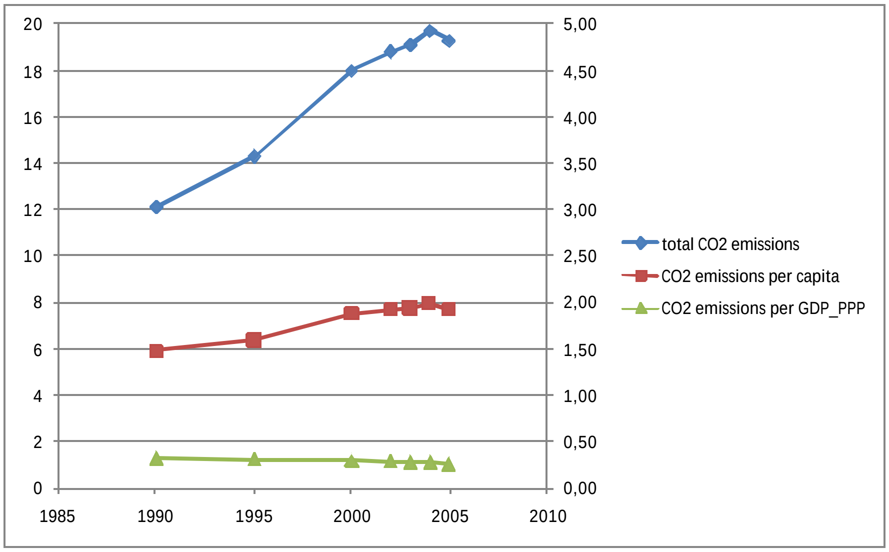

Figure 3. Carbon Emissions in Tunisia from 1990 to 2005
Source: IEA CO2 statistics 2006

Total CO_2 emissions have grown in sync with overall energy use (figure 3).[5] Between 1980 and 2005, they have grown from 8 million tonnes to 20 million tonnes, an increase by a factor of 2.5. Nevertheless, the growth has slowed down in recent years. CO_2 emissions per capita were slowly rising, but not as steeply aselectricity consumption per capita (decarbonization). In addition, the CO_2 emissions per unit of GDP are stagnating but with a falling tendency (decarbonization and energy efficiency).

2.2 Government Activities in the Energy Sector

End-user energy prices and products from oil and gas (including car fuel and electricity) are highly subsidized in Tunisia. As a traditional self-supplier of oil and gas, Tunisia has fixed prices for almost all forms of energy. As the energy import balance swayed from export to import of oil and gas, Tunisia continued subsidizing fossil fuel consumption in the fiscal budget. The increasing oil

[5] Interestingly and for comparison, in the Initial National Communication of 2001, total GHG emissions — mostly CO2—were expected in 2010 to total 31 Mt for the business-as-usual scenario and 24 Mt in the mitigation scenario. It does not seem likely that even these levels will be reached.

prices over the past years have imposed a steadily rising burden on the budget—so much so that in 2006, 1.3 billion Tunisian dinars (TND) (U.S.$923 million) have been spent on energy subsidies, an amount that is equal to the total budgetary deficit, or 3% of the national GDP (ANME 2008a).

Apart from perverse incentives that stimulate inefficient electricity consumption, rising oil prices are a real threat to the stability of the government's budget. To stave off the rising costs of oil imports and electricity substitution, the Tunisian government launched a number of programs to substitute oil with natural gas, and to encourage energy savings, energy efficiency, and initial investments in renewable energy. Compared to a business-as-usual scenario, the energy-efficiency measures have led to cumulative emissions savings of 2 Mt CO_2eq over the past 20 years. Of these savings, 10% came from renewable energy appliances such as solar water heaters, but most of it came from public awareness campaigns, car check-ups, and labeling of household appliances.

Energy efficiency even has its own government agency in Tunisia, the National Agency for Energy Management (ANME). Important opportunities to reduce the energy dilemma and to abate GHG emissions can still be leveraged. Under the impact of high oil prices of over U.S.$100/barrel, the government of Tunisia paid increased attention to the energy sector: In the 11th Five-Year Plan (2007–2011), it put forward a suite of energy-efficiency activities expected to reduce energy intensity by 2% per year. Activities are as follows: allowing industries to self-generate electricity, introducing minimum energy-efficiency standards for buildings, supporting solar water heating on large buildings, introducing 2 million energy-saving lamps, energy audits, and cogeneration of heat and electricity. These plans are supported by a World Bank project currently being developed. It will extend the use of energy audits in industry and impose a permitting process for the energy requirements of new industrial installations including the promotion of cogeneration and self-generation, improve thermal insulations of buildings, develop energy-efficiency standards for appliances, replace old appliances and incandescent bulbs, improve energy efficiency in transportation through mandatory check-ups and a system of car fees, and further increase the use of natural gas in the residential and commercial sectors (World Bank 2008).

Renewable energy and the substitution of fossil fuels with carbon-free alternatives play little to no role in these government policies. As the Tunisian government is losing money on each kilowatt hour (kWh) of electricity consumed no matter if it is from gas or from renewable sources, it only considers energy efficiency and energy conservation for the relief of the public budget deficit.

2.3 Putting Tunisia into Perspective

Tunisia can be taken as a role model for almost all small countries and for some large ones in the developing world.

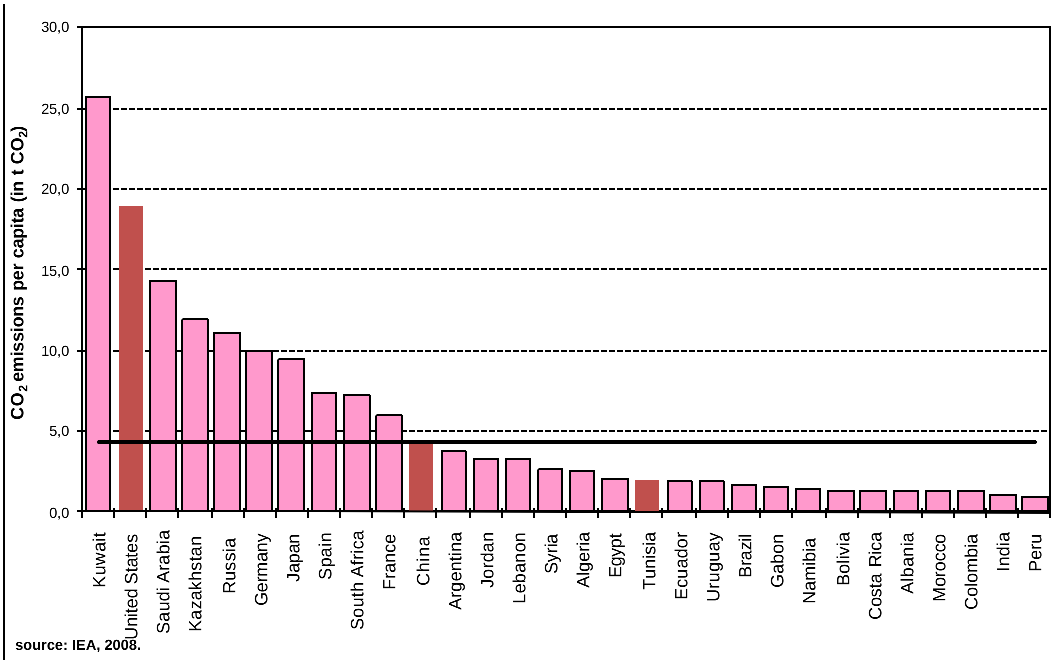

Figure 4. CO_2 Emissions per Capita of Selected Countries in 2005
Source: IEA Statistics 2008

With two tonnes of CO_2 emissions per capita, Tunisia's emissions per head are significantly below the global average of 4.28 tonnes (figure 4). Some of the oil- and gas-rich countries of the region, such as Algeria and Egypt, have similar CO_2 emissions but much larger populations, and thus significantly lower emissions per capita. Tunisia's structure is more comparable to smaller Middle Eastern countries such as Jordan or Syria. Like Tunisia, they depend on imports of fossil fuels and have high electrification rates. Of these, Tunisia is lowest in its per capita emissions and highest in its overall energy efficiency. This implies that Tunisia is somewhat ahead in terms of its energy efficiency compared with its neighbors, but there are still a large number of opportunities to reduce energy consumption or substitute fossil fuels with renewable energy sources.

Energy efficiency is recognized in Tunisia as a means of economic development rather than a burden imposed by international politics. Tunisia has put some effort into doing the cost-effective thing in avoiding additional and unnecessary energy consumption. Its experiences can and should be transferred to many other places that have ambitious economic development plans yet fight the same issues of resource scarcity, lack of rural energy access, and wasteful use of energy.

Nevertheless, Tunisia has not developed in the renewable energy area even though it offers some of the same and also other economic development benefits. Renewable energy can increase energy security, can lead to stable energy prices and healthy government budgets, can generate revenue from international carbon trading, and can create local jobs. Tunisia has extensive renewable energy resources, and by systematically exploiting them it can progress the goals of reduced energy imports and increased energy independence. Not only would renewable energy offer perfect energy price stability, but for Tunisia as for most countries on the planet, it is the only viable substitute for fossil fuels and thus for mitigating GHG emissions.

3 Long-Term Prospects of Renewable Energy in Tunisia

Like many other countries, Tunisia has large wind resources that can be tapped for wind power, and it shares with its North African neighbors unique solar radiation conditions for concentrating solar power generation. In the remainder of the paper, we will focus on two utility-scale renewable energy technologies and discuss what it would take to deploy large-scale solar power generation and wind energy in Tunisia.

3.1 Wind Power Generation in Tunisia

Wind power generation is one of the most competitive modern renewable energy technologies. The past two decades have seen exponential growth of the industry as well as the installed capacities, as figure 5 indicates. However, this growth has taken place in only a small number of countries, mainly those in Europe and North America as well as India and China.

