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PROMOTING LARGE-SCALE RENEWABLE ENERGY APPLICATIONS IN THE ARAB REGION: AN APPROACH FOR CLIMATE CHANGE MITIGATION

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Preface

The appropriate management of natural resources in an integrated manner is the subject of debate at the public policy level. In the Arab region, this debate is linked mainly to sustainable development, and climate change adaptation and mitigation.

Within this context, the Sustainable Development and Productivity Division (SDPD) of the Economic and Social Commission for Western Asia (ESCWA) has started a Working Paper Series on issues related to integrated management of natural resources in order to raise awareness and stimulate discussion around this subject.

This paper tackles the importance of natural and sustainable resources, especially wind and solar energy, which can play a role in climate-change mitigation. The paper provides an overview of technologies available for large-scale application of renewable energy, the current situation in the Arab region, the challenges facing the adoption of large-scale renewable energy (RE) applications, and recommendations for promoting these applications in the Arab region.

This paper is the result of efforts of the staff of the Energy Section in the context of their work on RE. Under the overall guidance and support of Ms. Roula Majdalani, Director of SDPD, and the direct supervision of Dr. Walid Deghaili, Chief of the Energy Section, the paper was written by Mr. Ziad Jaber, Economic Affairs Officer. It was reviewed and finalized by Dr. Deghaili before its publication. Sincere gratitude is addressed to the Energy Section team for their support and contributions.

This paper is preliminary and has not gone through the usual review process for ESCWA publications. The author therefore welcomes feedback from readers, who may direct any comments and suggestions to: http://www.escwa.un.org/main/contact.asp.

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Introduction

Climate change is becoming a fundamental challenge of our century. Even if the minimum predicted increase in temperature takes place, consequences for sustainable development and the environment will be immense, with enormous impact on economic and social growth, human habitat and the possibility of achieving the Millennium Development Goals (MDGs) and other internationally-agreed development objectives.

The use of renewable energy (RE) is one of the most effective methods of mitigating climate change. The Arab region enjoys large untapped potential in terms of wind and solar energy. REs can thus play a significant role in the energy mix of the region to help reduce the adverse environmental impact of fossil fuels, as well as satisfy increasing energy demand.

This paper looks at RE resources, especially wind and solar energy, as natural and sustainable resources that can help prevent climate change. We begin with an overview of the technologies available for large-scale applications of RE and the current situation in the Arab region. We then turn to the challenges facing the adoption of large-scale RE applications, and make recommendations for promoting these in the Arab region.

I. RENEWABLE ENERGY TECHNOLOGIES AND GLOBAL TRENDS

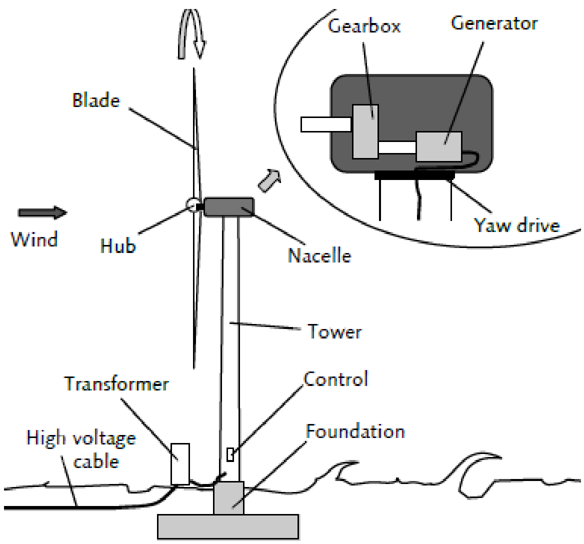
A. HYDRO ENERGY

Hydropower has been used for decades as an energy source for electricity generation and/or other energy-related applications having well-established technology. The advantages of its use are various, including operational, technical, financial and economic benefits. However, as water resources are also needed for irrigation, drinking and household use, national policies are usually set according to priorities based on each country's circumstances and as part of an overall plan for integrated water resources management. As hydropower is well established and is already considered as a prime energy source contingent on availability, this report will concentrate on the other sources of energy.

B. WIND ENERGY

A wind farm composed of several turbines generates power on a large scale from a naturally occurring and previously unexploited source. On-shore wind farms are built on land, while off-shore wind farms are built in the sea, have higher energy-generating capacity but require more civil and maritime infrastructure.

Figure I. A sketch of a modern wind turbine



Source: Painuly, J. et al., *Wind power and the CDM*, p. 20. (See footnote 30).

All modern turbines have variable pitch or angle of inclination and variable angular velocity. As wind intensity increases, the pitch adapts accordingly, permitting the best aerodynamic flow of wind through the blades and angular speed increases for absorbing torque or the rotary force, which exceeds the power train capacity. The turbine must also yaw, or rotate vertically into the wind. Thus, on top of the nacelle (see figure 1) an anemometer, or wind gauge, together with a wind vane, determine intensity and direction of the incoming wind. The output signal directs the electric motors located inside a cog ring at the top of the mast.

The start-up wind velocity (cut-in) of a wind turbine is from 3-5 m/s.[1] While wind speed increases, power production grows until the rated power for optimum performance is reached and exceeding output is limited. At a fixed value of wind speed (cut-off), typically around 25 m/s,[2] the turbine stops for safety

[1] EnerNex Corporation, *Final Report-2006 Minnesota Wind Integration Study, Volume 1*, prepared for Minnesota Public Utilities Commission, in collaboration with The Midwest Independent System Operator, Saint Paul, MN, p. 86.

[2] Ibid.

reasons (standstill). Control systems maintain correct functioning of a wind turbine, making it work with maximum efficiency until rated power is reached, and keeping power production constant thereafter. Proper brake systems allow for emergency stops and maintenance. Usually, wind turbines are equipped with both an aerodynamic and a mechanical brake.

The size of commercial wind turbines has been steadily growing in the last 25 years, in terms of capacity, increasing from nameplate rated power of approximately 50 kilowatts (kW) and a rotor diameter of 10-15 m, up to today's commercially available 5-6 megawatt (MW) machines with a rotor diameter of more than 120 m. Modern wind technology is able to operate effectively at a wide range of sites. Clusters of turbines collected into wind farms operating with high availability, are generally well integrated into the environment and accepted by the public. According to the Global Wind Energy Council (GWEC), in 2007, global turbine installations had an average capacity of 1.49 MW.[3] The past few years have seen a levelling of turbine size in the 1.5 to 5 MW range. This has enabled series production of many thousands of turbines of the same design, reduced technical problems and increased reliability. The average operational life of such a machine is 20 years and the actual operational time about 120,000 hours. The world's largest wind turbine of 6-7 MW (the E-126 model) has a rotor diameter of 127 m with a tower 135 m tall. The overall height of the machine is thus 200 m from tower base to blade tip.[4]

By the end of 2008, worldwide capacity of wind-powered generators reached a cumulative total of about 121 gigawatts (GW). According to the World Wind Energy Association (WWEA), total worldwide installations in the year 2008 itself were more than 27 GW, a growth of 28.8 per cent compared to 2007, and dominated by the three main markets in Europe, North America and Asia.[5] The main demand for higher-capacity machines has been from the offshore market, where placing turbines on the seabed requires optimum use of each foundation. Securing large foundations, collecting the electricity and transmitting it to shore all increase the costs of offshore development.

Low-cost onshore wind resources, regulatory delays and uncertainty associated with offshore development, turbine supply shortages, high and uncertain offshore project costs, and public acceptance concerns have hindered progress in the offshore wind sector worldwide. Nonetheless, there is interest in offshore wind power in many countries, especially in Europe, due to the unavailability of land (in such countries as Denmark) for new onshore projects, the proximity of offshore wind resources to large population centres, advances in technology and potentially superior capacity factors.

"Wind energy penetration" compares how much energy is actually produced in relationship to total available generation capacity. The maximum level of wind penetration varies from one country's electricity grid to another. It depends on existing generating units, type, capacity for storage or demand management, interconnection with neighbouring grids and other factors. An interconnected electricity grid compensates for the variability of a wind plant to generate power by its capacity to generate and transmit reserves. Analysts indicate that a maximum of 20 per cent of total electrical energy consumption may be incorporated with minimal difficulty.[6] Beyond this level of penetration, intermittency poses a more significant challenge on system stability and economics. However, such limited estimation assumes locations with geographically-dispersed wind farms, availability of other fast dispatchable energy units, or hydropower with storage capacity, demand management, and interconnection to a large grid that allows export of electricity when needed.

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[3] GWEC. Greenpeace and Wind Power Works, *Global Wind Energy Outlook 2008,* p. 36.

[4] ENERCON/Energy for the World, *Wind Energy Converters, Product Overview,* Aurich, Germany, 2010.

[5] WWEA, 2009. *World Wind Energy Report 2008*, Bonn, Germany, p. 4.

[6] See: - European Wind Energy Association (EWEA), 2005. *Large Scale Integration of Wind Energy in the European Power Supply: Analysis, Issues and Recommendations,* p. 9.

- Kema-Xenergy, 2004. *Intermittent Wind Generation: Summary Report of Impacts on Grid System Operations,* Consultant Report prepared for California Energy Commission, United States of America.

- EnerNex Corporation, *Minnesota Wind Integration Study*. (See footnote 1).

