Climate Change Research on Energy Efficiency in the Arab Region

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Climate Change Research on Energy Efficiency in the Arab Region

Report Objectives

- Present an overview of current research on energy efficiency and renewable energy in the Arab region
- Prospects of the research agenda in this field for the five coming years based on the needs of the region, the market dynamics and the global context.
- Provide recommendations on major opportunities for interventions to enhance sustainable energy practices and development at the policy, institutional, technical, research, and advocacy level, and the impact of these interventions on economic growth, private sector development, governance, security, education, and quality of life.

Introduction

The aim of this report is to present the most prominent research work undertaken in the Arab region during the past five years in the area of energy efficiency and renewable energy. Information and analysis are presented in three sub-regions as defined in the Arab Human Development Report (2010): 1) The Middle East and North Africa (MENA), namely, Algeria, Egypt, Iraq, Jordan, Lebanon, Libyan Arab Jamahiriya, Mauritania, Morocco, the Occupied Palestinian Territory, Tunisia, Syria, and Yemen; 2) the States of the Gulf Cooperation Council (GCC), namely, Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates; and 3) the Sub-Saharan countries, namely, Comoros, Djibouti, Somalia and Sudan.

The division of the Arab countries into these regions is strongly linked to geographic connectivity, climatic zoning, socio-economic aspects, natural resources, vulnerability patterns to climate change, and development status. The UNDP Arab Human Development Report pointed out the high vulnerability of the Gulf region to climate change and to mitigation policies aimed at reducing oil consumption, while the MENA region is most vulnerable on accounts of water scarcity, and the sub-Saharan region is vulnerable to the risk of environmental changes where adaptation strategies are not affordable by the poor population. The above division of sub-regions is also applicable to research foci related to energy efficiency and renewable energy resources and systems. Much of the research work targets water desalination and water production technologies, renewable energy source assessment and its use in electricity generation, solar energy applications, energy conservation and efficient energy systems in the building sector including district cooling, heat recovery, efficient cooling and heating systems and processes. Universities and research centers have dedicated resources to energy research.

Addressing ongoing energy research in the Arab countries cannot be separated from the surrounding market changes, governmental projects, partnerships, and policies in renewable energy applications, and private investments in green products. A growing concern in many Arab countries has led to the consideration of strategic energy options beyond oil and gas. Some countries have declared their interest in nuclear power generation while a few are considering wind and solar energy in a region which is rich with sun energy almost the year round. Arab countries in the MENA region are estimated by the firm Forst and Sullivan [Ramavarman, 2009], to have a potential to generate 630,000,000 megawatts of solar power, and also 75,000 megawatts of wind power potential. The UAE is now hosting the newly established International Renewable Energy Agency (IRENA), a step which may encourage other Arab countries to engage more fully in renewable alternative energy generation. According to the Gulf Research Center (GRC)'s online newsletter *alert,* in October 2009, the Six GCC countries will invest $200 billion in 120 renewable energy projects, to be implemented in the next two decades. The UAE signed a $20 billion contract to build nuclear power plants in December 2009 with a Korean Consortium, led by Korea Electric Power Cooperation (KEPCO). This partnership will design, build, help operate and maintain four civil nuclear power plants, at 1.400 MW each, for a peaceful energy program for the UAE. Egypt, Kuwait, Saudi Arabia and Morocco, have been considering the nuclear option without any commitment to the near future. Jordan, on the other hand, has opted to build a 5MW Nuclear Research Reactor for training and research.

Algeria announced an ambitious plan to generate 10% of its electricity from renewable energy sources by 2020 (reported by the Algerian News agency, in October 2009). One project initiated in 2007 by the New Energy Algeria (NEAL) in partnership with the Spanish company Abener, is a $350 million natural gas and solar energy hybrid power station 1,000 kilometres south-west of Algiers. The plant is the first in a series of combined-cycle hybrid plants that will have the capacity of 500 MW, or 5 percent of national generating capacity, by the end of 2012. Morocco is to use the most recent technology of solar energy to build a large solar project; the $9 billion project is expected to produce 38% of the country's power by 2020. The project consists of five power generation sites, to produce 2000 MW of electricity, with a combined surface area of 10,000 hectares.