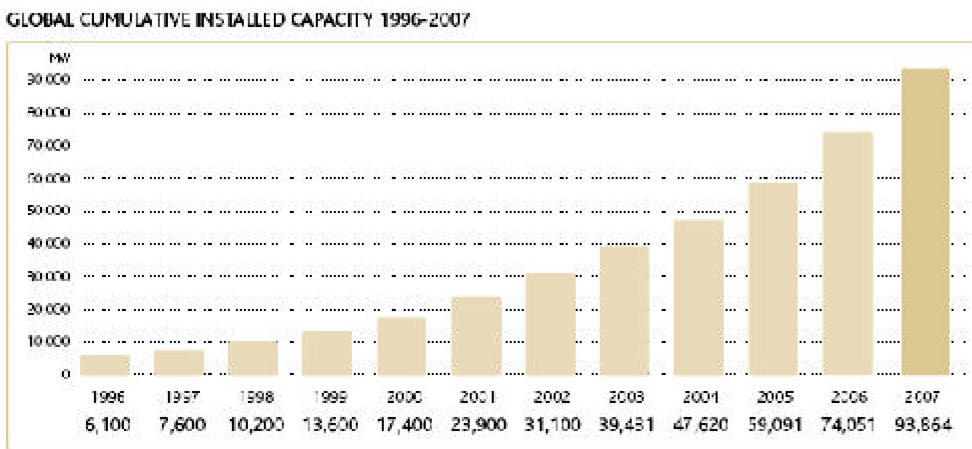

Figure 5. Worldwide Installed Capacities of Wind Power
Source: GWEC 2008

The total potential for wind power in Tunisia is large, although no reliable estimates are available. According to assessments made for or by ANME, the natural potential for wind power in Tunisia would suffice for 1,000 MW. But this figure is not based on actual wind measurements. More detailed measurements indicate that the total potential in the country is far higher than the 1,000 MW estimate. For illustration, 1,000 MW is less than Italy's additional wind power installations during 2008 alone.

The costs of wind power have come down over the past years. For the sake of this study, we assume that in Tunisia, wind capacity can be built on average at a cost per kWh of U.S.$.08 in 2009, and that this will come down further to U.S.$.05 in 2020 and U.S.$.04 in 2025.

3.2 Concentrating Solar Power Generation in Tunisia

Most spots in Tunisia enjoy between 2,700 and 3,600 hours of sunshine per year. Annual irradiation is around 2,000 kWh/m²a. Two of the world's most vibrant photovoltaic (PV) markets darken in comparison: Solar radiation reaches only 1,700 kWh/m²a in southern Spain and only 1,000 kWh/m²a in southern Germany (OME 2007).

In concentrating solar power (CSP) technology, optical devices (e.g., mirrors, lenses) focus the sunlight on receptor devices (e.g., tubes) so that a heater fluid is heated to high temperatures (between 130°C and 1,000°C, depending on the optical technology and overall efficiency of the system) and can be used to produce electricity in steam turbines. Per square meter of solar optical array ("solar field") of the most established such technology (parabolic trough), about 2,400 kWh of electricity could be generated with this technology per year in Tunisia, without any GHG emissions (MED-CSP 2005).

The technology has been tested on a utility scale since the early 1990s but because of high generation costs and low oil prices, no follow-up investments have been made. Only in the past couple of years has this technology experienced a second round of commercial-scale investments, mostly in Spain and the United States, with favorable sun regimes and support schemes. For example, in the past three years in the United States alone, 70 MW have been built, and by 2011, more than 1,300 MW more are scheduled to come online (Morse 2009, parabolic trough only). In Spain, 1,100 MW are under construction. In Morocco, Egypt, and Algeria, construction contracts for 20–30MW plants have been awarded.

In 2005, the German Aerospace Center (DLR) upon request of the Club of Rome, produced a study analyzing the CSP potential of all Mediterranean countries and identifying what share of their energy needs could be satisfied by CSP (MED-CSP 2005). For Tunisia, they estimate that in 2050, 9,250 terrawatt-hours (TWh) of electricity (i.e., Tunisia's total electricity consumption of 2006 times 1,000) could be cost-competitively supplied by CSP as the technology becomes commercialized and then ubiquitous. Analysts' opinions differ on how long it will take for CSP to become economically competitive; some say as few as 5 years (MED-CSP 2005) and others as many as 10 to 25 years (World Bank/GEF 2006).[6]

The speed of global cost reduction depends roughly on the experience gained in the industry on a global scale as well as the opportunity to leverage economies of scale in production and operation. Theory predicts that costs for technology will go down smoothly with the increase of capacity deployed, but a number of factors can disturb this development, including industry-side bottlenecks (such as insufficient manufacturing capacity and difficulties in financing or supply chain management) or a loss of confidence in the technology that leads to a breakdown of demand. For the sake of this study, we will assume the following: For today's prices, we assume that Sarrasin (2006), who wrote that the CSP plants "currently" (i.e., 2006) under construction could achieve unit costs of €.16/kWh (U.S.$.20/kWh), is correct. For comparison: The Spanish feed-in tariff, under which most of the current construction projects are supported, is €.25/kWh. Molenbroek (2008) assumed €17.9/kWh. Sarasin (2006) assumed that within five years, 40% investment cost reduction could be achieved, leading to around €.10/kWh (U.S.$.13/kWh in 2011), but he significantly overestimated the ramp-up speed of the current construction boom. Thus, we will (arbitrarily) assume that this reduction will take nine years rather than five, resulting in €.10/kWh (U.S.$.13/kWh) in 2015. Continuing that trend of 40% in nine years would take us down to €.06/kWh in 2024—a rate that most of the published studies support (Annex 1). Molenbroek (2008) took a different wild guess and estimated that in 2026, a CSP plant in southern Spain will have a unit generation cost of €.075/kWh (U.S.$.096/kWh), which might be an upper limit for Tunisia, with better solar irradiation. Therefore, for the sake of this study, we could place our guess at around €.07/kWh (U.S.$.09/kWh) in 2025. This would be rather close to parity with natural gas (if one assumes some rate of increase in the price of imported natural gas in line with historic experiences; figure 6).

[6] For a comparison of a number of studies, see Annex 1.

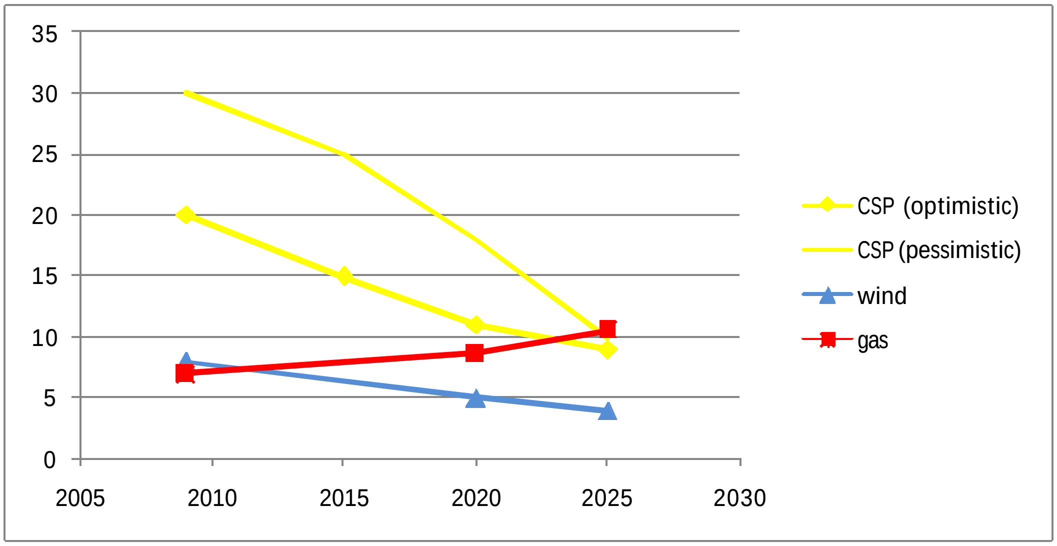

Figure 6. Potential Cost Development for CSP, Wind Power, and Natural Gas (Power Generation Cost in U.S.$cts/kWh) Source: see Annex 1

Figure 6 summarizes the cost assumptions that we arrived at for wind, CSP, and gas-based electricity generation. For natural gas, we started at today's costs of generation and escalated them by 2% per year as global energy prices rise. Wind power and CSP follow the assumptions described above. As soon as the price of carbon emissions is factored in, however, the cost of electricity from natural gas and other fossil fuels is higher than shown in figure 6. Even today, a CSP plant in Tunisia would qualify for the Clean Development Mechanism (CDM), and this has not been factored into the specific electricity costs in this comparison. Accordingly, the time of achieving grid or marginal cost parity will be reached earlier than in the analyses found in the literature.

4 Two Different Renewable Energy Futures for Tunisia

4.1 Tunisia's Official Plans with Renewable Energy

Tunisia's Initial National Communication (INC) of 2001 to the UNFCCC presented some abatement options with renewable energies (table 2) but allocated minimal roles for renewable energy: Wind energy is expected to save 130 kilotonnes of oil equivalent (ktoe) in 2010, PV 7 ktoe, microhydro 4 ktoe, charcoal management 9 ktoe, and the utilization of biogas 170 ktoe of fossil fuels.[7] As table 2 clarifies, this equals around 2.5% of the expected PES necessary in the long run. In terms of CO2 emissions, this would avoid fewer than 800,000 tonnes in 2010 and slightly more than 1 million tonnes in 2010.[8]

Tunisia is looking at renewable power mainly as an option to supply small, isolated rural consumers. The government has promoted retail technologies, including solar water heaters, rural electrification with solar photovoltaic, house hold-scale biogas digesters, improved wood-burning technologies, and wind power for water pumping. The promotion of solar water heaters was overall quite successful with 57,000 m² of solar collectors installed by 2006.

The government is not considering renewable energy as a serious alternative for the country's main power supply, in spite of the fact that electricity is the largest consumer of primary energy and the largest single source of CO_2 emissions. As of 2007 only 20 MW of wind power was installed. STEG, the national utility, is skeptical with respect to the influence wind power has on its power grid.

Table 2. Potential for Energy Savings by Using Renewable Energy for 2010 and 2020 According to the Initial National Communication to the UNFCCC, 2001

Source: INC 2001

		2010	2020	cumulative 2001 - 2020
wind energy for power production	**ktoe**	129	258	2710
solar photovoltaics	**ktoe**	7	7	107
micro-hydro	**ktoe**	4	4	56
charcoal efficiency strategy	**ktoe**	9	10	145
biogas	**ktoe**	170	229	2883
total	**ktoe**	319	508	5851
total PES	**ktoe**	13224	20265	
total renewables as share of total PES	**%**	2.4%	2.5%	
expected CO2 emissions from energy	**kt CO2eq**	31636	48993	
avoided CO2 emissions through renewables	**kt CO2eq**	782	1260	14509

Luckily, as described in the first section of this paper, reality has already overtaken the plans as described in the INC, in terms of both energy efficiency and renewable energy. The 11th Four-Year Plan assumes savings in terms of primary fossil fuels of around 3.2 Mtoe (World Bank 2009). It also envisages a share of 4% of PES to be covered from renewable energies. A large program to

[7] The INC does not specify the expected installation figures.