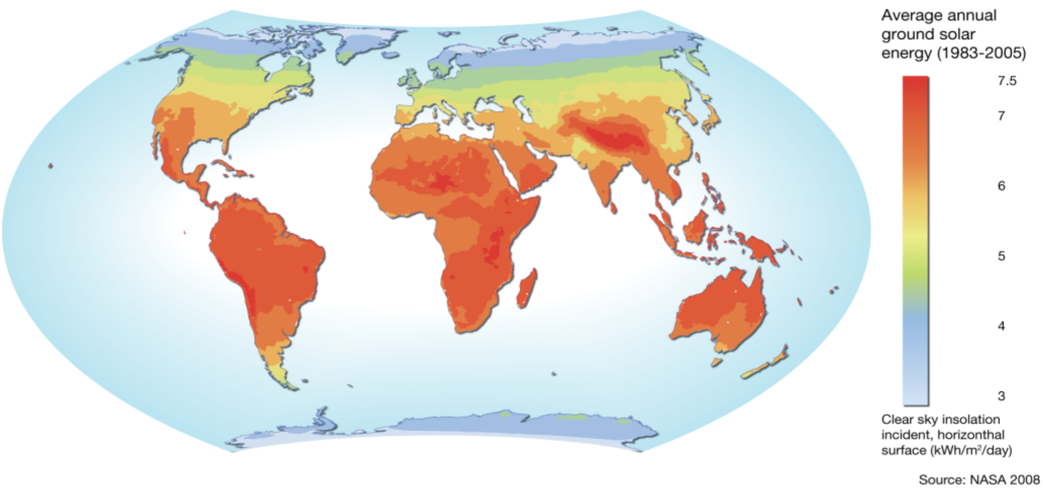
In general, until now, wind power is non-dispatchable, meaning that for economic operation, all output must be used when available. In 2007, a few grid systems had penetration of wind energy above 5 per cent (Denmark 21.3 per cent, Germany 7.0 per cent, Ireland 8.4 per cent, Portugal 9.3 per cent and Spain 11.8 per cent).[7] The reason for high penetration in Denmark is that the Danish grid is connected by transmission lines to other European countries and therefore it does not need to install additional peak-load plants to balance its wind power. Further, the interconnection allows exporting a significant portion of its wind-generated electricity to neighbouring countries.

Recent wind integration studies show that integrating wind projects into power systems is manageable, but not costless. The cost of wind integration rises with higher levels of wind penetration, but remains below US$10/megawatt hours (MWh) and is often even lower then US$5/MWh for wind-capacity penetrations of as high as 30 per cent of the peak load of the receiving system.[8] Grid operators are developing methods to accommodate increased penetration, such as the use of larger balancing areas, wind power forecasts to inform operational decisions, and intra-hour scheduling. It is worth mentioning that grid operators in a number of European countries, including Portugal and Spain, have now introduced central control centres, which can monitor and efficiently manage the entire national fleet of wind turbines.

C. Solar energy

Solar energy is the largest and most widely distributed RE resource on our planet, as shown in the following figure. There are two methods of generating electricity from the sun: solar-thermal and photovoltaic (PV) technologies.

Figure II. Global potential of solar power



Source: Ahlenius, H., UNEP/GRID-Arendal, available at: http://maps.grida.no/go/graphic/natural-resource-solar-power-Potential.

1. *Concentrating Solar-thermal Power technologies*

Solar-thermal technologies are based on traditional electricity-generating technology. Concentrating Solar Power technologies (CSP) build on the concept of concentrating solar radiation either on line or point-focusing systems to be used for electricity generation within conventional power cycles, using steam turbines, gas turbines or Stirling engines. CSP technologies rely on normal, direct irradiance of solar energy in order to raise the temperature of a receiver to appropriate levels for use in power generation.

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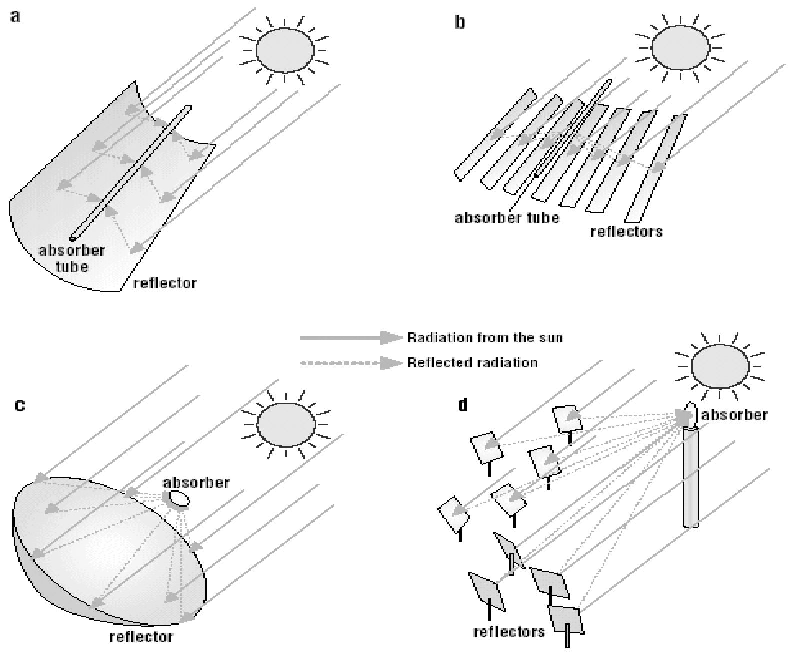
[7] EWEA, 2008. *Wind Energy-The Facts, Part II, Grid Integration*, p. 156.

[8] Wiser, R. and Bolinger, M., 2009. *2008 Wind Technologies Market Report*, US Department of Energy, p. 48.

Basically, four main elements are required: a concentrator, a receiver, some form of transport media or storage, and power conversion. For concentration, most systems use hundreds of glass mirrors as reflectors that continuously track the position of the sun. A distinction can be made between one-axis tracking systems which concentrate sunlight onto an absorber tube in the focal line, and two-axes tracking systems which do so onto a relatively small absorber surface near the focal point. The concentrated sunlight is absorbed on a receiver that is specially designed to reduce heat loss. A heat transfer fluid flows through the receiver, carrying the heat in the direction of the power cycle, where steam created under high pressure and high temperature drives a turbine. Water, oil, air and molten salt are the most common heat transfer fluids.[9] The following figure shows the concepts behind the four CSP technology main streams realised to date; namely: (a) parabolic trough systems, (b) linear Fresnel systems, (c) dish systems, and (d) power tower or central receiver systems with distributed reflectors called heliostats, which are large mirrors with sun-tracking motion.

Figure III. Concepts of the four concentrating solar power technology main streams



Source: Quaschning, V., 2003, Solar thermal power plants Technology Fundamentals, *Renewable Energy World*.

Concentration ratios of incoming direct solar radiation for parabolic troughs range from 10 to 100, and temperatures range up to 400°C.[10] Most plants use synthetic thermal oil as a heat transfer fluid within the collectors, and as a heat exchanger for producing slightly superheated steam at high pressure to feed a steam turbine connected to a generator for electricity production. The maximum temperature of thermal oil is about 400°C, which limits conversion efficiency of the turbine cycle.

Solar tower technology is based on a circular array of heliostats concentrating sunlight on to a central receiver mounted at the top of a tower. Temperatures from 800°C to over 1,000°C can be reached as the sunlight is concentrated 600 to 1,000 times, enabling power towers not only to drive steam cycles, but also drive gas turbines and combined-cycle systems. Coupled with a combined-cycle power unit, peak and annual

[9] German Aerospace Centre (DLR), 2005. *Concentrating Solar Power for the Mediterranean Region*, Institute of Technical Thermodynamics; Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Germany, p. 41.

[10] Quaschning, V., 2003. Solar thermal power plants; Technology Fundamentals, *Renewable Energy World*, pp. 109-113.

solar-electric efficiencies of 35 and 25 per cent can be achieved. However, the real reported efficiency values on the existing demonstration projects are 8-10 per cent.[11]

A Linear Fresnel Collector (LFR) array is a line-focus system, similar to the parabolic trough, in which solar radiation is concentrated on an elevated, inverted linear absorber using an array of nearly-flat reflectors. The system has low structural support costs for reflectors, fixed fluid joints, a receiver separated from a reflector and long focal lengths allowing the use of conventional glass reflectors. It has a thermal efficiency of 30-40 per cent and can reach 200 MW of electric capacity using steam cycles.[12] The horizontally-arranged heliostats almost completely cover the land area and form a bright, semi-shaded space below for agricultural or other purposes.

A parabolic dish-shaped reflector concentrates sunlight on to a receiver located at the focal point of the dish. The concentrated beam radiation is absorbed into the receiver to heat a fluid or gas (air) to approximately 750°C, which can be used to generate electricity in a small piston, Stirling engine or a micro turbine, attached to the receiver. The dish is designed to track the Sun along two axes. Prototypes of dish systems ranging from 10 kW to over 100 kW (the 'Big Dish' of the Australian National University) have been successfully operated.[13] Dish systems are well-suited for decentralized power supplies and remote, stand-alone power systems due to their size.

Large-scale CSP projects would use parabolic troughs, linear Fresnel systems and power towers coupled to steam cycles. Individual CSP plants are now typically between 50 and 280 MW in size, but could be larger still. Until now, as demonstrated in the last two decades, such systems achieve annual solar-to-electricity-efficiencies of about 10-15 per cent. CSP plants can work in hybrid operation in which electricity is generated using fossil fuel as well as solar energy as a primary source. This hybrid operation would permit greater power availability and cost reduction by more effective use of the power block. Another operational mode is storage, wherein solar heat collected during daytime can be stored in liquid or solid media such as molten salts, ceramics, concrete or a phase-change media. The stored heat can then be extracted at night to run the power block. Certain CSP projects with heat-storage capacity, able to run the plant for eight hours are already in operation. Fossil and renewable fuels like oil, gas, coal and biomass can be used for co-firing the plant, thus providing power capacity whenever required. Their thermal-storage capability and hybrid operation with fuels, allow CSP plants to provide power on demand with availability and capacity credit considered to be 90 per cent. When integrated into conventional combined-cycle or steam turbines, large-scale CSP technology reduces fuel consumption. CSP plants could also be linked with desalination projects, especially as the Arab region suffers from water scarcity, and water is usually brought from desalination plants in certain countries.

2. *Photovoltaic technology*

Initially developed for the space program over 45 years ago, PV cells are small, square-shaped semiconductors manufactured in thin film layers from silicon and other conductive materials. When sunlight strikes the PV cell, it releases electrons, generating electric current. The small current from individual PV cells, which are installed in modules, can power individual homes and businesses or can be plugged into a bulk electricity grid. Their capacity ranges from a few watts to several MW. Batteries are usually linked to smaller decentralized supply systems to store the solar energy over night.