KSA is hoping to produce enough solar energy for local consumption and for export, within 30-50 years. It established a "Silicon Wafers" manufacturing plant in Joubeil Industrial City in November 2009, with an investment capital of more than $ 1 billion that would include acquiring needed technologies and building local expertise and capacity. Tunisia is building 40 solar plants by 2016, as part of a national solar plan aiming at reducing GHG emission by 22%. The plan is supported by the World Bank Clean Technology Fund. Tunisia has already launched several solar energy cooperation projects with German, Italian and Japanese companies (reported by *Almagharibia online* [http://www.almaghribia.ma/] on 20 October 2009). In April, 2009, he Tunisian electricity and gas company (STEG), announced the launch of a project dubbed "Solar Roofs" which offers the possibility for individuals to produce and sell their own electricity from solar photovoltaic panels. A subsidy of about 30% of the cost will be absorbed by Tunisia's National Energy Management Fund (FNME). In the Syrian Arab Republic, a government directive was adopted in the mid nineties, in favor of the utilization of solar energy, whereby new houses, whether in the city or in the countryside, cannot be licensed unless the solar system plans are taken into consideration. Furthermore, the Syrian government offers a loan of about 640 Euro to the buyers of solar systems for a period of 3 to 5 years.

The Arab governments' and public and private companies' investments in the Gulf and MENA region have also resulted in the expansion and the re-direction of research priorities in universities and educational institutions. More funding is available to develop, adapt, train and prepare for the demands of the new labor markets of green energy businesses and product investments. Serious research output relevant to the local market is taking place and is attracting students and faculty to contribute to the development of knowledge at home.

New research institutions established in the Gulf countries in partnership with US and European institutions have directed energy research to topics relevant to the region. KSA and the UAE started the race for utilization of solar and wind power. A few examples are listed here among the many projects within GCC countries:

- The Gulf Research Center (GRC) in the UAE, in association with the Institute of Communications and Computer Systems of the National Technical University of Athens (ICCS-NTUA), and with other partners http://www.ameinfo.com/219791.html , is working to establish a permanent network of institutions from the GCC and the EU to act as catalysts to coordinate and develop cooperation on clean energy and related policy and technology needs among various stakeholders in the EU and GCC countries.
- Masdar Sustainable City is producing its electricity through solar power complexes [Sgouridis and Kennedy, 2010]. Masdar Institute of Technology (A cooperative program with MIT) is pursuing advanced research in areas of energy efficiency and renewable energy tackling hybrid solar thermoelectric and photovoltaic efficient energy conversion at low cost and high efficiency, energy generation from waste, and improving efficiency of building cooling systems.
- At King Abdulaziz City for Science and Technology (KACST), the Energy Research Institute in KSA has launched the first Middle East research center for developing more energy efficient solutions http://www.ameinfo.com/215469.html. The Middle East Energy Efficiency Research Center aims to promote more efficient use of energy in technology devices through conducting and sharing research with leading universities across the Middle East.
- King Abdullah University of Science and Technology (KAUST) http://www.kaust.edu.sa/research/research.html, inaugurated in September 2009, has placed energy research as one of its strategic research thrusts. It has established the Clean Combustion Research Center, the Solar and Alternative Energy Science and Engineering Research Center, and the Water Desalination Research Center among its other research centers.
- In 2007, the Ministry of Higher Education (KSA) established a Center of Research Excellence in Renewable Energy (CoRE-RE) at KFUPM. The aim of the center is to further the scientific/technological development in all the major areas of renewable energy with an emphasis on Solar Energy http://corere.kfupm.edu.sa/.

These centers are directed and run by some of the most prominent researchers in the world, and in partnership with top institutions which are targeting research advancement and knowledge generation at global and regional levels. Research and development has accelerated in the GCC countries in the past five years despite the world economic crises, and has attracted skilled academics and professionals from around the world.