[8] Still, the INC ends on the optimistic note that with the 33 measures discussed, the emissions in 2020 from the energy sector would not be 49 Mt CO_2 as projected in the reference case but 36 Mt CO_2, a reduction of 27%.

promote solar water heaters has been put in place, with an overall target of 740,000 m² in 2011 (ANME 2008b). The economic development plan (2008–2011) specifies for wind that on top of STEG's 20 MW park at Sidi Daoud, another 55 MW should be added at Sidi Daoud, plus another 60 MW of captive generation with energy-intensive industries. Currently, STEG is also preparing a new wind site at Bizerte with the expectation of adding another 120 MW there. A capacity-building program for wind energy is expected to develop a wind atlas.

In light of these trends, table 3 is probably similar to what the government could expect on the basis of today's level of activity. However, no official plans exist to expand wind power on a large scale beyond these 255 MW, and for biomass and solar electricity, no additional activities are specified on ANME's website.

Table 3. Potential Business-As-Usual Development
Source: ANME 2004, own calculations

	2010	2020	2030
MW onshore	280	800	1840
MW offshore	30.00	330	700
total MW	310.00	1130.00	2540.00
wind power production in TWh/a		2.80	4.60
avoided CO2 emissions in Mt/a		1.50	2.80
cumulative CO2 avoided in Mt	2	13	37
savings in primary energy in ktoe	500	1700	2800
cumulative investment in MUSD(2000)	226	671	2104

4.2 An Alternative: Renewable Energy Reliance Scenario

Alternatively, Tunisia could start on an ambitious deployment path for renewable energy. The underlying assumptions for such a path were described in chapter 3. The path consists of a systematic deployment of wind power and CSP until 2030, with the goal of ultimately replacing all fossil generation with renewable generation.

Tunisia has a track record of keeping its energy consumption per unit GDP on a stagnant level, but overall this means still rising energy consumption in times of economic growth. In addition, Tunisia has been increasing its electricity consumption as a share of total energy consumption. Therefore, we have two different growth scenarios in mind when looking at Tunisia's future energy needs, a low and a high scenario (table 4); both allow room for growth. The high scenario assumes that Tunisia keeps doubling its electricity consumption every 10 years as it has done between 1995 and 2005. This is a very unlikely and worst-case scenario. A more likely scenario is that power production would keep rising by only 4%, which tracks the increase in the years since 2000. The low scenario roughly doubles Tunisia's electricity consumption by 2020 and triples it by 2030. This would indicate a continuation of the existing trends in the consumption sectors and the energy-efficiency efforts of the government. In this case, total power demand in 2030 would be 38 TWh. Thus, 85 TWh of electricity are needed in 2030, and the two types of renewables would be able to cover 33% of the electricity demand. To cover significant amounts of this electricity consumption, we propose that in 2020 6 TWh and in 2030 28 TWh shall be produced from renewable energy, which would be between 33% and 75% of the demand in 2030.

Table 4. Renewable Energy Generation Scenario for the Tunisian Power Sector

REG Scenario	**2010**	**2020**	**2030**
total MW	175	2200	11000
renewable power production in TWh/a	0	6	28
total power production in TWh (low)	17	25	38
total power production in TWh (high)	21	42	85

Theoretically and disregarding the technical feasibility of that scenario, about 5,600 MW of wind turbines would suffice to cover the current nationwide power consumption of 14 TWh (as of 2007), assuming a mediocre average wind resource of 2,500 full load hours[9] per year. Table 5 shows a potential deployment path for this. It is only slightly more ambitious than table 3 until 2020, but of course continues on a systematic expansion path after that.

Table 5. Wind Power Scenario

scenario wind power focus	**2010**	**2020**	**2030**
total MW	175	2000	8000
wind power production in TWh/a		5.00	20.00
avoided CO2 emissions in Mt/a		2.89	11.54
cumulative CO2 avoided in Mt	2	15	83

This scenario provides for electricity from wind power that is similar in order to all of Tunisia's electricity consumption. It is clear that there are technical and other obstacles to the integration of such a large share of fluctuating power generation. On the other hand, this is a scenario for a long-distant future, and technologies, prices, and electricity systems in general will have changed by then. This scenario is not technically implausible just because today's electricity systems cannot absorb so much wind.

Wind power will become cost-effective in a couple of years while CSP will reach grid parity only after 2020. For the sake of this study, we will therefore assume a cautious expansion path for CSP, listed in detail in table 6. It should be noted that deployment of the first plant in this scenario does not wait until CSP is the least-cost technology. Instead, Tunisia would build its first 30 MW of CSP generation capacity in the year 2015 in order to gain some experience. Moving early on CSP and building a prespecified number of plants at regular intervals would allow Tunisia to occupy a strategic niche and thus leverage local advantages other than reduced pollution. Tunisia would build up local knowledge and competence for a technology that will be widespread throughout the Middle East and North Africa (MENA) region and the African continent as well as many other sun-rich countries. In this case, Tunisia might want to invest in one such power plant every three years. This will be associated with incremental costs (see chapter 5). On the other hand, by then all its neighbors will already have CSP power plants in operation, and Tunisia would be the laggard in the region. The first couple of plants are considered "teaching plants" that help develop local capacities. As illustrated in figure 7, the deployment of CSP in Tunisia will trickle at a rate of 30 MW per year until 2019, and then have annual additions gradually increase to around 300 MW in 2023 and every year through 2030. This is an idealized path; it might be more cost-effective to add larger chunks of capacity at once, but this serves as an average scenario for illustration purposes.

[9] STEG assumes 2,500 full load hours for its expansion of the park at Sidi Daoud in the CDM Project Idea Note (NIP 2007b)—a number that should be influenced by the performance of the existing plant. On the other hand, other sources assume around 3,500 full load hours on Cap Bon, and attribute the same quality to a number of other sites in Tunisia (UNDP 2007).

Table 6. CSP Deployment Scenario

scenario CSP	**2010**	**2020**	**2030**
total MW	0	200	3000
solar power production in TWh/a		0.54	8.10
avoided CO2 emissions in Mt/a		0.31	4.67
cumulative CO2 avoided in Mt		1	27

The synopsis for capacity additions of both technologies is given in table 4.

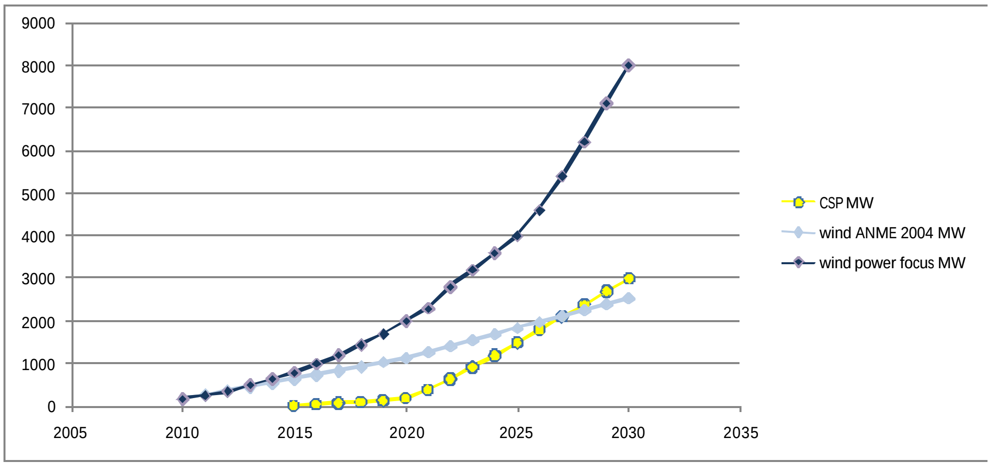

Figure 5. Potential Deployment Scenarios for Wind and CSP in Tunisia, our estimates.

The targets of the renewable power scenario in table 6 look feasible, particularly if compared with the typical size of wind power portfolios in a larger country. The wind power capacity proposed for Tunisia for 2030 is only 5% of the current wind capacity installed in Germany today and 10% of the wind energy produced. The state of Lower Saxony with smaller area and a short coastline already has 6,000 MW of wind installed. To produce power equal to the current consumption in Tunisia of 14 TWh (as of 2007), and assuming a mediocre average wind resource of 2,500 full load hours per year, about 5,600 MW of wind turbines, or around 25% of the currently installed capacity in Germany, would be necessary.[10]

Together, the two technologies can cover a significant share of Tunisia's overall electricity generation. In fact, if domestic electricity consumption does not rise as fast as we have implied in the scenario, a complete coverage of domestic electricity demand plus some export of renewable power seems possible, although the technical side of this poses some questions that have not been solved as of today.

Obviously, none of this deployment will happen without an ambitious program to promote these two technologies, demanding concentrated efforts from both industry and government. With international help, many activities need to be undertaken in order to provide the grounds for this scenario to come true, as both technologies are hampered today by significant nonfinancial barriers to their adoption, on top of high costs. To reach these scenarios, these barriers need to be removed, and this is where UNFCCC mechanisms for mitigation and technology transfer need to provide the help necessary.

[10] Of course, there are some technical aspects, in particular with intermittency issues, that imply that this type of calculation is only theoretical in nature at the current stage of storage technology development.

To identify these barriers and the possible means of their removal, we will develop a barrier analysis framework that will then help us to categorize and systematize the barriers for each of the two technologies. We will then discuss what activities are necessary and how an international climate financing mechanism can help best.

5 What does it take?

5.1 What are the barriers to large-scale renewable energy deployment?

For the large-scale deployment of renewable energy technologies in Tunisia, a number of barriers have to be removed. They vary from technology to technology, depending on the stage of commercialization of the respective technologies. A close-to-commercial technology such as wind power faces a different set of barriers, in terms of policy frameworks, access to information, and access to technology and financing, than does a technology such as CSP that is not yet supplied by a large industry or commercially tested on a wide scale.

Barriers for the widespread use of a new technology can be divided into technology-specific barriers—arising from the fact that the market for these technologies is a global market in a stage of rapid growth—and country-specific barriers. Though the latter can be found in all countries in varying degrees, abatement of these barriers requires country-specific action. Among these are barriers that affect all renewable energies and CSP- or wind-specific ones. For this analysis, they can be grouped in the following categories:

1. information and awareness barriers among would-be customers of the technology;
2. policy frameworks, including technical standards, grid codes, intellectual property rights (IPR), safety, and other enabling factors;
3. limits to the availability of financing, in particular from local sources;
4. lack of access to the actual technology;
5. lack of local operation and maintenance (O&M) capacity; and
6. shortcomings of technical infrastructure.

To remove these barriers, a large number of different measures are necessary. They range from capacity-building measures to financial measures including support from international financial institutions (IFIs); from the implementation of policy frameworks to the facilitation of local credit and equity financing and advanced financing schemes; and from foreign direct investment (FDI) to transfer of nonfinancial assets such as hardware and intellectual property. They can be delivered via intergovernmental mechanisms on the United Nations/IFI level, or bilateral cooperation. They are typically more effective when they are well coordinated by the host country.