Especially in Europe, the feed-in tariff model has proven to be the most successful incentive model. The year 2004 was a milestone year, when for the first time, grid-connected PV-capacity for the production of solar energy surpassed off-grid systems. During the period 2004-2008, European demand for large-field,

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[11] Müller-Steinhagen, H. and Trieb, F. *Concentrating solar power: A Review of the technology*, Institute of Technical Thermodynamics, German Aerospace Centre (DRL), Stuttgart, Gremany, pp. 47-48.

[12] Ibid, p. 44.

[13] Müller-Steinhagen, H. and Trieb, F. *Concentrating Solar Power*, p. 47. (See footnote 11).

grid-connected, utility-scale PV solar power plants (defined as larger than 200 kW), largely driven by the feed-in tariff model of incentives, created the largest global market for solar systems. The industry's compound annual growth for this period was 51 per cent. Accelerated growth in the PV industry continued in 2008, with 79 per cent market growth over the previous year, reaching a global PV market of 5.6 GW and the cumulative amount of PV power installed totalling from 15 to 16 GW.[14]

Large-scale PV power plants have tripled in capacity in 2008, reaching a total of 3 GW. From approximately 1,000 PV power plants in existence at the end of 2007, the total number of operational plants reached 1,800 by the end of 2008. Spain was the leader in new PV installations in 2008 with over 1.9 GW added.[15] PV plants were also installed in the Czech Republic, France, Germany, Italy, Korea, and Portugal. Many other countries in Europe as well as Asia and the United States have considered plans for new utility-scale plants. About 94 per cent of total PV systems sales in 2008 were grid-connected applications (residential, small, medium and large commercial, large-field commercial and utility).[16] Strong growth in grid-connected systems is the primary contributor to PV industry development.

PV technologies have witnessed the introduction of new products to the market. In addition to the widely-used wafer-based crystalline silicon technology, these products include amorphous/micromorph silicon, thin film cadmium telluride (CdTe), copper indium gallium selenide (CIS or CIGS), and dye-cells. The entry of these technologies to the market will lead to further cost reduction, though wafer-based crystalline silicon technology still dominates PV production lines with about 90 per cent of production shares.[17] This is mainly due to the fast installation and commissioning of the production line, resulting in low-risk ventures with high return on investments. However, the rapid expansion of investment into thin film capacities is a response to the development of the PV market worldwide and the increase in the number of turn-key production-line services provided by new firms. Silicon-based PV cell manufacturers are joining new players to the solar energy production industry in venturing into thin film technology.

The PV industry witnessed sustained accelerated growth between 2004 and 2008. In 2009, a reduction in demand was observed, even though PV module prices decreased to about 40 percent below 2008 levels.[18] However, with anticipated lower production costs and higher efficiencies of the different PV technologies, especially those adopted for larger-scale utility applications as well as new business models, accelerated demand is expected.

In general, PV systems are most applicable to remote areas. However, unless we witness a great decrease in PV prices and/or the application of government subsidies to the industry through a feed-in tariff or any other mechanism, the spread of PV applications in the Arab region will remain limited, due to financial and commercial constraints. Moreover, with higher ambient temperatures, PV system-efficiency decreases and may experience problems in reliability and availability. Therefore, in the Arab region, CSP technologies are preferable on a large scale, especially if integrated into desalination processes in areas suffering from water scarcity.

D. Other renewable energies

Other REs that can have an effect on climate change mitigation include geothermal energy and energy generated from biomass, bio fuel or waste.

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[14] European Photovoltaic Industry Association (EPIA), 2009. *Global Market Outlook for Photovoltaics until 2013*.

[15] Renewable Energy Policy Network for the 21st Century (REN21), 2009. *Renewables Global Status Report: 2009 Update*, Paris.

[16] For more in-depth analysis see Mints, P. 2009. *The PV Industry 2009: In Search of Stability and Sustainability*, at: http://www.renewableenergyworld.com/rea/news/article/2009/08/the-pv-industry-2009-in-search-of-stability-and-sustainability1?cmpid=SolarNL-Tuesday-September1-2009.

[17] Jäger-Waldau, A., 2008. *PV Status Report 2008*, European Commission, Joint Research Centre, Institute for Energy, Italy.

[18] Mints, P., *The PV Industry 2009*. (See footnote 16).

Geothermal energy is thermal energy stored in the earth. The difference in temperature between the surface and the earth's depth causes a flux of heat from the centre of the earth to the surface as continuous thermal energy conduction. Geothermal power is environmentally friendly, sustainable, reliable, and cost effective. The use of the geothermal energy is limited to areas around tectonic plate boundaries. One of the limitations of geothermal energy is that exploration and drilling deep into the earth in order to extract heat is expensive. Recent technological advances have led to a wider and less-costly use of geothermal energy, exploiting a broader range of viable resources in different locations, and allowing for home applications such as heating.

Raw biomass includes wood, waste, and other biological material. In a narrower sense, biomass can be understood as plants especially grown and harvested to generate electricity or heat. Such plants as sugarcane, corn and other tree species are usually used for industrial biomass. Although the process is determined by the particular plant used, the end product is the same. The conventional method is through direct incineration. Forest residues, including branches and dead trees, wood chips, and garbage are often burned directly. In a broader sense, biomass is biological matter that can be used to produce heat, chemicals (like alcohol fuels) or fibres. This includes biodegradable wastes, burnt as fuel or fermented to produce gases (such as methane) or alcohols.

Biofuels, used in Brazil, Europe and the United States, are derived from biomass and consist of a wide range of fuels that include biogases, liquid fuels and solid biomass. As oil prices rise and energy security requirements increase, along with an increase in public awareness about greenhouse gas (GHG) emissions, biofuels are gaining more attention at scientific and public levels. Plants with high sugar components, such as starch crops or sugar cane, are used to produce Bioethanol through fermentation. Bioethanol is an alcohol that can be used as an additive to gasoline in order to increase its octane level and reduce vehicle emissions. More advanced technologies are needed to produce ethanol from trees, grasses and other cellulosic biomass. Biodiesel is produced from animal fat, vegetable oils, or recycled greases. It is used as an additive to diesel engines, reducing emissions of carbon monoxide, hydrocarbons and levels of particulates.

Finally, energy can be generated from waste either by direct incineration or by the production of methane, methanol, ethanol, or other combustible synthetic fuels. The energy delivered by the incineration or the combustion of the produced fuel can be used as a heat source for electricity generation. Creating energy from waste can be seen as a form of energy recycling or recovery. Capturing the gases formed by the degradation and fermentation of organic material available in the wastes, and then using them as sources of energy rather than letting them go in the atmosphere helps reduce GHG emissions.

However, as these sources of RE in the Arab region would be more suitable to smaller-scale applications due to limited resources, this document concentrates on wind and solar energy.

II. ROLE OF LARGE-SCALE RENEWABLE ENERGY APPLICATIONS IN MITIGATING CLIMATE CHANGE

A. GREENHOUSE GAS EMISSIONS AND CLIMATE CHANGE IMPACTS

As confirmed in the fourth Assessment Report of the Intergovernmental Panel on Climate Change, the activities related to energy production and consumption are key contributors to the rise of GHG emissions. Promoting RE in the power sector is one of the most significant means of limiting such a rise. The Arab region does not enjoy a high industrialization rate; consequently, the region's total GHG emissions (especially carbon dioxide (CO_2)) are low. Greenhouse gas emissions vary widely among Arab countries, reflecting variability in energy consumption, levels of development, fuel mix and change in climatic conditions. For the year 2008, the International Energy Agency (IEA) reported that the world's total GHG emissions from fuel combustion was about 29,381 metric tons of carbon dioxide ($MtCO_2$), with the Arab region contributing about 4.44 per cent of these emissions. Saudi Arabia is contributing the highest percentage of the GHG emissions from the Arab countries, followed by Egypt. Regionally, the Gulf countries emit more than 50 per cent of that of the entire Arab region (table 1).

TABLE 1. TOTAL CO_2 EMISSIONS FROM FUEL COMBUSTION, ELECTRICITY AND HEAT PRODUCTION; CO_2 EMISSIONS IN 2008 IN THE ARAB REGION

Country	Total emissions from fuel combustion $MtCO_2$	Percentage of world total	Electricity and heat production $MtCO_2$
Algeria	88.1	0.30	24.0
Bahrain	22.3	0.08	7.8
Egypt	174.0	0.59	60.2
Iraq	97.4	0.33	29.9
Jordan	18.4	0.06	8.2
Kuwait	69.5	0.24	31.8
Lebanon	15.2	0.05	7.5
Libyan Arab Jamahiriya	44.8	0.15	25.4
Morocco	42.1	0.14	14.9
Oman	34.9	0.12	13.5
Qatar	53.9	0.18	11.5
Saudi Arabia	389.2	1.32	154.0
Syrian Arab Republic	54.4	0.19	25.1
The Sudan	12.1	0.04	2.8
Tunisia	20.7	0.07	8.0
United Arab Emirates	146.9	0.50	72.6
Yemen	21.9	0.07	4.2
Total	1 306.0	4.44	501.3

Source: CO_2 Emissions from Fuel Combustion, 2010 Highlights, IEA.

Most of the Arab countries are located in arid and semi-arid zones where the climate is extremely hot and humid in the summertime. In most countries, during the summer, temperatures can exceed 50°C, and humidity exceeds 90 per cent in coastal areas. In addition, the region suffers most of the year from deficient precipitation, which ranges from 50 to 150 millimetres (mm). The hot and humid climate requires extensive use of indoor air conditioning. In addition, the lack of precipitation and the scarcity of water resources dictate the need for high desalination capacity, especially in the Gulf Cooperation Council (GCC) countries. This has led to comparatively high rates of electricity consumption, and corresponding rates of carbon dioxide emissions.