Research and development in energy efficiency and renewable energy utilization has emerged in the MENA region as a strategic priority. This is the result of relentless work of regional governments with the UNDP, the World Bank, USAID, ESCWA, IDRC and EC organizations to push forward sustainable development, mitigate climate change, seek alternative energy sources to expensive conventional fuel commodities, and conserve energy in the production, economic, agricultural and transportation sectors.

The non-profit organization DESERTEC Foundation http://www.desertec.org/en/concept/summary/, was founded in 2008, to realize the use of the deserts solar and wind energy around the equatorial regions of the Middle East and North Africa. The foundation seeks to study desert environments and to bring existing renewable energy generation technology into service to improve the global security of energy, water and the climate. The DESERTEC concept describes the use of renewable energies to produce sustainable electricity for Europe, North Africa and the Middle East up to the year 2050 and to use fossil fuel only as back up. One of its recent projects is the DESERTEC Industrial Initiatives (DII) in which twelve European countries agreed in July 2009 to use the Moroccan Desert in order to import green energy into Europe. Concentrated solar power, photovoltaic systems and wind systems will be installed on 17,000Km^2 in the desert. The generated electricity will be transported into European and African countries by a super grid of HVDC lines; losses from transmission will be up to 15%. This initiative will increase green labor markets in the MENA sub-region and will influence its research and green development activities. MENA sub-region countries have already been involved in several energy activities in the past two decades with main financing sources coming from foreign funds creating massive human expertise, local capabilities in the renewable energy and energy efficiency fields [ESCWA, 2008].

MENA benefits also from the UNEP Mediterranean Action Plan (UNEP/MAP) that was founded in 1975 by 16 Mediterranean countries and the European countries http://www.unepmap.org/. The MAP is concerned with helping to assess and control marine pollution and to formulate environmental regulations. One of its centers is the Regional Activity Centre for Cleaner Production (CP/RAC) which promotes mechanisms leading to sustainable consumption and production patterns and sound chemicals management in Mediterranean countries. In the framework of the Mediterranean Action Plan, in 2009, the countries of the Mediterranean joined forces with the World Bank, regional and international organizations, as well as non-governmental organizations, to establish a Strategic Partnership for the Mediterranean Large Marine Ecosystem (LME) with over 100 million US$ in funding for the joint implementation of actions for the de-pollution of the Mediterranean. This project will contribute to sustainable development and promotes the use of renewable resources in the MENA countries that include Algeria, Egypt, Lebanon, Libya, Morocco, Syria, Tunisia and the Palestinian Authority. In addition, energy research centers are flourishing in MENA countries in various terms of association with governments and or public and private universities [GNESD, 2006]. Examples include:

Jordan : National Energy Research Council, Renewable Energy Department at the Ministry of Energy and Mineral Resources and Renewable Energy Center.

Syria : National Energy Research Center and Renewable Energy Office at the Ministry of Electricity.

Lebanon : The Lebanese center of energy conservation (LCEC) is a national organization supported by the Lebanese government and associated with Ministry of Energy and Water Resources.

Egypt : National Renewable Energy Authority (NREA)

Algeria : Agency for Promotion of conservation of Energy Utilization.

Libya : Renewable Energy Authority of Libya (REAOL)

Morocco : Center for Information of Renewable Energy and Environment

These centers aim at promoting the use of renewable energy resources such as solar, biomass, wind, and geothermal energy. They are involved in operating labs and developing standards for energy efficiency in various systems and processes. Their impact remains limited because of constrained financial support and incentives. Many of these centers have become partners in the Regional Center for Renewable Energy and Energy Efficiency (RCREEE). This center was established in 2008 by Denmark, Germany, the European Union, and Egypt as an independent regional think tank based in Cairo. It is dedicated to the promotion of renewable energies (RE) and energy efficiency (EE). RCREEE formulates and disseminates policies in support of RE and EE and provides a platform for the regional exchange on policy issues and technological questions. The Center organizes workshops in the region and has some limited research support to pilot projects.