Sometimes barrier removal activities are more effective if groups of countries or regions join forces and use a coordinated approach. One example is a necessary buildup of industrial capacities for manufacturing renewable energy equipment. Here, renewable energy technology companies would invest in manufacturing capacities in a region, if they see a guaranteed market size. The required market size is often too large for any single country to guarantee. In addition, for single-country markets, political risk is higher than for regions, which can deter investors. Regional markets are more attractive. Economies of scale apply to other types of barriers as well. In the area of energy-efficiency standards for appliances, for example, manufacturers would find a global top-runner model with the same global energy-efficiency standards easier to deal with than fragmented national standards. In the following, we discuss these barriers and the appropriate removal activities for both wind and CSP.

5.2 Barrier Removal for Concentrating Solar Power

5.2.1 Barrier Group 1: Lack of information and awareness of the potential of the renewable energy technologies

A three-year study (ANME 2004) conducted a barrier analysis for the introduction of renewable energies to Tunisia. At that time, the main problems the authors found regarding renewables were related to their very nature of being uneven over time, low energy density, lack of storability, and insufficient research. This perception indicates a very important image-related barrier for the deployment of renewable energy technologies: renewable energy technologies are perceived as difficult to manage, potentially unreliable, technologically immature, and so on. That this perception is wrong is demonstrated by the increasing share of global electricity generation coming from renewables. Government commitment is a prerequisite for further action and in turn requires heightened awareness for the potential of renewable energies. Typically, it is necessary to remove this perception-related barrier with all major players, including the utilities and the financial sector. Local champions are crucial for a long-term renewables effort.

Studies and public discussion of local potential, resources, etc.: The barrier can be most effectively removed through more information on the scientific level, but also more exposure of decision makers to real-life examples of "renewables at work" and trends in other countries. Awareness can be raised through studies, conferences, and international exchange. A large number of studies and scientific advice are typically necessary to raise confidence levels.

To take meaningful action, and even to commit to meaningful targets, stakeholders need good information about renewable (solar, wind, biomass) resources. Over the past 10 years, this information has been made available for most countries, and if it does not exist, it can be derived by institutions such as Riso (National Laboratory for Sustainable Energy Denmark) or the National Renewable Energy Laboratory or through the UNEP SWERA program in short time and very cost-effectively.

In total, the overall financial scale of all these measures of creating awareness and an information base for decision makers in a country such as Tunisia and regarding one technology, such as CSP, has in the past typically not exceeded U.S.$30,000 per year.

Building up local champions: Already, regional efforts to increase the awareness for the potential of renewable energies are under way. In the context of the large global International Conference for Renewable Energies 2004, a series of regional conferences for renewables in the Mediterranean region, the MENA Renewable Energy Conferences, have been a regular platform for exchange between Europe and the MENA region on their experiences with renewable energy. Once a year, the most important experts of the region met to discuss lessons and experiences from the deployment of renewable energies and the respective national strategies. The respective host governments took great pride in hosting the conferences, and the high-level attention in the host countries facilitated conference declarations of increasing commitment to the deployment of renewable energies.

The role of local champions in spreading awareness and trust in the potential of local resources cannot be underestimated. To strengthen local champions, the international efforts toward clean energy need to include incentives such as conferences, conventions, awards, training, and teaching opportunities.

Pilot plants: A second way of abating this barrier is through reference plants and pilot and demonstration projects. Pilot plants and demonstration programs have been implemented in Tunisia in the field of solar water heaters, but there is no test plant for CSP yet. The closest CSP projects to Tunisia are the projects in Spain, Morocco, and Egypt. Trips to these plants, supported by an overall discussion of the host countries' policy framework and approaches to supporting domestic renewable energy capacity, can be very effective in increasing awareness with decision makers and creating local champions. But stakeholders from non-Annex 1 countries insist that having a demonstration at home is in fact the most effective way to create local awareness. Also, the utility and the wider local engineering community learn how to deal with the technical characteristics of the plant and all aspects of the technology, and the broad public can become sensitive to energy issues.

Local demonstration plants affect not only the first group of barriers ("information and awareness") but are also crucial for barrier group 2 (e.g., in the realm of technical standards and grid codes), barrier group 4, and barrier group 5. Depending on the size and scale of the technology, however, they are very expensive. Global Environment Facility (GEF) grants for a CSP plant were about U.S.$50 million. These covered only parts of the cost of the solar field, not the steam turbine and grid connection cost. In total, such a plant today costs U.S.$100 to $150 million. Furthermore, a pilot plant makes sense only if it is part of a consistent and credible country-wide strategy for systematic deployment of the technology, for which awareness on the part of decision makers is a precondition. A stepwise approach of awareness-raising and the correct timing for the demonstration plant are crucial for its effectiveness as a barrier removal activity.

5.2.2 Barrier Group 2: Lack of amenable policy frameworks, including technical standards, grid codes, and other enabling factors

The question of policy frameworks is hard to separate from the question of the financial support scheme. In this analysis, we consider the financial aspects—in particular, the question of incremental investment costs—as part of barrier group 3 ("availability of financing"). Nevertheless, policy frameworks influence the availability of financing: typically it becomes easier the more stable and credible the policy framework is, particularly in the long run. Generally, barrier removal for renewable energy is necessary in more than one area: energy policy targets and sector policies, overall investment conditions, and technical aspects of infrastructure codes and performance standards need to be clear and transparent as well as in favor of integrating renewables into the energy system.

Energy policy and deployment targets: Often, the overarching objective for the energy policy is the affordability of energy supply, that is, low consumer prices. In many countries, overshooting has led to a situation in which sclerotic subsidy systems restrict the ability of the policy makers to introduce any kind of changes to the system. For example, in Tunisia, energy subsidies are reaching heights at which they become problematic for the public budget, and there are few ways out of this dilemma but to raise power tariffs, which is a very unpopular measure and can harm the poorest parts of the population. Therefore, the first principles need to be fixed before energy policy can really stop being a budgetary black hole and start being an active field of sustainability policy, and part of the solution is to provide clarity regarding the actual motivation of energy policy and remove unsustainable subsidization policies, particularly if they put in place perverse incentives.

Adding to the mix a technology that is supposedly more expensive than the fossil fuel conventional alternative needs a good justification in this context. Climate awareness is one, but in most cases, renewables could also justify earning a premium: renewables add resilience to a power system through increasing independence of imports and local self-reliance. In addition, most of the time the impact of small amounts of new renewables on consumers' bills is overestimated in the public debate.

An overall renewables target is the first step for a favorable policy framework. The public declaration of renewable energy deployment targets seems a merely political act, but it has a strong signaling effect, and has the character of a publicly binding commitment that can compromise a government's credibility if not adhered to. Tunisia, as described above, has a comparatively good history of formulating targets and implementing measures for reaching them. Thus, first of all, commitment to renewable energy needs to find its way into the official mission statements of energy ministries and governments. This barrier is not associated with incremental costs and hardly influenced by a potential international financing mechanism.

Effective power sector framework: In terms of implementation, there are different ways to facilitate renewable energy deployment depending on the institutional structure of the power sector. In Tunisia, the vertically integrated national utility STEG could be a natural investor in CSP, as most generation capacity is owned by STEG. Alternatively, independent power producer (IPP) frameworks can be used for deploying specific technologies. This is more involved, as the IPPs need to be given certainty on the pricing and amounts of electricity that they want to sell. Often, this is not necessarily the least-cost way to integrate a new technology into the existing power system in terms of cost per kWh. The argument brought forward in favor of specialized IPPs is that they are more flexible than public utilities in their investment activities, and in the buildup and application of specialized technical expertise.

The policy framework needs to be different, depending on who is expected to build the renewable capacity. If the national utility is expected to build the renewable energy capacity, a simple order to do so is sufficient. If the private sector is expected to install renewable energy IPPs, more emphasis has to be put on how to make renewables an attractive investment.

The overall investment conditions are affected by factors such as taxes, construction and other permitting processes, registering property, regulations for employing workers, conditions for getting loans, and trading across borders. The World Bank and some private rating agencies give Tunisia excellent grades in this respect. Tunisia is able to attract large amounts of FDI, which is a good indicator of a sound investment environment. On the other hand, if this were not the case, it would be hard to influence these larger governance parameters through a financial mechanism under the UNFCCC, and the associated costs would not be additional in the sense of the UNFCCC.

Technical standards and grid codes: Setting technical standards can be done on a national basis and supported from international sources with funding for studies and the development of regulations. A more efficient way can be to adopt international or regional cooperation with the goal of common standards. To do this, transnational organizations and agreements such as the European Union, North American Free Trade Agreement, Asia-Pacific Economic Cooperation, and African Regional Organization for Standardization have common organizations and platforms for resolving standardization issues. The International Organization for Standardization and World Trade Organization could also play a role in this effort. The overall costs of this barrier removal activity are small and comparable to the need for additional studies under barrier group 1.

5.2.3 Barrier Group 3: Lack of availability of financing, particularly from local sources

Financing for renewable energy investments typically encounters three problems:

- In comparison with traditional energy generation, the cost per kWh is often higher.
- Compared with traditional fuel-consuming energy generation units, the cash flow is asymmetric, as almost all the costs are upfront investment. This makes investments less appealing and more risky.
- Investors and banks are unfamiliar with the technology and therefore perceive these investments as riskier than conventional investments. Risk and perceived risk will result in higher cost of capital.

For each of these barriers, different abatement options are available.

But first of all, Tunisia should start avoiding artificially increasing the cost of a technology that it wants to install locally, and stop subsidizing other forms of electricity. For example, putting import taxes on hardware that must be imported for building the CSP plant is not a good idea if it has to be compensated with higher expenses from the public budget or from rate payers' pockets. A global mechanism could supply a checklist for artificial barriers like these but not offer funding for their removal.

Two ways of dealing with the higher per kWh costs of the new technology are possible: pay higher prices, or wait until costs come down. The first option is appropriate for developed or Annex I countries, but can also be useful for non-Annex I countries, particularly if they want to gain a technological headstart in a technology like CSP. Under the cost assumptions for CSP made above, and under the assumption that today the generation of a "conventional" kWh in Tunisia costs around U.S.$.07, and that this price rises by 2% per year, grid parity will be reached in 2024. Until then, costs per kWh of CSP are higher than the average kWh "from the grid."