Certain Arab countries are among those likely to be at risk from climate change-related threats. Some are more exposed to accelerated desertification, soil aridity and water scarcity while others are highly vulnerable to sea-level rise, erosion problems, and marine pollution. According to recent modelling studies, the Arab region will face an increase of from 2 to 5.5°C in surface temperature by the end of the 21st century. In addition, this temperature increase will be coupled with a projected decrease in precipitation of between 0 and 20 per cent. The results for the region include shorter winters, dryer and hotter summers, a higher rate of heat waves, increased weather variability and more frequent occurrence of extreme weather events.[19]

As climatic conditions and energy demand are linked, the increase of ambient temperature through the summer period translates to an increase in energy consumption in the Arab region, mainly due to extensive use of air conditioning. The increase in demand suggests a need for additional generating capacities, over and above the needed additional capacities to cater for projected economic growth. The peak in energy demand is in the summer "dry" season, which is expected to become even dryer in the future. Low water supply will reduce energy generation from hydropower plants, significant for certain countries. Conventional fossil fuel power plants requiring water for plant cooling will also suffer lower efficiencies. Combined with the desire of individuals to experience a higher standard of living, and the repercussions of higher incomes that permit more comfortable living conditions, including a higher energy demand (at least for air conditioners and home appliances), adds more heat to the surrounding environment.

In fact, limited water resources are of primary concern. The United Nations designates that a country faces water scarcity when its per capita share of annual water resources is below 1,000 cubic metres. Except for Iraq, possessing water resources of more than 2,600 cubic metres/capita/year, all Arab countries can be classified as vulnerable in this regard. The Syrian Arab Republic is currently facing water stress (1,000 to 1,500 cubic metres/capita/year), while the rest of the Arab region is facing water scarcity.[20] Typically, heavy reliance on surface and groundwater prevails in all countries of the region, with 60-90 per cent of water being used for agriculture. Water resources will be subject to more stress due to climate change. Rising temperatures will increase demand for freshwater supplies for drinking and especially agricultural irrigation, which, due to shifting precipitation patterns, reduced fresh water supplies in many regions, including the Arab region, will fail to meet.

Complicating the situation are rising sea levels which can impact desalination plants that are the source of water for the region. Two-thirds of water needs in countries of the GCC are met with water from desalination plants. The GCC is also host to about two-thirds of desalination capacity worldwide. The increase in demand would, in turn, reduce freshwater levels and increase salinity in sea water. Thus, the efficiency of desalination plants will be affected, and there will be a need for more desalination units, which are already energy intensive and a source of greenhouse gases. For other parts of the Arab region, the United Nations Food and Agriculture Organization projections show that Algeria, Egypt, Morocco, the Syrian Arab Republic and Tunisia are expected to experience severe water shortages by 2050 as a direct consequence of climate change, and the current rapid trends of population increase.[21] In the Arab region, while water supply is consistently declining, water demand is rapidly increasing.

Knowing that parts of the Arab region have economic structures that are more strongly dependent on natural resources, as well as technical and financial capacities that are too limited to help implement large-scale mitigation or adaptation options, deployment of REs promises to be one of the most appealing solutions allowing many Arab countries to confront, or even benefit from, the climate change issue. Some of the other solutions for adaptation or mitigation are relatively difficult. The lack of arable land and water resources in much of the region prevents the development of carbon sinks, forests, and green areas.

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[19] United Nations Development Programme, *Arab Human Development Report 2010*.

[20] E/ESCWA/SDPD/2007/6.

[21] United Nations Food and Agriculture Organization, *The State of Food and Agriculture 2002*, Rome.

B. ROLE OF THE LARGE-SCALE RENEWABLE ENERGY APPLICATIONS IN REDUCING GREENHOUSE GAS EMISSIONS

Renewable electricity plants affect the merit order of the different available power plants. Once built and the capital cost paid, the operating costs of RE plants are less than operating costs of fossil-based plants due to the costs of the fuel itself. Moreover, RE plants are non-dispatchable, in that all generated energy should be either used directly or stored for later use. The highest priority would be to fully use energy generated from RE plants, thereby reducing costs related to energy storage. Fossil fuel plants would then be used to cover the rest of the demand. As a result, the carbon dioxide emissions due to the electricity sector would be reduced.

Table 2 shows the average of CO_2 emission per kWh electricity generated for the Arab countries based on the current primary energy mix used for electricity generation. Energy generated from renewable systems can replace and offset energy generated from fossil fuels. Adding large-scale RE plants would thus reduce the CO_2 emissions and therefore the average emissions per kWh. Furthermore, if the solar energy is integrated with desalination plants, energy needed in the desalination process from fossil fuels or gas would be replaced by the sun's sustainable energy with zero emissions.

TABLE 2. AVERAGE CO_2 EMISSION PER KWH ELECTRICITY GENERATED

Country	CO_2 emission factor g/KWh
Algeria	670.9
Bahrain	890.1
Egypt	471.5
Iraq	700.7
Jordan	660
Kuwait	807.5
Lebanon	667.3
Libyan Arab Jamahiriya	899.4
Morocco	777.5
Oman	854.5
Palestine	-
Qatar	618
Saudi Arabia	747.6
Syrian Arab Republic	587.5
The Sudan	848
Tunisia	481.6
United Arab Emirates	843.6
Yemen	845.5

Source: United Nations Environment Programme (UNEP). Greenhouse Gas Calculator, 2009.

Table 3 shows the amount of CO_2 that is emitted for each ton of fuel burnt. The fuel types mentioned below are typical fuels used in the Arab region for electricity generation.

TABLE 3. CO_2 EMITTED PER TON OF FUEL BURNT

Type of fuel	Quantity used	CO_2 emissions
Gas/diesel oil	1 ton	3.2033 ton
Natural gas	1 ton	2.6993 ton
Residual fuel oil	1 ton	3.1430 ton

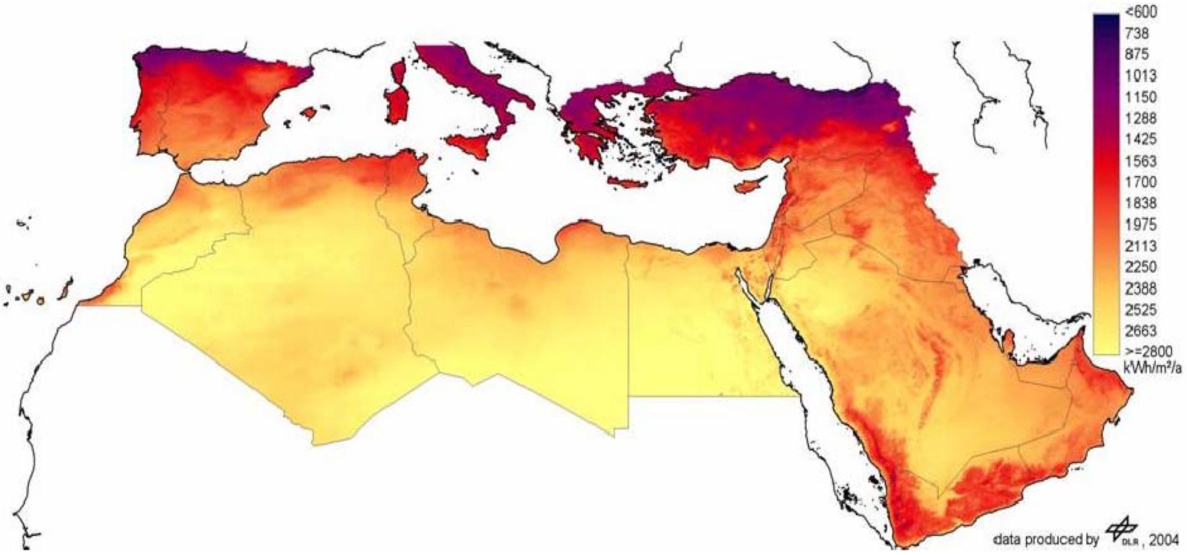
Source: UNEP. Greenhouse Gas Calculator, 2009.

III. LARGE-SCALE RENEWABLE ENERGY APPLICATIONS IN THE ARAB REGION

A. POTENTIALS

The Arab region lies within the Sunbelt, experiencing about 300 sunny days a year, with maximum-recorded annual mean sunshine duration ranges from 7.5 h/day (Tunis), to 10.7 h/day (Egypt).[22] Furthermore, there are abundant sunny arid desert areas with low precipitation. Solar energy prevalent in the region can be used for both photovoltaic and CSP systems. The MED CSP study (Concentrating Solar Power for the Mediterranean Region), defined a threshold for economic potential for CSP, at which direct normal irradiance exceeds 2,000 kWh/m^2/y. As shown in table 4 all countries in the Arab region have good potential, with incident solar radiation higher than the required value. The table also shows high values for average annual global irradiance, which is used for estimating potential for PV systems.

Figure IV. Annual direct solar irradiation in the Arab region



Source: DLR, *Concentrating Solar Power for the Mediterranean Region*. (See footnote 9).

TABLE 4. ESTIMATED AVERAGE ANNUAL SOLAR RADIATION INTENSITIES IN THE ARAB REGION

Country	Direct Normal Irradiance kWh/m^2/y (for CSP)	Global Horizontal Irradiance kWh/m^2/y (for PV)
Algeria	2 700	1 970
Bahrain	2 050	2 160
Egypt	2 800	2 450
Iraq	2 000	2 050
Jordan	2 700	2 310
Kuwait	2 100	1 900

[22] Rahoma, U. A., 2008. Utilization of Solar Radiation in High Energy Intensive of the World by PV System, *American Journal of Environmental Sciences* 4 (2): pp. 121-128.