Universities have moved faster in terms of providing energy education at the graduate level and in steadily tackling applied energy research issues that are relevant to their countries. Another example is the Lebanese Center of Energy Conservation (LCEC) initially established in 2002 as the Energy Planning Center housed in the Ministry of Energy and Water (MEW) with support from UNDP. It is now receiving more support from the EU to expand its mandate and transformed into a full-fledged national agency under the MEW. The center will have extended responsibilities for energy audit/saving incentive schemes, standards and labeling, promoting the use of renewable energy and, importantly, become a promoter for the Clean Development Mechanism (CDM) for carbon off-sets. Since 2005, the LCEC has operated on a project basis with the support of GEF, the MEW and bilateral donors, and under the project supervision of UNDP. LCEC has developed energy efficiency standards and labels for appliances (in cooperation with Libnor), helped in the launch of Energy Services Companies (ESCOs) able to conduct LCEC-funded energy audits for companies and institutions, helped to install solar panels donated by China, Sweden, and Greece in poor villages, and conducted awareness campaigns.

The Sub-Saharan region is the least research-oriented and its research work in the past few years has targeted water desalination and the use of renewables in the desalination systems.

The increasing availability of research funds from the Gulf region has enabled researchers from the ARAB region to tap into these resources to work jointly with researchers from Gulf and international universities. Examples include the Qatar National Research Fund (QNRF) http://www.qnrf.org/newsroom/press_releases/1360/ which recently announced (June 2010) the research awards for the 3rd cycle of its flagship program, the National Priorities Research Program (NPRP), with $113.8 million. The funds were divided among 126 proposals (out of around 536 proposals) from 14 submitting institutions from Qatar as well as 373 institutions from more than 49 countries. The 126 awarded proposals are distributed across Natural Science, Engineering and Technology, Medical and Health Sciences, Agricultural Sciences, Social Sciences, and Humanities. 20% of the grants were awarded to scientists from Lebanon, Jordan, and Egypt. Eight proposals were granted to faculty at the American University of Beirut with budgets of approximately $1 Million/project for three years.

The Arab Science and Technology Foundation (ASTF) at UAE http://www.astf.net/site/funding/index.asp has been supporting, promoting and facilitating scientific research and development in the Arab World since 2000. ASTF created a Research Funding Program for the amounts ranging from $15k to $50k/grant. The ASTF Business Development department assists technopreneurs to secure funding for their startup companies from the ASTF network of investors. ASTF will also assist technopreneurs in developing the necessary documents, like business plans and placement documents, needed to approach such investors. ?

The MIT Arab Business Plan Competition, begun in 2008 in partnership with Abdul Latif Jameel (ALJ) Company, is designed to support entrepreneurs in starting their own companies, and ultimately, to create a nest of leading firms in the Arab world. The competition covers energy, engineering, healthcare, internet, software and telecom. In 2009-10, the first place winner of the MIT Arab Business Plan Competition was the Little Engineer from Lebanon, recognized as one of the Middle East and North Africa's most promising entrepreneurs. The project titled "*The Little Engineer is the Lifetime Education for Kids and Teens with Hands-on Learning Activities*" was awarded $50,000 as start-up capital. The *Little Engineer* is an after-school edutainment center which introduces children and teens. [Ages 4-16] to pre-engineering courses such as robotics, physics, electricity, electronics, renewable energy and more. The Little Engineer's offerings were viewed as unique, creative, educational to the participants, affordable to the parents, and reflecting technological innovations bridging the gap between schools and universities. It also provides job opportunities for undergraduate students who work as tutors for the children. The trend of supporting home grown initiatives in the Arab world is beginning to pay back.

Energy Research in Arab countries over the past few years will be presented below for each sub-region, showing research thrusts and potential gaps to be strengthened so as to enhance economic and human development, energy security, sustainable practices in various sectors, and adaptive policies. The research in each sub region is presented under these subheadings: nonconventional energy sources for energy production, energy conservation and energy efficiency technologies including desalination, and energy economics and policies.