Under the cost assumptions for CSP and gas specified above and the assumptions that 1 kWh of gas-based grid power in Tunisia in 2009 costs U.S.$.07, the incremental cost in the first year of CSP deployment (i.e., 2015) would be U.S.$4.5 million. Under optimistic cost assumptions for CSP, the annual subsidy for the proposed expansion path would rise every year and level out at around U.S.$40 million per year in 2024. After that, when grid parity is reached, the incremental costs would turn into incremental benefits. The total discounted net present value of this subsidy in 2015 is around U.S.$150 million of "subsidy cash flow" until 2030.

Figure 8 demonstrates, however, how sensitive this assessment is with respect to the cost assumptions for the CSP development. If our pessimistic assumptions hold, grid parity will be reached only in 2029, and incremental costs will pile up. In this case, the expansion path should be optimized for reducing incremental costs. Even so, none of these assessments includes the price of carbon in the analysis; the price of carbon (through certified emission reduction [CER] or emissions trading or any other kind of scheme) should be deducted from these costs, as the basis for calculating the increment is gas-based power generation.

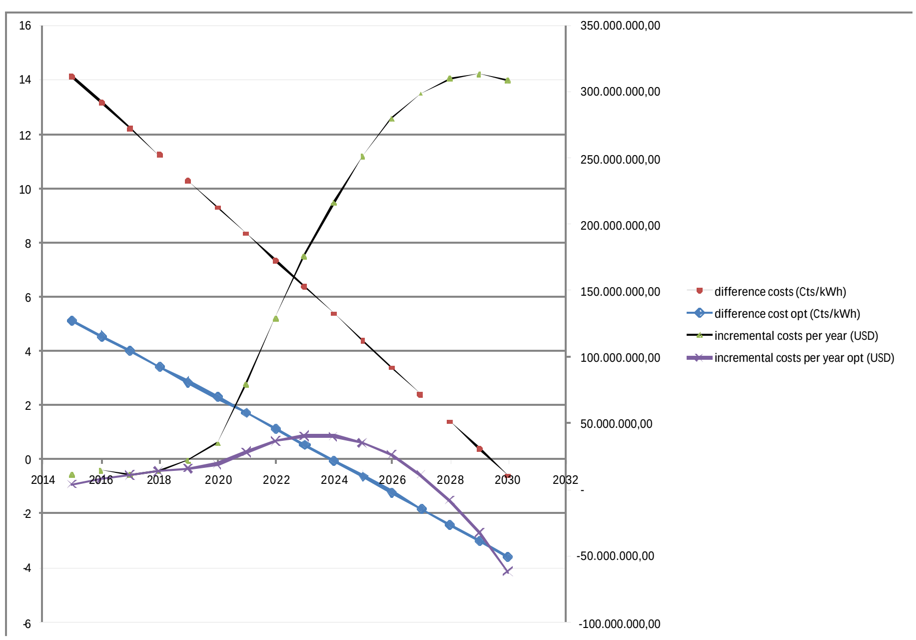

Figure 6. Incremental Costs of Proposed CSP Path under Optimistic and Pessimistic Cost Assumptions. See Annex 1.

Governments or donors can compensate investors for higher initial investment costs, most prominently through feed-in tariffs, investment subsidies, or tax breaks. That is, the incremental costs would come from the government budget, potentially compensated for from a global financial mechanism and/or carbon revenues. It is good practice to design subsidies along the lines of output, as investment cost buy-downs do not incentivize efficient use of the technology, but do incentivize the purchase of the equipment. Therefore, they should not be used for a larger market roll-out or a large number of CSP plants. Here, output-based compensation mechanisms should be used. For example, fixed feed-in tariffs or tradable green certificates (an option that has been discussed in Tunisia for the deployment of renewable electricity generation) are measures to allow for incremental generation costs per kWh while at the same time get some control over these costs. Plus, in these two systems, the government budget does not need to be involved, but a more flexible system through the private sector can be used. In particular a feed-in tariff regime can be managed such that the industry understands the need to drive down costs and can strive to achieve the necessary cost reductions. Experience[11] has shown that in order for these output-based systems to work and effectively unleash investment activity, funds must be available on a continuous basis.

Alternatively, Tunisia could also wait to support CSP until 2025 when the cost will have come down to market-compatible prices and CSP will have reached marginal-cost parity. In this case, no incremental costs are incurred. Then, Tunisia will depend on the technical capacity and knowledge of its neighbors who by then will be experienced users of CSP.

Financial tools that mitigate the cash flow uncertainty: The second financing problem was the asymmetry in cash flow. In CSP, like most renewable energy technologies, almost all costs are incurred in the form of upfront capital expenditure, rather than fuel costs, so that variable costs are low. This asymmetry can be mitigated with lending or leasing mechanisms. This does not add incremental costs, as the calculation above already accounts for this phenomenon.[12]

Access to commercial finance: Third, a financier needs to have confidence in the investor, the proposal, and the technology. This learning process can be accelerated with some financial support or participation of foreign (private sector) lenders in financing the initial projects. Foreign investors will come to Tunisia, if the conditions for an investment there are better than in their home country. There are too many variables influencing this comparison to put a value on it. An international finance mechanism can help guide this process in very cost-effective ways, such as by supporting credit guarantee schemes.

5.2.4 Barrier Group 4: Supply-side issues and inherent limitations of the technology

The fourth group of barriers to large-scale CSP deployment in Tunisia are barriers specific to the technology and its usefulness. These affect all countries to the same degree. Currently, limitations for the use of this technology on the supply side are as follows:

- Limited usability as it depends on the local geographic factors such as the solar resource or the availability of large land areas; and
- Limited availability as a result of a small industrial base and restrictive IPR regime.

Some experts include in the list of technology-side barriers the fact that the sun shines only during the day. This study assumes that as CSP becomes closer to commercial, efficient heat storage

[11] For example, a comparison of the feed-in tariffs in Germany with the feed-in tariffs in Spain.

[12] It uses an interest rate of 5% which is a rate at which government agencies such as STEG or KfW can borrow money through bonds.

will be developed that helps produce electricity also at night and on schedule. Also, many countries with an abundant solar resource incur a day peak of electricity consumption, caused by the use of air conditioning, so that the production of solar power during the hottest hours of the day might be appropriate.

Availab ility of the technology: There are only a small number of specialized components (absorber tubes, parabolic troughs) in CSP. However, these specialized components are produced by only a small number of companies worldwide, and because for a long time no new plants have been built, these companies were small and undercapitalized until recently. The industry has changed significantly in capitalization over the past couple of years, through mergers and acquisitions and joint ventures with large companies as well as through initial public offerings. It has been able to serve a number of parallel requests for proposals and bidding processes and currently a dozen or so plants are being built simultaneously. The boom of utility-scale CSP in the United States and Spain has certainly given a boost to the development of the industry. Nevertheless, the global demand for CSP is high, and it is questionable that Tunisia is the main focus of the industry. To change this, Tunisia could concentrate on attracting production facilities for CSP components as part of its industrial development strategy, which would not imply incremental costs caused by climate commitments but rather promise a new economic development direction and thus "incremental benefits." Industry can advise on the minimum market size for creating more local capacity up to manufacturing some parts of the hardware locally.

On the other hand, the history of the more established technologies, wind and solar PV, has demonstrated that specific bottlenecks can occur in sequence; for example, the first bottleneck can be wind generators, the second bottleneck wind blades, the third bottleneck construction cranes, the fourth bottleneck steel or cement, and so on. The increased demand for the technology throughout many developing and developed countries will always constitute a threat to local availability of components. Here, a global financial mechanism under the UNFCCC could intervene not on a national but on a regional or global basis. A role model for this could be the Global Market Initiative for CSP (Global Market Initiative 2004), which tried among other things to harmonize investment plans between utilities interested in CSP and the industry providing the CSP components and plants. Through dialogue, investment certainty for both sides can be provided and investments in power plants as well as production capacity for power plant components can be better scheduled. The incremental cost of such a global effort can be on the scale of U.S.$100,000 per year, working through participatory processes and stakeholder consultations with governments and industry facilitated, for example, by an international institution.

5.2.5 Barrier Group 5: Lack of local operation and maintenance capacity

Training of local technicians: Typically, when a new technology is introduced to a country, very few people know how to deal with it. To ensure the functioning of the technology, local technicians need to be trained. Though this is very important for retail technologies such as solar home systems or energy-efficient refrigerators, this is a minor problem for utility-scale CSP. The local utility as well as the local operator will have to be trained, but similar and related costs have been incurred as part of the awareness-raising activities and the overall investment activities. Overall costs for training local support staff and building this type of technical capacity should be less than U.S.$70,000. It is questionable whether these costs would be incremental or part of normal education efforts. In fact, some regions offer cost compensation for training of local staff as an incentive for attracting foreign investors.

Training of local engineers: However, in order to introduce a new technology in a more consistent and long-term manner, it is highly recommended to introduce national curricula and courses for technicians and engineers, also on university levels. In the past, the best successes have been achieved by doing this in a bilateral or partnership manner. The costs of introducing this can be high for the initial installation (U.S.$100,000–400,000), but will be moderate and nonincremental for operation, as every development effort requires some further expansion and development of the educational system.

5.2.6 Barrier Group 6: Shortcomings of technical infrastructure

In Tunisia, infrastructure is very well developed. The population is concentrated along the coast, and roads as well as power lines reach the majority of the population. CSP plants require large swaths of land and access to water. The electricity then needs to be transmitted to the load centers for which power lines would have to be built (see figure 9). This is not an unprecedented effort for large power plants. For example, the hydropower schemes along the Nile in Egypt have provoked the construction of a system of 500 kilovolt (kV) power lines. But it constitutes an additional expense and an investment on the side of the grid owner/operator. The cost of a kilometer of 380 kV transmission line in Germany is estimated to be about €1 million. In the Tunisian desert, it should be lower. Assuming the costs were only 40% of what they are in Germany, this can still result in significant incremental investment costs of several tens of millions of dollars, depending on the distance between the power plant and the nearest grid connection point.

Figure 7. National Electricity Grid of Tunisia
Source: GENI 2008

5.3 Summary of Barriers, Barrier Removal Activities, and Incremental Costs of Deploying CSP Technology in Tunisia

Table 7 gives an overview of the barriers, barrier removal activities, and cost implications discussed above. As the above discussion shows, for the different types of barriers, different types of removal activities exist. Two different levels of activity with two different sets of cost implications are necessary:

- Capacity-building efforts abate the lack of soft factors such as information, awareness, and know-how. Partnership programs, studies, and education programs can be helpful here. Limited amounts of money are required. Overall in Tunisia, one could not meaningfully spend more than U.S.$300,000 per year for the case of CSP technology.
- Actual investment in pilot and demonstration plants: Here, large sums of money are required, particularly for the first CSP demonstration plant.

- Additional finances will be necessary to help access not only the existing infrastructure but potentially also incremental cost coverage for infrastructure investments that were not otherwise necessary.