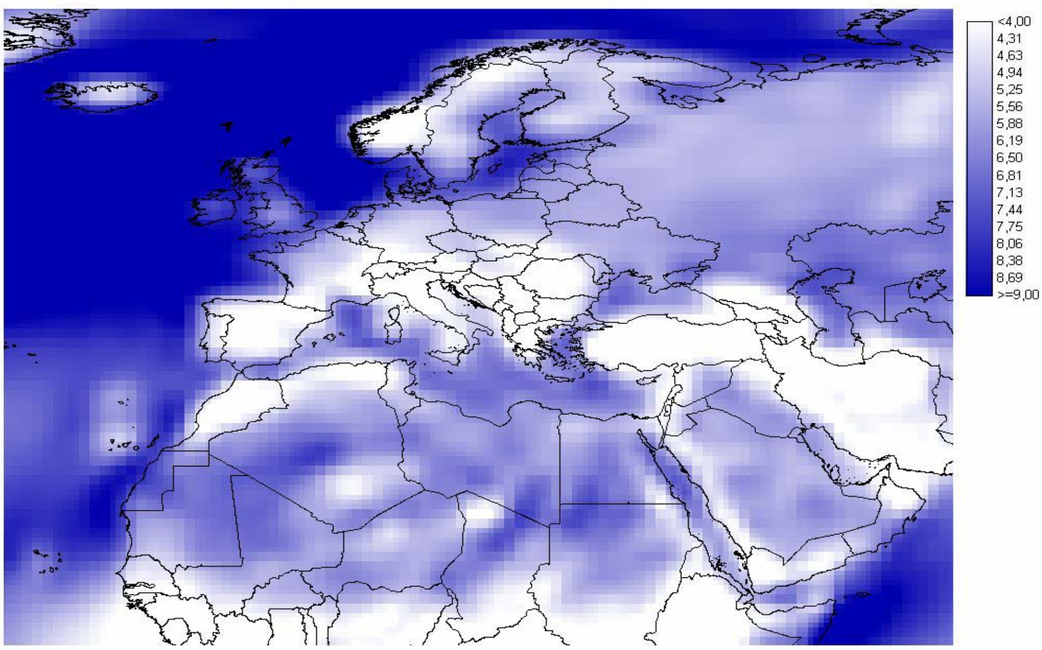
TABLE 4 (*continued*)

Country	Direct Normal Irradiance kWh/m^2/y (for CSP)	Global Horizontal Irradiance kWh/m^2/y (for PV)
Lebanon	2 000	1 920
Libyan Arab Jamahiriya	2 700	1 940
Morocco	2 600	2 000
Oman	2 200	2 050
Qatar	2 000	2 140
Saudi Arabia	2 500	2 130
The Syrian Arab Republic	2 200	2 360
Tunisia	2 400	1 980
United Arab Emirates	2 200	2 120
Yemen	2 200	2 250

Source: Al-Karaghouli, A., 2007. *Current Status of Renewable Energies in the Middle East and North African Region*, United Nations Environment Programme, Regional Office for West Asia (UNEP/ROWA).

Wind resources are more or less locally concentrated and not everywhere available, though the energy they produce can be distributed throughout the electricity grid. Many locations have superb wind conditions for electricity production. These include such countries as Egypt, Morocco, and Oman, which have high average annual wind speed (9-11 m/s in certain locations) together with relatively high capacity factors when compared to a worldwide average of 20-25 per cent. Several other locations have moderate wind speed (6-8 m/s) that is also sufficient for generating electricity.

Figure 5. Annual average wind speed at 80 m above ground level in m/s



Source: DLR, *Concentrating Solar Power for the Mediterranean Region*. (See footnote 9).

TABLE 5. ESTIMATED AVERAGE ANNUAL WIND ENERGY FULL-LOAD HOURS AND CAPACITY FACTORS

Country	Full-load hours per year (h/y)	Capacity factor (percentage)
Algeria	1 789	20
Bahrain	1 360	16
Egypt	3 015	34
Iraq	1 789	20
Jordan	1 483	17
Kuwait	1 605	18
Lebanon	1 176	13
Libyan Arab Jamahiriya	1 912	22
Morocco	2 708	31
Oman	2 463	28
Qatar	1 421	16
Saudi Arabia	1 789	20
Syrian Arab Republic	1 789	20
Tunisia	1 789	20
United Arab Emirates	1 176	13
Yemen	1 483	17

Source: Calculated based on data from Al-Karaghouli, *Current Status of Renewable Energies.* (See table 4).

Note: Capacity factor refers to the percentage of average annual full-load hours to total annual number of hours (8,760 h/y).

The Arab region is witnessing an increasing interest in RE technology, as indicated by the objectives announced by many countries for integrating mainly wind and solar systems in their energy mix. Almost all countries in the Arab region expressed their political willingness to promote RE utilization. In addition to valuable experience gained, various areas of the Arab region have made progress in that direction.

For Arab countries that are net oil and/or natural gas importers, and those with relatively limited reserves, the need for RE resource utilization has direct economical and financial impact in terms of reduced dependency on imported fuel. As for countries with considerable reserves, there is also a need for renewable resource utilization in order to keep, as long as possible, strategic reserves for future generations, and to widen opportunities for economic development in new and promising business areas. Within such context, these countries need to free up as much oil and gas as possible for both export and economic development of the petrochemical sector, powerful incentive for diversification in power generation. The importance is reflected by the fact that certain Arab countries seek to restrict the use of feedstock in power generation. As a matter of fact, utilization of RE resources is not only to secure energy supply, because of cost, or even to protect the environment; it has wider scope related to sustainable development. In contrast to neighbouring European countries, uncertainty in much of the Arab region does not concern future energy consumption levels but rather the socio-economical level of the development countries may reach with the energy available. The challenge for the Arab region is to allow balanced growth while realizing sustainable development.

Scrutinizing the current situation and future prospects for energy demand in the Arab region reveals that RE is a promising development path in terms of electricity generation. RE can relieve part of the economical burden of oil-dependency through expanding the lifetime of existing fossil resources and/or reducing the need to import energy. Furthermore, renewable sources help reduce pollution and limit greenhouse gases. Within the regional context, the potential exists for achieving sustainable energy in the future, not only for the Arab region but also for the neighbouring Northern-Mediterranean countries, a new dimension for regional cooperation which favours both Europe and the Arab world. RE helps mitigate the environmental impact of existing energy systems and generates opportunities for green energy trade and green certificates.

B. EXISTING APPLICATIONS

In general, despite the huge potentials available, it can be stated that REs have played a minor role in the energy mix of the Arab region.

The Experts Committee for Renewable Energy and Energy Efficiency (EE), formed by the Arab Ministerial Council for Electricity and including ESCWA experts as members of the committee, has developed the Arabic Strategy for the Use of Renewable Energy and the Guide to the Potentials of Arab Countries in Renewable Energy, Energy Efficiency, Production and Consumption of Energy. The Strategy and the Guide will be presented to the Arab Ministerial Council for Electricity by the end of 2010 for adoption.

Table 6 shows key activities in the Arab region as well as targets for large-scale renewable capacities announced by Arab countries related to wind and solar power, the main renewable resources under consideration in the study.

TABLE 6. KEY ACTIVITIES IN THE ARAB REGION AND TARGETS FOR LARGE-SCALE RENEWABLE CAPACITIES

Country	Existing and under-construction capacities (MW)		Additional capacity		Country strategy	Comment
	Wind Power	Solar (CSP/PV)	Wind Power	Solar (CSP/PV)		
Algeria		25 (CSP in 150 MW ISCC)* 1.1 (PV)	10	2x70 CSP	10 per cent of electricity from RE by 2030	
Egypt	430	20 (CSP in 140 MW ISCC)* 5.2 (PV)	6 670	240 (CSP) 20 (PV)	20 per cent of electricity from RE by 2020	
Jordan	1.5	0.5 (PV)	>300	8.5 (CSP)	10 per cent of primary energy from RE by 2020	
Kuwait	-	-	-	60 (CSP in 280 MW ISCC)*	5 per cent of electricity from RE by 2020	Technical feasibility study for a ISCC project of 280 MW including 60 MW solar component, has been completed
Lebanon		3 (PV)	>50	50 (PV)	12 per cent of electrical and thermal generation from RE by 2020	
Libyan Arab Jamahiriya	-	0.218 (PV)	1 110	100 (CSP) 17.5 (PV)	10 per cent electricity from RE by 2020, and 25 per cent by 2030	
Morocco	210	20 (CSP in 470 MW ISCC)*	1 440	2 000 (CSP)	21 per cent of primary energy and 42 per cent of electricity from RE by 2020	A plan for a 2000MW CSP plant has been declared

TABLE 6 (*continued*)

Country	Existing and under-construction capacities (MW)		Additional capacity		Country strategy	Comment
	Wind Power	Solar (CSP/PV)	Wind Power	Solar (CSP/PV)		
Qatar	-	-	-	100MW		A 100 MW solar power plant in Qatar Science and Technology Park within the next five years
Saudi Arabia	-	-	50	10 (PV)		10 MW PV systems are expected for water desalination by 2012
The Sudan		0.5 (PV)			1 per cent of electricity from RE by 2011	Hydro Power is not included in the 1 per cent
Syrian Arab Republic	6	0.08 (PV)	150		4.3 per cent of primary energy from RE by 2030	PV cells to be manufactured and put in the market (expected 15 MW PV yearly)
Tunisia	55	1 (PV)	190	200	4 per cent of primary energy from RE by 2014	
United Arab Emirates	-	10 (PV)	>100	1 100	7 per cent of electricity in Abu Dhabi from RE by 2030	Masdar has already connected a 10 MW PV plant to the grid, and expects the 100 MW Shams 1 CSP plant to be on line by late 2011, and the Shams 2 plant in mid-2013
Yemen	-	0.44 (PV)	460	1 (PV)		60MW wind farm is in the development phase

* ISCC: Integrated Solar Combined Cycle

Sources: The Arabic Strategy to Develop the Use of Renewable Energy (2010-2030) and the Guide to the Potentials of the Arab Countries in the Renewable Energy, Energy Efficiency, Production and Consumption of Energy.

IV. CHALLENGES FACING THE ADOPTION OF LARGE-SCALE RENEWABLE ENERGY APPLICATIONS

A. AWARENESS CHALLENGES

Collaborative activities of different stakeholders (governments, developers, investors, lenders, financiers, renewable manufacturers, renewable services firms, traditional energy utilities and companies, trade and export organizations, energy and environmental non-governmental organizations (NGOs), and consumers and energy off-takers) are essential in bringing investment opportunities in REs to top-of-the-list awareness of decision makers, project developers, venture capitalists, banks and insurance institutions. Lack of awareness and information leads to certain misperceptions that include assuming RE systems are small, dispersed, uncertain resources, technologically immature, still in the research and development (R&D) phase, only for environmental concerns, expensive, “only for the rich”, sophisticated in design, installation and maintenance, and not suitable for growth of electrification. Certain misperceptions can be corrected by demonstrating the current position of leading large-scale renewables, especially wind, and their competitiveness in different on-grid and off-grid markets as compared to conventional technologies with fuel price risks.