Research on Non-Conventional Energy Sources including Biofuels, Solar, Wind and Geothermal Energies

Gulf Region

Energy Supply and Alternative Energy Technologies

Renewable energy resource assessment and renewable energy applications have been the foci of research papers in all Gulf countries. The GCC country is rich in renewable resources with high values of daily solar radiation, humid and desert climates, high wind areas, and geothermal resources. The objective here is not to provide specific country data on these resources but to show ongoing research work on the assessment of renewable resources and its potential use in electrical and thermal energy generation and storage.

Alawaji (2001) evaluated solar energy research and its applications in Saudi Arabia addressing the viability of use of PV systems, seawater desalination, solar thermal energy conversion and water heating in remote regions of KSA. KSA has made reasonable progress in demonstration solar energy projects. Commercialization of renewable energy technologies is still, however, dependent on joint international programs. Their economic effectiveness is faced with the obstacle of the relatively cheap and subsidized conventional energy sources and the reduction in performance between 10 to 20% of most renewable systems by the dust effect. Rehman (2005) presented the KSA energy output of wind farms in terms of unadjusted energy, gross energy, renewable energy delivered, specific yield and wind farm capacity factor. His study is performed for 30 MW installed capacity wind farms at five coastal locations in Saudi Arabia; Hee concluded that of the five wind parks, Yanbo and Dhahran are the only two sites where wind park development is economically feasible.

Shaahid and El-Amin (2005) conducted a techno-economic evaluation of off-grid hybrid photovoltaic–diesel–battery power systems for rural electrification in Saudi Arabia. Solar photovoltaic (PV)-diesel- battery power hybrid system technology is found to provide great opportunities in remote areas to meet the load requirements of a typical remote village --Rawdhat Bin Habbas (RBH)-- with an annual electrical energy demand of 15,943 MWh. The monthly average daily global solar radiation is reported to range from 3.04 to 7.3 kWh/m^2. Their results indicated that for a hybrid system composed of 2.5 MWp capacity PV systems together with 4.5 MW diesel systems and battery storage of 1 h of autonomy, the PV penetration is 27%. The cost of generating energy from the hybrid system was found to be 0.170$/kWh (assuming diesel fuel price of 0.1$/l) and the decrease in carbon emissions by using the hybrid system is about 24% as compared to the diesel-only scenario.

Alnatheer (2006) examined environmental benefits of energy efficiency and renewable energy in Saudi Arabia's electric sector using an expanded Integrated Resource Planning (IRP) framework. He reported that making use of renewable energy and energy efficiency resources to provide energy services to the electricity consumers of Saudi Arabia can provide significant environmental benefits for the Kingdom.

Elhadidy and Shahid (2007) assessed the wind resources of the eastern coastal region of KSA. The long-term monthly average wind speeds for Dhahran range from 4.2–6.4 m/s. More importantly, the study deals with impact of hub height on wind energy generation. They reported that for a given 6 MW wind farm size, at 50m hub height, a cluster of 150 kW wind machines yields about 48% more energy as compared to 600 kW wind machines. Concurrently, they used that data for a case study to investigate the potential of utilizing hybrid (wind plus diesel) energy conversion systems to meet the load requirements of a hundred typical 2-bedroom residential buildings (with annual electrical energy demand of 3,512 MWh). The evaluation of the hybrid system shows that with seven 150 kW WECS and three days of battery storage, the diesel back-up system has to provide only 17.5% of the load demand.

Rehmana and Al-Abbadib (2008) presented local values of wind shear coefficient (WSC) and turbulence intensity using wind speed measurements made at 20, 30 and 40m above ground level in KSA. These local values of WSC were used to estimate the wind speed at hub-height of the wind turbines used in their study to recommend optimal hub-height for the highest annual energy yield. Taleb (2009) assessed the barriers for the utilization of geothermal energy in KSA. Despite the availability of some potentially resource-rich geothermal locations, he has concluded that the KSA has not undertaken any serious geothermal projects. The main obstacle is the availability of cheap sources of energy.