For both investment needs, the actual costs are hard to estimate ahead of time. More or less, the numbers in table 7 are dummies, for lack of a better estimate.

Table 7. Barrier Groups and Barrier Removal Activities for CSP (our estimates)

		per year	for how many years?	cumulative need for financing until 2020	remarks
Barrier Group 1: Information and Awareness					
	Studies of local potential, technical aspects, resource map	30,000.00	7	210,000.00	
	Demonstration plant			100,000,000.00	
Barrier Group 2: Policy framework					
	Target setting - sector studies	30,000.00	7	210,000.00	
	Subsidy removal				non-incremental, negative costs
	overall investment conditions				non-incremental, no costs
	technical standards, grid codes	10,000.00	12	120,000.00	non-incremental, some costs
Barrier Group 3: Availability of financing					
	higher costs per kWh	12,000,000.00	5	59,090,708.92 €	more incremental costs after 2020
	lending mechanism				incremental, but included above
	foreign direct investment				non-incremental, no costs
Barrier Group 4: Access to the technology					
	Global Market Development Initiative	100,000.00	5	500,000.00	
Barrier Group 5: Lack of local operation and maintenance capacity					
	technicians	70,000.00	7	490,000.00	non-incremental
	university twinning			400,000.00	not necessarily incremental
Barrier Group 6: Shortcomings of technical infrastructure					
	power and water lines			2,000,000.00	
sum				163,020,708.92	more incremental costs after 2020

6 Wind Power

In Tunisia, the foundations for wind power development have been laid since 2000. In a UNDP/GEF project to promote private sector investment in wind power, STEG, ANME, the government, and some of the large energy-intensive industries have been working together on ways forward for more deployment of wind power. A model for wind IPP and a performance-based subsidy system has been discussed but been discarded (probably after STEG raised real or perceived concerns over the stability of the electricity grid).

Expansion to the scale envisioned by the wind power focus scenario encounters a different set of barriers than does CSP. In particular, the cost barriers will not be as high, but the infrastructural and technical difficulties with integrating intermittent power generation will be higher. All barriers will be discussed in the following section.

6.1 Barrier Group 1: Information and awareness among customers regarding the technology

Resource map: The initial and fundamental barrier to large-scale wind deployment in Tunisia is the fact that the wind resource in the country is not yet well mapped. There seems to be a hunch that the wind resource is excellent, but so far no detailed mapping exercises have been undertaken, and in fact, the total technical potential has never been clearly determined. A capacity-building program by ANME is currently looking into this issue and creating a wind atlas for Tunisia, and a project of the University of Navarra seems to be working on a wind map (OME 2007). If that were not the case, the resource map could be produced in cooperation with international organizations and networks, such as through UNEP's SWERA program, as was suggested for CSP. This mapping exercise is more expensive than for solar, as onsite measurements are required.

Knowledge and awareness: In Tunisia, three potential groups of actors could build wind power plants: STEG, IPPs, and energy-intensive industries. According to a project document by UNDP (UNDP 2007) the IPPs and the energy-intensive industries seem to have significant knowledge about wind power technologies, and have access to the resource and an active interest in investing in wind power. STEG is currently collecting first-hand experiences with wind from its own wind farm, which it has just expanded. More wind power plants are now being built as captive plants for the self-generation of high energy-consuming industries like the cement industry. Though this is laudable and smart, the potential is limited to a fraction of the power consumed by these industries, which is less than 10% of the Tunisian total. The capacity of an international financial mechanism under the UNFCCC to influence local attitudes may be limited and indirect, such as through a combination of institutional strengthening, capacity building, awareness raising, and experts exchange programs. This could be facilitated through partnership programs and staff exchange programs, such as between European and Tunisian utilities and energy ministries. The costs for these programs could be in the range of U.S.$40,000 to 250,000 per year. Bilateral programs seem to be equally or more effective than multilateral programs in this respect.

6.2 Barrier Group 2: Lack of amenable policy frameworks, including technical standards, grid codes, and other enabling factors

Target setting/sector studies: As discussed above, the necessary policy framework is different for investment by a utility than for investment by an IPP. The strongest policy that can be put in place in a country with a vertically integrated power sector like Tunisia is a straight government mandate to the utility. Private investors in the context of an IPP framework can be motivated (only) via a financial stimulus. A number of European project developers and wind turbine manufacturers regularly contact national authorities in the MENA region and discuss investment opportunities with them. If offered attractive framework conditions, they will be able to bring financing, supported by traditional tools of (international) financing (e.g., export banks, development banks, or IFIs). Their engagement depends on the local policy framework conditions.

Whether or not an IPP framework is used is a general policy decision. It should not be mixed with the question of whether or not to support renewable energy. A number of good practices, notably the feed-in tariff, have been identified to stimulate private investment while not allowing excessive rents. The most important aspect is investment security, which private IPPs will require for a rather long time (e.g., 20 years). A lack of investment security prevents private investment. However, the costs attached to investment security are low, in fact potentially negative, and nonincremental.

Subsidy removal, overall investment conditions: Power sector setup, subsidy issues, and investment framework conditions have even more importance than in the case of CSP, as the investment in larger amounts of wind power affects more players sooner than would a demonstration plant in 2015. But as in the case of CSP, no specific and incremental costs are attached to that.

Technical standards, grid codes, etc.: Bigger incremental costs are associated with more technical aspects of the policies, such as grid codes and electricity system analyses that are necessary to maintain grid stability while integrating large amounts of intermittent power. Additional investment needs can arise for reinforcing the grid at later stages (see section 6.6). But even at initial stages, provisions need to be put in place in terms of who bears the costs of grid connections and additional balance power needs, whether wind power feed-in will be prioritized over conventional power feed-in, what levels of grid overload can be tolerated before the wind turbines will have to shut down, what technical standards will apply to wind turbines, and so on. These are more prominent and explicit if the wind power is operated by IPPs, but the same questions exist in a monopolistic environment, so as to make sure that wind power production is maximized. Incremental costs caused by these aspects can run as high as U.S.$40,000 for a number of years for transferring the experiences from industrialized countries and adapting them to the local environment.

6.3 Barrier Group 3: Lack of availability of financing, particularly from local sources

For a well-tested and cost-effective renewable energy technology such as wind power, the financing issues are different than in the case of CSP. The incremental generation costs per kWh are negligible compared to the ones in the case of CSP, as in our scenario we deploy wind power on a large scale only when it reaches grid parity. For investments in the future, the picture is likely to look better every year, as the trend for fossil energy is upward and the trend for wind-generation costs is downward.

As in the case of the policy frameworks, utilities face different financing issues than do IPPs. Typically, IPPs are offered long-term power purchase agreements (PPAs) from the utility that guarantee them an amount of wind power and a price at which they can sell. In a feed-in-tariff scheme, a fixed rate is guaranteed to any operator of a renewable energy facility for every kWh. Whether or not the rates guaranteed to IPPs through PPAs are higher than conventional power prices depends on many factors, including the oil price and the cost of conventional power generation technology as well as the power sector setup. In Germany, with high wind penetration and a feed-in tariff as well as priority feed-in for wind power, wind power has crowded out some expensive power from the power exchange and therefore led to a slight reduction of the power price for conventional power (Sensfuß 2007). Fixed prices for wind power—in the form of either long-term PPAs or fixed feed-in tariffs—have considerable hedging effects against global energy price swings.

Nevertheless, in a country such as Tunisia, the subsidy policy for all forms of energy and electricity in particular is making the whole price-setting system more complicated and adding confusion over budgetary implications. Electricity prices in Tunisia were subsidized by 47% on average in 2006. The delivered price of electricity in Tunisia on the high voltage level is 0.057 TND/kWh (U.S.$.0413/kWh) during the night and 0.072 TND/kWh (U.S.$.0521/kWh) during the day. At the time of high gas prices, this subsidy cost the government about TND 420 million (U.S.$300 million) in subsidies (ANME 2008b).

Assuming that the delivered prices above depend mostly (e.g., 80%) on generation charges (and not transmission or wheeling charges), and assuming that the government reduces the generation price by 47%, the actual cost of a kWh generated by the (gas) power plant portfolio could be in the range of 0.086 TND/kWh to 0.109 TND/kWh, that is, somewhere between U.S.$.06/kWh and U.S.$.08/kWh. For locations with a good wind resource, wind power can today be generated at this cost, even by a private investor. This means that incremental costs are not necessarily added on top of the existing generation costs if some of the generation is replaced by wind power. In terms of the government's budget, potentially, this means a relief, for example, if the revenues from carbon trading (or CERs) are earned by the government, or if this initiative is triggering some form of subsidy removal policy (which would be nonincremental, though).

In Tunisia, the public company STEG invests in wind. This could be cheaper than an IPP framework, because a typical public investor like STEG should apply lower expectations for its return on investment.

The asymmetry of the cash flow remains a problem for financing. IPPs from Europe have developed business models around this and are able to raise finances if long-term security is granted through the policy scheme. But STEG and others should also be able to access mainstream (nonconcessional) funds from international financial institutions. Nevertheless, a credit line offered by a public development bank would increase investor confidence and help raise financing.

6.4 Barrier Group 4: Technology-related issues

Technology-related issues in wind power are fourfold: currently, the global demand for wind turbines is so strong that there is a real scarcity of the hardware in a sellers' market. In addition, there are geographic constraints (wind resource, siting issues, not-in-my-backyard issues, proximity to load) and hardware and logistics issues (transportation facilities, cranes). In some countries, there are also issues with IPR regimes that would prevent some companies from selling technology to these countries, but this is not the case in Tunisia.

The global wind power industry is rapidly growing, but the demand from a number of very attractive markets is growing even faster. Therefore, it is hard to secure the supply of wind power plants to a new market and in small amounts. Even in the financial crisis, as countries are introducing more ambitious and profitable schemes for green energy deployment, the demand has only slightly weakened, not subsided. Wind turbine manufacturers just slowed down a little from the growth rates of 50% per year that they have experienced in the past.

Siting issues can be a problem, but once the resource is clearly mapped and measured, they are no different from the siting issues with other types of power plants.

Wind turbine construction and O&M require some threshold in terms of minimum power plant portfolio size, as the logistics of transporting the parts to location, erecting the towers, and maintaining operations are highly specialized. Large cranes, for example, need to be transported to the site, which adds significantly to the construction costs. Wind turbine operation is typically monitored remotely in somewhat centralized facilities, which reduces specific operation costs for each one of them. To make access to machinery for countries such as Tunisia affordable, regional market harmonization schemes have been proposed that give reason to manufacturers to treat a region with preferential attention. For example, Morocco, Algeria, and Tunisia could demonstrate common interest in wind power through policy commitments and attractive support schemes. These schemes could add up to a secure demand of 200 MW per year in wind turbines. If that is the case, a wind turbine manufacturer could start to place some parts of its manufacturing capacity there (e.g., a blade factory) as well as station maintenance personnel in the region. Then it would be interested in selling within the region. The region would benefit from additional jobs and economic growth. Facilitating such a scheme would be a typical activity for a multilateral body like UNEP or the International Renewable Energy Agency, and might be associated with costs on the order of U.S.$30,000 per year over three years for the facilitation of the joint market commitment of the participating governments.