It is important to illustrate the various benefits related to large-scale deployment of RE sources, leading to economic development, job opportunities and the availability of electricity and drinking water. Taking into consideration the difficult environmental situation in part of the Arab region, it is important that all stakeholders recognize that the costs of conventional-based energy do not completely reflect real costs without taking environmental and social costs into consideration.

Information sharing and the development of networks among multiple stakeholders within the Arab region and abroad is essential and key to success in deploying large-scale RE utilization, permeating all technical, economic and regulatory capacity-building activities.

ESCWA has been active in organizing workshops, experts’ group meetings and seminars and conducting pilot projects and giving technical assistance to the Member states. In the last two years, cooperation with the League of Arab States had been made stronger after the establishment of the Renewable Energy and Energy Efficiency Experts Committee by the Arab Ministerial Council for Electricity, where ESCWA is a member. The joint efforts between the Arab countries, the League of Arab States, the international and regional organizations, including ESCWA, led to the development of the Arabic Strategy for the use of Renewable Energy and the Guide for the Arab Countries Potentials in Renewable Energy and Energy Efficiency.

The situation varies from one Arab region to the other in terms of acceptance or opposition of residents to adjacent renewable projects. For example the study “Climate Change and Energy in the Mediterranean” prepared by Plan Bleu in 2008,[23] reported that in Tunisia, during the establishment of the Sidi Daoud wind farm, a number of initiatives were necessary to convince the local population, farmers and stockbreeders of its benefits, including an information and consultation campaign, compensation for losses of agricultural earnings during the assembly of the farm and, whenever possible, participation in the project. In the case of wind farms in the Egyptian Zafarana desert, the opposite was true; the projects were accepted and even supported by the local communities, requesting only greater access to jobs created. Furthermore, the projects brought with them the establishment of high-quality infrastructure, allowing the construction of world-class touristic villages and resorts on the nearby Red Sea coast, and attracting tourists themselves to visit the wind farms.

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[23] Plan Bleu, 2008. *Climate Change and Energy in the Mediterranean*, A study carried out by Plan Bleu Regional Activity Centre, Sophia, Antipolis, for the European Investment Bank.

B. Institutional challenges

Several national institutions are concerned with or related to RE in the Arab region. As shown in table 7, certain countries have national RE agencies, while others only have departments at the ministerial level. The activities of these national institutions include capacity building, resources/potential assessment, techno-economical studies, R&D activities and pilot/demo and commercial projects. However, it can be noted that not all countries have independent organizations specialized in RE, which reflects the level of development.

TABLE 7. EXAMPLES OF NATIONAL INSTITUTIONS RELATED TO RENEWABLE ENERGY IN THE ARAB REGION

Country	Institution
Algeria	Centre for Renewable Energy Development (CDER); New Energy Algeria (NEAL).
Egypt	New & Renewable Energy Authority (NREA); Academy of Scientific Research & Technology (ASRT); National Research Centre (NRC); Housing & Building Research Centre (HBRC); Egyptian Organization for Standardization & Quality.
Jordan	National Energy Research Centre (NERC).
Lebanon	Lebanese Centre for Energy Conservation (LCEC).
Libyan Arab Jamahiriya	Renewable Energy Authority of Libya (REAOL), Centre for Solar Energy Studies (CSES).
Morocco	Centre for Development of Renewable Energies (CDER); National Centre for Scientific & Technical Research (CNRST).
Palestine	Palestinian Energy & Environment Research Centre (PEC); Energy Research Centre (ERC).
Syrian Arab Republic	National Energy Research Centre (NERC), Scientific Studies & Research Centre (SSRC); Atomic Energy Commission (AECS); Syrian Arab Organization for Standardization & Measurement.
Tunisia	The National Agency for Energy Conservation (ANME); National Agency of Renewable Energy Sources (NARES); National Institute of Scientific & Technical Research (NISTR).
United Arab Emirates	MASDAR Institute of Science and Technology.
Yemen	Ministry of Electricity and Energy/Renewable Energy Section; Rural Electrification Authority.

Source: Based on Al-Yousifi, B. and Al-Karaghouli, A., 2006, *Institutional Prospective of Renewable Energy in the Middle East and North Africa (MENA) Arab Countries*, The Third MENA Renewable Energy Conference, Egypt. Updated with information obtained from member countries.

In addition to the creation of specialized national institutions, framework construction includes strategies, policies and legislation. Most of the Arab region has announced objectives for a RE contribution, either to the total energy production or to electricity generation. Certain countries such as Algeria, Egypt, Morocco and Tunisia have already passed laws for RE. The Algerian law provides preferential tariffs for electricity generated by RE. The Tunisian law applies tax exemptions to support RE and has initiated a financial mechanism to provide support to RE and EE projects. Tunisia and Morocco allow industrial companies to establish wind farms for their own consumption and sell excess power to the grid. Certain other countries such as Egypt and Jordan, have draft laws, ministerial decrees or policy directions for promoting renewables, encouraging private investment and “auto producers”; as well as providing incentives such as grid access, wheeling, preferential tariffs, tax and customs reductions or even exemptions on equipment, components, and materials used for manufacturing, equity subsidy and funds, in addition to having active implementation programmes.

However, in most cases, the Arab region is lacking the necessary effective laws. Even when legislation is enacted, its application, through clear rules and procedures, appears to be limited. An example of ambiguity can be seen in the complexity of grid access for independent power producers (IPPs) and the need to deal with both the transmission utility, and the regulator. The process, in several cases, is simply discouraging, time consuming, difficult and costly. A well-prepared legislative framework allowing easy procedures for access to the grid, accompanied by supportive electricity pricing and contractual obligations is needed to prove real willingness to promote large scale renewables.

Currently, political will for diversification of energy resources as well as initiatives for large-scale applications has been expressed in both national and regional contexts. Certain Arab countries have experience as well expertise, which can be of benefit through existing cooperation programmes.

C. Financial challenges

One of the prerequisites to accessing the huge, diversified and untapped renewable potential in the Arab region is to arrange and secure access to adequate finance for sustainable business development. The large-scale renewable market should be attractive to private investment on one hand, while on the other hand, should provide services that are affordable as well as acceptable to customers.

In most of the Arab region, renewable resource assessment and development costs for projects (resource mapping, exploration and area planning) can be tolerated by Governments but rarely by private developers. Moreover, project location is decided by the relevant governmental entity as infrastructure needs to be available.

Provided that there is a political will, oil-rich, high-income Arab countries can easily assume the investment risks associated with such development phases. However, for the rest of the Arab region this will be difficult, considering the economic situation and financial structures, as well as priority lists that include health, education and infrastructure. Based on experiences of the Arab region's leading countries in large-scale wind and solar projects, the support of bilateral/multilateral agencies has proven to be indispensable at these introductory stages.

However, to get this support, there should be clear commitment by the Government in considering renewables in its energy mix. Furthermore, Governments are responsible for minimizing market distortions, economic and political instability, regulations and dispute risks which will encourage the interest of project developers and financiers as well as other key stakeholders.

Governmental support is a prerequisite, especially in the introductory phases. Egypt announced strategic and dynamic resource assessment activities with the help of the international community as well as incentives (land allocation, grid connections, finance of local costs and governmental payment guarantees) that attracted international financiers to contribute to several wind projects in Egypt. Similar examples exist to different extents in Algeria, Morocco and Tunisia.

A World Bank survey[24] investigated the conditions a foreign private investor seeks for entering the power sector business in developing countries, and the causes for the success or failure of the executed investments. It was found that primary conditions for entering into business are adequate legal protection and framework, and guarantees from Government or multilateral agencies. For large-scale renewable projects, the latter are crucial to the support of business until it reaches commerciality. The second key condition is consumer payment discipline, indicating that investors expect that adequate, sustainable revenues to fund the proposed investment will be collected from the customers. As a consequence, the key factors for success or failure identified were the level of tariffs received, tariff adjustments, and regulatory commitment (sustained through long-term contract). Thus, two major prerequisites for success are that renewable-based projects be competitive and economically feasible in that revenues are sufficient to cover all costs plus an "adequate" expected return on investment, to compensate for potential associated risks, and that institutional and legal frames are clear, and give enough confidence to the investor and the financier to guarantee sustainability of the business.

[24] Lamech, R. and Saeed, K., 2003. *What International Investors Look For When Investing In Developing Countries. Results from a Survey of International Investors in the Power Sector*, Energy and Mining Sector Board Discussion Paper, No. 6, World Bank.

Most existing financing and incentives schemes applied in European countries allow money to flow at the end of the construction period after projects begin operating, but not up-front, where most of the costs are incurred. Different schemes include feed-in tariff/premium incentive systems (Germany, Spain); quota systems including tradable green or RE certificates (Britain, Italy) and production tax credit (United States of America). Application of these schemes in the Arab region must be encouraged. In particular, the feed-in scheme is known to have greatest impact in mobilizing investments and accelerated renewable technologies development. However, any scheme must be adapted to the capacities of the financial sector and private investors.

Certain Arab countries have already realized the importance of adopting supporting schemes for renewable electricity. For example, in 2004, Algeria issued a decree on energy diversification introducing attractive feed-in tariffs for the electricity produced by REs. A law on RE was enacted in the same year, setting concrete objectives of RE contributions in the national energy mix and establishing incentive measures (green certificates and carbon credits). In 2008, Egypt announced policies to increase the contribution from wind power, consisting of two phases. The first will adopt a competitive-bid approach through issuing tenders requesting the private sector to supply power from wind energy and sign long-term power purchase agreements (PPA) with the selected investor. The second phase will increase opportunities for market forces through implementation of feed-in-tariffs, taking into consideration the prices achieved in the first phase. The prequalification document for the first wind competitive-bidding project of 250 MW was issued in May 2009.