The actual technology transfer will take place through local investment of established wind turbine manufacturers in the region or through joint ventures. Countries such as Tunisia have been very successful in attracting FDI for manufacturing plants. These activities are carried out under nonclimate regimes, and can be considered nonincremental for the purposes of the UNFCCC. Some capacity-building measures from Barrier Group 5 can support this effort.

6.5 Barrier Group 5: Lack of local O&M capacity

As mentioned above, wind turbine maintenance is rather specialized. Typically, the suppliers of wind turbines also supply the maintenance, although in established markets a separate service industry is growing. However, in order to plan and build wind farms, additional specialized resources are necessary, ranging from meteorologists who assess site quality to construction firms that erect the towers to the exact specifications of the turbine manufacturers. In addition, integrating intermittent power into the electricity grid also requires special capacities in the utility.

These capacities range from technicians for simple maintenance tasks to engineers for planning, construction, and R&D. It is reasonable to expect that the wind companies can train their own low-level staff to tighten nuts and bolts at no incremental costs. For the training of engineers, a possibility is to send them abroad for training, but for large-scale deployment of renewable energy it is advisable to strategically support the capacity buildup with specialized engineering programs at national universities. This can be done in bilateral fashion. For example, Egypt and Germany have just established a cooperation for a binational training program for engineers. The cost for such a program could be approximately U.S.$400,000.

6.6 Barrier Group 6: Shortcomings of technical infrastructure

Wind power has limitations because of the intermittency of wind. A rule of thumb for the contribution of wind power to power supply says that 15 to 20% can be easily integrated into a standard electricity grid. Higher shares of wind electricity require more careful integration activity, but it is feasible, as shown in Denmark. Here the wind power share in annual electricity production is more than 25% and peaks at 100% on a regional and temporal basis. STEG assumes that until 2011 no more than 205 MW of wind could be integrated into the Tunisian power grid.

The issue can be tackled by increasing transmission capacity, cooperating with flexible load, or introducing electricity storage. All of these options impose additional investment costs, and these costs can be quite high, as, for example, electricity storage is not commercially available at the power costs encountered in Tunisia. Other countries, such as Germany and some regions in the United States, already encounter these problems, and the hope is that cost-effective technical solutions will be developed in the near future that can then be transferred to Tunisia.

Today, no estimate for these costs can be given. Grid expansion costs can be substantial. Beyond the 15 to 20% penetration, reinforcements of the infrastructure are important but it is not possible to put a price or cost on it. Incrementality issues are complicated, too.

6.7 Summary for Wind Power in Tunisia

Wind power is a promising and commercially available renewable energy technology. In Tunisia, it should be possible to build about 600 MW of wind turbine capacity in the near future, with limited incremental cost. The necessary activities are mainly targeted to changing some attitudes through better information and to international bilateral cooperation programs that build some of the necessary capacity. These 600 MW could provide around 1.8 GWh of electricity (around 14% of national electricity consumption), assuming good-quality wind locations with 3,000 full-load hours are available. Around 1 $MtCO_2$ per year could be avoided that way.

The main limiting factor for the further expansion of wind power in Tunisia is the capacity of the transmission grid to cope with the intermittency of the wind power supply. Much larger penetration of wind power, however, could either require some solutions that are not currently fully developed even in countries that reach that limit or lead to a situation where wind power production needs to be curtailed in specific grid situations, which makes every kWh of wind power more expensive. The costs of these two solutions are hard to quantify but consist of (expensive) hardware and (less expensive) capacity-building costs that are partially incremental. This overshadows the attempt to put an overall price tag on the incremental costs of large-scale wind power deployment in Tunisia. A rough estimate is that the other costs are in the range of a couple million dollars.

Overall, the incremental costs for deploying wind power are much lower than for deploying concentrating solar power, as the technology is much closer to commercial maturity.

Table 8. Barrier Removal Activities for Wind Power Deployment (our estimates)

		per year	for how many years?	cumulative need for financing until 2020	remarks
Barrier Group 1: Information and Awareness					
	Studies of local potential, technical aspects, resource map	150,000.00	3	450,000.00	
	staff exchange programs	40,000.00	5	200,000.00	
Barrier Group 2: Policy framework					
	Target setting - sector studies	30,000.00	7	210,000.00	
	Subsidy removal				non-incremental, negative costs
	overall investment conditions				non-incremental, no costs
	technical standards, grid codes	40,000.00	5	200,000.00	
Barrier Group 3: Availability of financing					
	lending mechanism				non-incremental, no costs
	foreign direct investment				non-incremental, no costs
Barrier Group 4: Access to the technology					
	Regional Market Development Initiative	30,000.00	5	150,000.00	
Barrier Group 5: Lack of local operation and maintenance capacity					
	university curricula			400,000.00	not necessarily incremental
Barrier Group 6: Shortcomings of technical infrastructure					
	expansion of national grid			10,000,000.00	not necessarily incremental
sum				11,610,000.00	

7 Summary

7.1 Is Tunisia a role model for the Non-Annex I World?

7.1.1 Energy Efficiency

Tunisia is a small country with good governance and good investment climate. In the interest of energy security, it has already undertaken significant efforts toward an energy-efficient economy and successfully kept the energy intensity of the economy low. These efforts might have cost around U.S.$200 million over the past 10 years, including the operation costs of an energy-efficiency agency, some endogenous technical developments, and a number of incentive programs, such as for solar water heaters or efficient appliances. Parts of these funds were provided from abroad, but Tunisia invested a large amount of domestic resources in this effort. Tunisia found these investments worthwhile as they maintained low energy prices for end consumers and saved gas imports as well as government subsidies. Under these auspices they were considered cost-effective for the government budget.

Many of the experiences made in this context can be transferred to other countries that could adopt similar policies with similar amounts of international aid to reduce their energy intensity while maintaining or stimulating economic growth. Typically, the more energy-efficient an economy is, the higher the mitigation costs of additional measures. Therefore, most developing countries will face lower abatement costs than does Tunisia, or will find measures easier to implement. However, Tunisia has already created a national energy-efficiency awareness and a number of institutions and attitudes that are lacking in other countries.

7.1.2 Renewable Energy

Tunisia has shown less interest in renewable energy than have many other developing countries. Nevertheless, renewables are the natural next step in these countries' decarbonization trend. The natural resources are more than sufficient. Compared with many other countries, Tunisia has well-established trade links, such as to the European Union; a well-established domestic manufacturing and construction industry; and a well-trained workforce. These are good conditions for the systematic deployment of renewable energy for reasons of energy policy (energy security, GHG mitigation) as well as industrial development.

Most renewable energy technologies are more expensive today than their fossil fuel alternatives. This will change in the next decade, as costs of renewable technologies go down through economies of scale, learning, and new technological adaptations, and as costs of fossil fuels go up through scarcity effects. A global price on carbon as it exists today through the CDM and as it is likely to exist in a post-Kyoto world will further tilt the scales in favor of renewables, either by providing additional revenues for renewables or by penalizing carbon emissions. This means that the incremental costs of deploying renewables will keep decreasing over the next decades. The assessment that we did for Tunisia in this study can be seen as an upper-limit assessment, as it assumes that action, at least preparatory action, is taken now, without delaying, until the incremental costs of barrier removal become zero (after 2030). On the other hand, some other countries will experience higher costs if they lack some of the overall positive traits such as good governance, political stability, or a healthy financial sector. Thus, overall, Tunisia is a good basis for illustrating the required actions and the necessary financial means to lead to an overall energy future that is in line with the requirements of the UNFCCC. Development will be slower in some countries, but if the political will is there, the costs of this transformation are no insurmountable barrier.

7.1.3 Energy Sector Setup and Level Playing Field

Tunisia is suffering from integrating power costs into the government's budget. Though this makes electricity affordable for the poor, it does not set the right incentives in terms of using electricity wisely. In addition, the government is taking a number of risks that could be borne better by other players, particularly in the private sector. The costs of this policy are in the range of several hundred million U.S. dollars per year, and thus far larger than either energy-efficiency or renewable energy activity costs.

Unfortunately, many developing countries have distorted energy prices. It is very difficult to remove these harmful subsidies in a way that does not endanger development efforts. The motivation of these subsidies is not environmental benefit but economic development—but on the other hand, energy efficiency and renewable energy also have economic development benefits, and through increasing domestic energy reliance and reducing import dependence on energy, they are actually providing the grounds for sustainable local economic development. In that sense, governments that can afford to spend hundreds of millions of dollars on electricity subsidies might also consider other energy sources as a worthwhile and cost-effective long-term investment.

7.2 How Can a Global Financial Mechanism Help Best

7.2.1 Barrier Removal for Renewable Energy—Bridging the Gap until Renewables Are on Par with Conventional Power Generation

Developing countries interested in scaling up renewable power face several challenges, including

- Information and awareness barriers that keep potential buyers (e.g., power companies and large electricity users) away from renewable options;
- Policy framework barriers, including lack of technical standards, grid codes, lack of regulation to allow independent renewable power providers to feed-in the electricity grid, and so on;
- Lack of access to the actual technologies and other technology-related issues;
- Lack of local O&M capacity;
- Limited financing availability, particularly for demonstrative or initial plants; and
- Shortcomings of physical infrastructure (e.g., power grids).

To identify all barriers, it is best to compare case studies of success and failure in other countries, or in the country's own history. This paper has presented a detailed but certainly incomplete discussion of the barriers for two technologies and one country, and illustrates that these barriers are surmountable with comparatively small input of financial resources once the political will for the deployment of renewable energy is manifest and reliable in the long term.

Once the barriers have been identified, they can then be grouped and prioritized, and the corresponding barrier removal activities can be carried out one by one: capacity can be built, policy frameworks can be put in place, and investment costs can be brought down. It is obvious that some barriers are more important than others, as not all barriers will restrict market growth at the same time. But as a general rule, all of them need to be removed for deployment to happen.

7.2.2 National Measures

As discussed, the first and foremost precondition for any kind of meaningful action is the government's commitment. National commitment is part of a number of general framework conditions that cannot be bought with money, or that are not incremental to the need to mitigate GHG emissions. Other such preconditions are favorable economic development frameworks that are open for international exchange of finances, goods, and capacities, and a reliable IPR enforcement mechanism.