In the Arab region, competition with conventional power projects is uneven, as conventional-based energy, in most cases, is heavily subsidized. For most RE technologies the kWh cost is higher than for the conventional kWh. On-shore wind energy has reached commercially-viable cost levels, provided subsidies on electricity and oil products are removed, or at least equivalent subsidy is provided to the wind energy industry. Market distortions generated by subsidies to fuel prices and end-user tariffs can prevent the creation of an attractive, transparent market, but rapidly phasing out subsidies to conventional energy, in the short to medium term, can have intolerable social and economic impact. Timely international support is imperative to overcome this critical issue.

One important way to tackle this challenge is the establishment of an RE fund to cover the gap between RE cost and market prices, taking into consideration adequate marginal profits that foster private sector investment in RE. The fund can be financed by different resources, the most appealing of which are the savings in fuel costs from RE that would have otherwise been consumed in conventional power plants to produce the same amount of electric energy. Such a concept of an RE Fund is already applied or foreseen in Egypt and Jordan. Moreover, Morocco has announced a US$1 billion fund for renewables and EE,[25] and MASDAR of the United Arab Emirates has invested heavily in R&D, education and capacity building as well as project development and implementation.

In general, if any renewable technology reaches a cost of US$0.10 per KWh of electricity generated (assuming an oil price of about US$70/barrel) it can be considered as being economically competitive or close to competitiveness. Provided that resource and market conditions are favourable, the economical or nearly-economical RE technologies are small and large hydropower, onshore wind power and biomass power. Solar PV and CSP technologies are expected to be economically competitive in the long term when cost reductions stemming from continued R&D seeking higher productivity and efficiency, as well as large-scale applications (economy of scale) are achieved. For the ESCWA region, wind and solar technologies are considered to be the most promising, as there are considerable potentials that will allow for large scale grid-connected electricity generation. Table 8 depicts the cost of electricity generation from different types of RE sources.

[25] REN21, *Renewables Global Status Report*. (See footnote 15).

TABLE 8. INVESTMENT AND ELECTRICITY GENERATION COSTS FROM RENEWABLE SOURCES

Energy source	2008 kW Investment (US$)	2008 kWh Generation cost (US cents)	2030 kW Investment (US$)	2030 kWh Generation cost (US cents)
Hydro	1 970-2 600	4.5-10.5	1 940-2 570	4-10
On-Shore Wind	1 770-1 960	9-10.5	1 440-1 600	7-8.5
Off-Shore Wind	2 890-3 200	10-12	2 280-2 530	8-9.5
Biomass	2 960-3 670	5-14	2 550-3 150	3.5-12
Grid Connected PV	5 730-6 800	36-75.5	2 010-2 400	14-30.5
Solar Thermal	3 470-4 500	13.5-37	1 730-2 160	7-22
Geothermal	3 470-4 060	6.5-8	3 020-3 540	5.5-7
Tidal	5 150-5 420	19.5-22	2 240-2 390	10-11.5

Source: Organisation for Economic Co-operation and Development (OECD)/IEA. *World Energy Outlook 2009*, p. 270.

D. TECHNOLOGICAL CHALLENGES

Certain technologies adopted for large-scale projects, such as wind and CSP systems, are considered technologically matured. However, these technologies are continuously being developed. For example, the wind turbine sizes and configurations that prevailed 10 years ago, have increased more than fivefold and the technology has dramatically changed from stall technology to pitch controlled and from gearbox drive to gearless drive. As for trough CSP systems, the troughs that are used today in Europe and the United States are the result of heavy R&D. All other CSP technologies being used in large-scale projects are only old in concept but recent in technology. Even so, it is clear that there are several challenges related to the lack of technical knowledge, limited industrial capabilities, insufficient R&D and inadequate technology transfer.

Furthermore, most technologies are designed for climatic conditions different from those prevailing in the Arab region, which experiences high temperatures, humidity and dust. Thus, technology providers have opted for some changes, adding extra cooling units and improved coating materials. Any project's economic viability depends on its life time and projects are typically amortized in an average range of 10 to 25 years, making it essential that such projects work efficiently throughout.

There are growing efforts, initiatives and agreements for R&D in different fields of renewables all over the region. This movement is noted, for instance, in Algeria, Egypt, Saudi Arabia and the United Arab Emirates. Mostly it takes the forms of bilateral and multilateral cooperation with relevant research institutes in industrial, typically European, countries. Such cooperation aims at strategic partnerships for electricity generation through renewable technologies. The interest in cooperating is mutual, as the Arab region benefits by developing its scientific base and realizing pilot power plants in different climatic conditions. Such opportunities lead to technological improvement while defining new commercial prospects for their development.

Technology transfer is a key element in the development of the RE market in the region. This includes learning, understanding, utilizing, choosing, replicating, adapting and integrating technologies appropriate to local conditions. Cooperation and diffusion of technology, including expertise, equipment, operations and maintenance, across and within countries, is needed to ensure knowledge transfer.[26] Different stakeholders must be involved in the process starting with governments, NGOs, private sector entities, research/education and financial institutions. R&D efforts and technology transfer will allow for the conceptualization of products adapted to regional weather conditions leading to new industries in the Arab region that promote national and regional interests. To achieve this, market volume must encourage investors to develop, expand or even initiate local industries, either through joint ventures, manufacturing under licenses, acquisition of shares in existing companies, or by developing their own products through engineering houses.

[26] Andersen., S. et al. *Methodological and Technological Issues in Technology Transfer*, Intergovernmental Panel on Climate Change, Special Report, UNEP, World Meteorological Organization, p. 3.

The wind energy project in Egypt encourages bidders to use existing local industrial capabilities, and provide lists of qualified industrial firms for different project components. From an economic perspective, it is less expensive to use Egyptian capabilities, while enhancing local manufacturing and services, generating job opportunities and gaining the technological know-how. The recorded local industry share of large-scale renewable wind projects in Egypt is about 40 per cent.[27] For example, the existing metal industry manufactured wind turbine towers that were even exported to other countries. This is not only relevant to the industry, but also to the services sector which benefits from such project investments. These local costs include turbine-tower manufacturing, civil and electrical works, as well as inland transportation, customs and any other local activities. However, the local components do not include certain major wind-turbine components such as blades, nacelles, gearboxes or generators. It is anticipated that the local share will increase with the growing demand for wind turbines in Egypt associated with the realization of the ambitious plan of 2020, prompting more reliance on local components. The signs of such transition are noticed as certain major private industrial firms have already bought shares in a Spanish company manufacturing wind turbines, and initiated local manufacturing activities, with the intent of serving expanding national and regional markets. CSP projects also provide excellent opportunities for local industries. The first Egyptian ISCC of 140 MW including a solar field of 20 MW, executed by a consortium headed by an Egyptian company, was commissioned during the fourth quarter of 2010. About 50 per cent of the solar field is locally manufactured. This includes the solar field steel structure, cables, civil, mechanical and electrical works. It is also foreseeable that in the future, existing industrial capabilities will be adapted to manufacture most of such important components of CSP technology, as mirrors and receivers.

One of the key challenges, the availability of qualified manpower, can be also viewed from the angle of potential job opportunities. Probably this is the main technological asset with respect to large wind power projects that is partially available in the leading Arab countries, notably Egypt and Morocco. For other technologies, capacity-building activities vary from one technology to the other, and vary from being diligently pursued in certain countries, to being ad hoc, on-the-job, random and infrequent in other countries. Even for the wind power projects, satisfying manpower needs for achieving the announced targets and ambitions may be difficult.

The Global Wind Energy Council estimates that employment in regular operations and maintenance (O&M) work at wind farms contributes 0.33 jobs for every megawatt of cumulative capacity.[28] Accordingly, about 17 jobs should be sufficient for each 50 MW. However, the local context must be taken into consideration. The wind farms are located in arid desert areas, with high capacity factor (more operating hours per year), high temperature, high turbulence and sandy weather, which result in accelerated wear and tear of components and a higher rate of failure after a few years. Such circumstances necessitate more employment in O&M activities. To date, considering only the announced plans for capacity increase in the Arab region, large wind farms are expected to generate a total of 12 GW by 2020, with a possibility for further expansion. Realizing such plans will require training a qualified work force of about 4,000, within the next few years, for O&M, only, consistent with international standards to ensure the sustainability of the business. Resource assessment, project engineering, installations, and manufacturing of plant equipment and components are areas where qualified human resources are required. In the field of solar energy, it is expected that 400 full-time manufacturing jobs, 600 contracting and installation jobs and 30 annual jobs in O&M will need to be filled for every 100 MW solar plant.[29] The approach of ad hoc, on-the-job training can no longer be implemented if large scale RE projects are intended.

The renewables potential in the Arab region is sufficient not only for development requirements locally, but also to partially satisfy needs of neighbouring regions. Thus, the Arab region can benefit directly

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[27] New and Renewable Energy Authority of Egypt, *Annual Report 2009-2010*.

[28] GWEC et al. *Global Wind Energy Outlook*, p. 45. (See footnote 3).

[29] European Solar Thermal Electricity Association (ESTELA), 2008. *Solar Thermal Electricity: Contributing to achieve the 20% of RES in the energy mix by 2020*, p. 5.

from existing European Union directions that open the door to RE electricity imports from the Middle East and North Africa countries, by allowing one or more member States to cooperate with one or more third countries on all types of joint projects regarding the generation of electricity from renewable sources, where cooperation may involve private operators. However, the shortage of electrical interconnection capacity between the south and the north is a major limitation.

The most ambitious plan for north/south cooperation is the Mediterranean Solar Plan (MSP). The MSP, born under the scope of the "Barcelona Process: Union for the Mediterranean (UfM)", and launched in July 2008, is one of the strategic processes for sustainable development responding to the foreseeable increase in energy demand and the need to cut back greenhouse gas emissions in the Euro-Mediterranean region. Its main objective is to develop 20 GW of renewable electricity capacity on the South Shore of the Mediterranean, and the necessary infrastructures for interconnection with Europe. MSP also envisages *Saving, Energy Efficiency and Technology Transfer*. A key element to the development of this plan is a suitable, new regulatory framework to promote the establishment of REs, and facilitate the exchange of electricity. MSP is a huge step forward in the development of Euro-Mediterranean cooperation policy in the field of energy, which began with the Barcelona Process in 1995, has been integrated in the European Neighbourhood Policy since 2007 and reinforced with the UfM since 2008.

V. RECOMMENDATIONS FOR PROMOTING LARGE-SCALE RENEWABLE ENERGY APPLICATIONS

The key stakeholders involved in the large-scale renewable business are governments, developers, investors, lenders, financiers, renewable manufacturers, renewable services firms, traditional energy utilities and companies, trade and export organizations, energy and environmental NGOs, and consumers and energy off-takers. Responsibilities must be shared by all stakeholders in all development phases.

However, in the Arab region, Governments are the main stakeholder and have a primary role in promoting and encouraging the deployment of large-scale RE and EE techniques and projects. The positive economic impact at the local and regional levels should be well understood and managed in order to fully benefit from the different opportunities that the introduction of a renewable economy offers. Adequate policies and incentives along with capacity building, and contractual and technical-enabling conditions are the main areas where Governments can intervene.

A. POLICIES AND REGULATIONS

As RE projects usually have a high capital to operations cost, where the initial investments form the greatest share of total project spending, investors are cautious to invest in RE in a country unless there are clear rules and regulations that would protect their investments at least for the anticipated project life cycle. These include clear ownership and facility control rules which would be strengthened with governmental and/or international multi-tier guarantees. Consistent rules and regulations at the local and national levels encourage developers to invest in areas that are most suited for the project.

Energy market structure and policies play a major role in promoting the deployment of large-scale RE. Electricity and oil product subsidies can hinder the development of RE projects, as conventional power supply based on fossil fuels becomes less expensive. Subsidizing RE projects through different funding and trading mechanisms helps counterbalance these market distortions. Such mechanisms can be established as RE funds using the “anticipated fuel savings” from RE projects for financing.

Government incentives in the form of tax reduction, exemptions and/or carbon credits would reduce initial investments costs and consequently, the capital to operations ratio. Moreover, the Government must clarify, facilitate and expedite protocols for applications, approvals, licensing and issuing permits for the RE projects. As a market driver and starter, governments might acquire RE through a competitive-bidding process with known renewable portfolio standards.

Finally, adopting favourable tariff pricing promotes investments in RE. Tariff pricing should include standby charges, capacity availability and feed-in tariffs. As feed-in tariffs play an important role in promoting RE applications, the following subsection deals with it in more detail.

B. FUNDING AND TRADING MECHANISMS

Regional or international mechanisms, such as the Clean Development Mechanism (CDM), are an option. The Kyoto Protocol has set emission reduction targets for Annex I (industrialized) countries, to be, on average, 5.2 per cent below 1990 levels during the first commitment period of January 2008 - December 2012. The Arab region is comprised of Non-Annex I Parties and therefore stands to benefit from CDM which also allows industrialized countries to achieve part of their emission-reduction commitments by implementing emission-reduction projects in developing-world countries without emission reduction targets.

The Arab region is a relatively new entrant when it comes to emissions trading. CDM projects have been undertaken in certain countries, mainly in cooperation with industrialized countries. In order for the Arab countries to tap the benefit of CDM or other similar mechanisms to follow, they have to prepare accordingly. Prerequisites are clear institutional structures and transparent CDM procedures to facilitate the smooth implementation of these ventures. Governments need to strengthen local institutions and build their own capacity to initiate and undertake projects. This desperately requires support from developed countries and multilateral institutions.

Currently, there are CDM projects in such countries as Egypt, Jordan, Morocco, Tunisia and the United Arab Emirates. In the Gulf, many companies and consulting firms have begun to explore this fast-developing field. The New and Renewable Energy Authority of Egypt was the first entity to pursue a CDM project in the field of RE (wind) in the ESCWA region.

The emissions factor may vary from less than 0.5 to more than 0.8 tCO_2 eq/MWh of electric energy produced depending on many factors, the most important of which is the type of fossil fuel used. Accordingly, the potential revenue from the CDM will be between 0.5 to 1.5 cent Euros per kWh, constituting between 4 to 20 per cent of the kWh cost. A study in 2005[30] presented the impact of carbon financing to a proposed 60 MW Wind Farm project in Zafarana, Egypt (table 9). This example showed that at the Certified Emissions Reductions (CER) price of US$10 per tCO_2, the project's internal rate of return (IRR) increased by 3.38 per cent while the return of equity rose by 8.24 per cent.

TABLE 9. CARBON FINANCING IMPACT ON PROPOSED 60 MW ZAFARANA WIND PROJECT IN EGYPT

Economic Indicators	Without Carbon Finance	With Carbon Finance at US$10 per tCO_2eq
Internal Rate of Return (per cent)	5.63 per cent	9.01 per cent
Net Present Value (US$)	US$ 2 954 117	US$ 20 320 777
Return on Equity After Taxes (per cent)	19.10 per cent	27.34 per cent

Source: Painuly, J. et al. *Wind power and the CDM*, p.40. (See footnote 30).

The study also presented a table (replicated in table 10) showing the impact of CERs on IRRs in selected projects including a project in Morocco. The table shows that the impact of CERs on wind power project IRR is relatively small.

TABLE 10: EXAMPLES OF IMPACT OF CERTIFIED EMISSIONS REDUCTION ON PROJECT INTERNAL RATE OF RETURN

Country	Project	IRR without Carbon Finance (per cent)	IRR with Carbon Finance (per cent)	Change in IRR (per cent)
Brazil	Biomass	8.3	13.5	5.2
Costa Rica	Wind power	9.7	10.6	0.9
Guyana	Bagasse	7.2	7.7	0.5
India	Solid waste	3.8	18.7	5
Jamaica	Wind power	17	18	1
Morocco	Wind power	12.7	14	1.3

Source: Painuly, J. et al. *Wind power and the CDM*, p. 40. (See footnote 30).

C. FEED-IN TARIFFS

Feed-in tariffs help in accelerating the deployment of RE, thus having a direct influence on the development of the RE market, with a greater impact than other tax incentives. Feed-in tariff-design should be seen as a powerful policy tool to enhance RE applications within the context of energy security and

[30] Painuly, J., Clausen, N., Fenhann, J., Kamel, S. and Pacudan, R., 2005. *Wind power and the CDM, Emerging practices in developing wind power projects for the Clean Development Mechanism*; Energy for Development, Risø National Laboratory, Denmark.

greenhouse gas emissions-reduction objectives. By guaranteeing long-term electricity purchase, developers benefit from the total amount of energy generated from the renewable source. To be effective and cost-efficient, the feed-in tariffs typically provide an encouraging price for every kilowatt-hour (kWh) of electricity generated from a renewable source for a period of 10 to 25 years. The kWh price levels differ according to the technology type, project location and resource quality. The success of feed-in tariffs depends on targets and policy goals set by policy makers. The main three components of a feed-in tariff policy are grid-access guarantee, clear long-term purchase agreements and kWh price levels that depend on the cost of the energy generated from the renewable source. The feed-in policy may include clear and coherent administrative procedures aiming at easing bureaucratic burdens, minimizing lead times and reducing projects costs.

Adoption of the European experience in feed-in tariffs and adapting it to the national and regional context would be crucial for the deployment of large-scale RE. Such a scheme would be funded from diverting part of the electricity and oil-product subsidies into the RE industry.

On the other hand, climate change mitigation is a global issue that requires the cooperation and coordination at the international level. The MSP project suggests generating electricity from RE on a large scale in southern and eastern areas of the Mediterranean region and transmitting the generated electricity to the north. If the northern countries buy this electricity from the Arab countries using feed-in tariffs adopted in Europe, the Arab region would become an attractive place for investment in REs.

D. CAPACITY BUILDING

Capacity building and awareness are of prime importance for the deployment of RE projects. The lack of know-how and expertise will jeopardize any promising project and be seen as a bad case study limiting the growth of future ventures.

ESCWA, along with other United Nations and regional institutions like the League of Arab States/Arab Ministerial Council for Electricity, are holding several capacity-building events and mounting awareness campaigns in the region. Centres of expertise in the Arab region have multiplied and professional networks have formed as a result of these efforts. Additional effort shall be made in this respect, building on past and international experience to create perception-correction campaigns, share risk management approaches, and give training in project development and financing. These activities will be aimed at overcoming the lack of knowledge and cautious attitude toward renewables.

In order to build knowledge and know-how, establishing specialized training and consultancy institutions should be encouraged to prepare qualified human resources for large-scale renewable projects. Other specialized service companies that would serve IPPs must also be established on both the national and regional levels.

E. CONTRACTUAL CONTEXTS

On the contractual context, clear regulations shall be adopted to facilitate the development of adequate PPAs suited for large-scale RE projects. Such PPAs would differ from fossil fuel-based projects' PPAs in that the major project cost of a RE project life cycle is paid during the initial capital investment period making developers and investors keen for long term guarantees of investment returns.

Moreover, contracts must allow developers to assess and access potential benefits from different financing mechanisms. Contracting parties as well as the Governments and other stakeholders must facilitate the processes needed to reach different financing mechanisms. Structuring RE projects for financing includes building an investment proposal (equity, debt, "Green" trades and financing mechanisms, grants) along with a clear PPA and a security package that contains the implementation, land conveyance, ownership structure, equipment, construction contract, and operation and maintenance agreements. Clear dispute-resolution processes and rules should be highlighted to provide a trustful environment needed for project start up.

F. Grid readiness

As mentioned above, building expertise and technical know-how for assessing grid connection points, grid stability and protection requirements and equipment and capacity needs is of prime importance for the rapid deployment of RE projects. Clear metering procedures must be adopted for contractual and technical issues. Metering processes should tackle telemetering/communication channels and net metering.

All concerned parties must cooperate to enable the existing transmission grid absorb generated power and remove bottlenecks that hinder the deployment or full use of the RE plant. Advanced control centres and transmission grids are needed to transfer large-scale solar or wind-based electricity generation from deserts and/or remote areas to the load centres in main cities.