National measures can be grouped in three categories:

- Political signaling and legislative action,
- Capacity building, and
- Investment.

It is obvious that a number of different local actors need to be integrated into these activities, at the very least government authorities, utilities, the private sector, and the educational and scientific community. Government signaling is the least costly of these measures, but these costs are almost completely incremental in the sense of the UNFCCC. Capacity-building activities take the middle ground on total costs and in terms of incrementality. Investments can be large.

7.2.3 Regional Synergies

Some of the barriers can be tackled nationally, but others may require or may benefit from an international approach. For instance:

- To scale up wind power, Tunisia would have to, in the country, increase power producers' and large power consumers' interest in wind power and develop the country's technical capacity and infrastructure, necessary to operate and maintain a large wind power sector; and internationally, wind power manufacturers would have to be attracted to a market—Tunisia—which, on its own, may be too small.
- To make CSP a large power generation alternative, Tunisia would need (a) nationally, to build capacity, pilots, and infrastructure and (b) internationally, to ensure that the maturation and deployment of the CSP technologies proceed at a pace that meets Tunisia's CSP expectations.

Of particular interest is the regional or international scale that an international financial mechanism can bring to bear in support of mitigation efforts in small and medium developing countries. Though large developing countries, such as China, India, Brazil, and Mexico, have the size to make mitigation initiatives totally or mostly a single country endeavor, this is not the case for Tunisia and similar small countries. A number of important capacities require a minimum market size in order to be built up in a self-sustaining manner.

- Take the case of developing industrial capacities for manufacturing, assembling, and maintaining wind power equipment. The Tunisian market on its own is too small to justify a wind power manufacturing plant in the country. On the other hand, the right demand size could be achieved if a group of countries move in a coordinated way to add up to a regional market.
- Take the case of R&D to bring a renewable technology to maturation. Establishing a new energy technology on the market may take as much as 25 years and cost billions of dollars. This is not a task for Tunisia, or for that matter for any small developing country. On the other hand, an international research, development, and commercialization

program could include Tunisia as an ideal partner where pilots and demonstrative plants could be built and tested, giving Tunisia an active role in the international R&D efforts, and helping build the country CSP O&M capacity that will be a necessary piece of a future commercial deployment of CSP.

A global financial mechanism should be in position to support regional initiatives as needed and create the financial incentives and align the technical support to facilitate the emergence of such regional initiatives. In many cases, this increases efficiency and effectiveness of the financial support as well as the mitigation action.

7.2.4 No One Size Fits All

This paper has emphasized that the activities that need support from a global financial mechanism are different in each country. We used Tunisia as a basis for a thought experiment to identify what is necessary here, but also highlighted those areas where Tunisia starts from a nontypical basis and might have an easier or a harder time than other countries to transform its electricity system.

Last but not least, there is another dimension in which the barriers are very different in nature: some are related to soft factors such as attitudes and knowledge, and some are related to hardware such as investments in power plants and infrastructure. The hardware—at least in the cases that we have looked at in this paper, which were large power plant investments—is much more bulky and difficult to fund. Nevertheless, depending on the maturity of the technology and its cost structure, large shares of these costs might be incremental and thus fundable under the UNFCCC. We have discussed CSP plants, for which this is true. The necessary funds and the incremental costs are both large. However, for other investments, such as wind power, the incremental costs in the actual plant might not be big even if the total cost of the investment is big. In addition, there might be big secondary costs, in this case in grid infrastructure, the incrementality of which is up for negotiation.

It is important to note that the finances need to be available for a global mechanism to facilitate these investments, and any single delivery mechanism for these finances is probably suited to only funding or delivering help on one specific type of barrier removal. There are only very few cases in which all costs will be incremental. This means that all these funding players and facilities will need to complement other players, including local funding sources but also including traditional official development aid and traditional export-import financing mechanisms. In this respect, too, no one size fits all, but there is more of a need to let a thousand flowers bloom. Local coordination, local ownership, and country drive then gain new importance in accepting and implementing these international flows.

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8.1 Data

Unless noted otherwise, all data are International Energy Agency (IEA) data. Main sources were:

- CO2 from Energy and Fossil Fuel Use. 2008
- Energy Statistics of Non-OECD countries. 2008
- Energy Balances of Non-OECD countries. 2008.

The IEA qualifies its data as follows:

In this edition, historical time series for combustible renewables and waste were revised to reduce discrepancies between supply and consumption and to ensure continuity of trends.

Sources 1992 to 2006:

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Annex 1: Literature Overview of Cost Reduction Assumptions for Concentrating Solar Power (CSP)

Author (s)	Projected CSP Costs (U.S.$Cts/kWh by year)						Comments (specific methodology and background information concerning cost figures)
	2010	2015	2020	2030	2040	2050	
German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Deutsches Zentrum für Luft- und Raumfahrt (DLR)	7,1	n/a	5,2	4,8	5	5,8	CSP study estimates the direct normal irradiance in Tunisia to be 2,400 kWh/m^2/y, or 9,244 economically recoverable TWh per year. The numbers to the left are not calculated by the study specifically for Tunisia, but rather for Egypt. In comparison, Egypt receives about 2,800 kWh/m^2/y of direct normal irradiance, which comes to more than 73,656 economically productive TWh per year. Despite the differences in economically productive TWh, Egypt and Tunisia are within a high range of irradiance, and hence comparable, though CSP prices in Tunisia should be higher because of a lower irradiance value. Also note these prices do not factor in 100% CSP production, but rather, gradual increases in the share of solar contribution to electricity production (2000 = 25% solar share, 2050 = 99% solar share, by individual power plant). CSP calculations are irrespective of specific CSP production technologies.
German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, DLR	7,4	n/a	5,6	5,2	5,5	6,4	Data specifically for Tunisia. Note, as above, the U.S.$cts/kWh has been calculated with a CSP solar share at 25% in 2000 and 99% by 2050. Therefore, costs factor in other electrical production technologies, fossil or otherwise. Again, CSP cost calculations are irrespective of CSP-specific production technologies.
GreenPeace, ESTIA, Solar PACES	*Case-study specific. See comment box.*						Cost trends for this study are project specific and therefore also CSP production technology specific. Projects are described with a global focus and show dramatic reductions in costs. Because most are case studies, the relevant U.S.$/kWh information is historical data, not projected cost information.

Robert Pitz-Paal, Jürgen Dersch, and Barbara Milow from the DLR	n/a	n/a	~5	n/a	n/a	n/a	Study assumes that long-term competitiveness is achieved at U.S.$.05–.07/kWh, and that current prices lie below a U.S.$.15–.20/kWh range, as the study refers to 2005 prices as "current." Prices are estimated here using parabolic trough systems around a 50 MW capacity. The 2010 value actually displays the 2010 value as a placeholder, as it is assumed the actual 2010 value will be lower than U.S.$.15/kWh. These values to the right are estimated in a desert climate with 2,700 kWh/m^2/y. This is lower than the values given in the MED-CSP study for Tunisia (as cited above), though Tunisian CSP generation prices are estimated to be higher. For perspective, a similar price study was compared with a project in Seville, Spain, with a 2,000 kWh/m^2/y value, and costs were estimated at U.S.$.172/kWh in 2005 and U.S.$.067/kWh by 2020.
Ludger Lorych, Verein Deutscher Ingenieure/Verband Deutscher Elektrotechniker (VDI/VDE) Innovation & Technik GmbH. Study commissioned by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	~14	n/a	~6	n/a	n/a	n/a	The study factors in cost reductions for CSP production, with a focus on cost reduction via storage. Note that this study was part of a presentation, and therefore, information on slides can be assessed only within an assumed context. The most relevant part of the study projects costs for the ANDASOL solar thermal power station in Granada, Spain, which was Europe's first solar plant. The plant came online in 2008, and uses storage technology in the form of molten sodium and potassium nitrate (total capacity about 50 MW). The presentation does not describe the ANDASOL installation, but more information can be found online with Renewable Energy World (http://www.renewableenergyworld.com/rea/news/story?id=54019&src=rss). Note that the ANDASOL project assumedly receives somewhat similar solar radiation conditions as does the Spanish project in Seville referenced above.

Frank Wilkins, DOE Solar Energy Technologies Program	=12–14	~5–7	5	n/a	n/a	n/a	Study also factors in cost reductions for CSP production, with a focus on cost reduction via storage. The DOE target costs for CSP in current prices were formatted for 2007, not 2008, so it is anticipated that actual 2008 prices are lower. DOE target costs for 2015 rely on 6 hours of thermal storage capability, under U.S.$15 per stored kWh with round-trip efficiencies of 93%. Cost targets for 2020 rely on 12–17 hours of thermal storage by 2020, same efficiency as in 2015. Assumes three principal technologies associated with production technology—parabolic trough, dish, and tower systems—coupled with thermal storage techniques, though the presentation slides do not specify what technology is dominant in these price projections, nor what specific radiation conditions or other important geographical factors should be considered in reviewing these targets.
OECD/Institution of Economic Development 2008	=15–20	n/a	n/a	10	n/a	n/a	Study predicts U.S.$100 per MWh in sunny areas by 2030. The lower end of the generation cost range is close to that of gas-fired generation at current gas prices. Expected to also reach 11 TWh by 2015 and 107 TWh by 2030. Note that the study does not provide research methodology or calculation guides as to how these values were calculated. Also, the definition of “sunny” areas, a requisite for the 2030 figure, is not fully explained. The specific CSP generation technology and location is not specified. Thus, values serve to show a general trend without direct contextual information for Tunisia.
Dr. Matthias Fawer	*Case-study specific. See comment box.*						Note the working language of this study is German. Study follows a case-study approach that details planned projects but does not provide price projects or future cost considerations on a price per kWh basis. However, the study does in fact provide cost-specific information with projections for investment pricing.

						The study assesses 2006 prices of €.16/kWh for CSP generation, irrespective of technology. The investment requirements thereof stood at €2,500 to 3,500/kW. The study believes that within five years or so the investment costs could sink to €1,500–2,000/kW.
UNEP, GEF; KfW Development Bank, German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	=20	~7	n/a	n/a n/a	n/a	Costs are expressed as being reduced not by year, but by installed megawatts. Assumes a 5,000 installation by 2014, which translates to a corresponding value of approximately U.S.$.07/kWh by 2015. Costs consider thermal storage, new heat transfer fluids, and operation advancement methods. It is not clear exactly what current costs would be from this study, as it appears the study uses 2004 prices (suggesting a 2004 publication date), but, based on the case study of the Solar Energy Generating Systems solar plant in the Mojave Desert in California, the current 2008 price should stand between U.S.$.20 and U.S.$.17 per kWh generated.

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