Marafia and Ashour (2001) assessed the feasibility of electricity generation using photovoltaic cells. They concluded that at the time PV stations are not economically feasible in Qatar compared with conventional gas turbine stations. Marafia and Ashour (2003) presented an economic assessment of off-shore/on-shore wind energy systems in Qatar using wind data measurements over 4 decades for Doha and the Qatari Haloul Island. The average annual wind speed (at 20 m height) was found to be about 5.1 m/s in onshore site compared to 6 m/s for the offshore site. Their study indicated that the cost of electricity generation from the wind in Qatar compares favorably to that from fossil fuel resources.

Similar work on wind power analysis was done in Bahrain by Jowder (2009) for site matching and optimal selection of wind turbine generators. The y reported that the maximum wind power density in February, for 10 m, 30 m and 60 m heights were 164 W/m^2, 624 W/m^2 and 1,171 W/m^2 respectively.

Ozalpa et al. (2009) studied thermo chemical hydrogen generation technologies via concentrated solar energy and predicted that hybrid solar/fossil technologies will take considerable share during the transition from fossil fuel dependency to clean energy-based systems in Qatar.

Islam et al. (2009) reported the measurement of solar energy radiation in Abu Dhabi, UAE for one complete year. The highest daily and monthly mean solar radiation values were reported as 369 and 290 W/m^2, respectively while the maximum solar radiation was 1041 W/m^2.Chaar and Lamont (2010) conducted multiple on-site assessments of solar radiation in Abu Dhabi, UAE to implement Photovoltaic (PV) technology. Their work highlights a promising future for Abu Dhabi in the solar energy sector and in particular Photovoltaic (PV) technology. Chaar and

Lamont (2010) presented renewable energy as the solution for a safe and efficient environment for the new generations.

Abdullah et al. (2002) investigated the feasibility of implementing grid connected PV systems in the Kuwaiti climate. They examined the performance as well as the economic feasibility of grid-connected PV systems and showed that electricity tariffs will have an important impact on the cost effectiveness of the system.

Dihrab and Sopian (2010) examined electricity generation of hybrid PV/wind systems in Iraq. They proposed a hybrid system with renewable resource of power generation for grid connected applications in three cities in Iraq. Results showed that it is possible for Iraq to use the solar and wind energy to generate enough power for some villages in the desert or rural area.

Al-Badi et al. (2009) assessed renewable energy resources potential in Oman and identified a barrier to their significant utilization. Solar and wind are likely to play an important role in the future energy in Oman provided that clear policies are established by the higher authority for using renewable energy resources. Rural Areas Electric Company has initiated solar and wind pilot projects in its concession area to confirm the performance and efficiency of renewable technologies in local conditions.

AL-Yahyai et al. (2010) assessed wind energy potential locations in Oman using data from existing weather stations. It is concluded that Qayroon Hyriti, Thumrait, Masirah and Rah Alhad have high wind power potential and that Qayroon Hyriti is the most suitable site for wind power generation. A. Al-Badi et al. (2009) analyzed the power sector of Oman where the government is moving towards setting up independent companies on a commercial basis shaping up for future electricity market. Beside these evolving structural changes, there would be a need to change their generation mix where there is a great incentive for Oman to exploit renewable energy in order to face the changing environment and to guard against future trends.

In the past two years research has shifted towards fundamental research work related to renewable energy systems. Janajreh et al. (2010) at Masdar city are studying aerodynamic design of wind turbine blades configuration with advanced 3-D simulations to enhance wind turbines performance. Kraemer et al. (2009) has introduced a new concept of a solar assisted method for the recovery of bitumen from oil sand in an environmentally friendly and sustainable way that has the potential of eliminating the need of natural gas as a process fuel. Their proposed concept involves mid temperature steam, generated with solar energy for stimulating an oil sand formation. Armstrong et al. (2009) modeled components and subsystems of efficient low-lift cooling with radiant distribution, thermal storage, and variable-speed chiller controls to predict significant energy savings with integrated optimized operation.

Philipps et al. (2010) developed a model to determine the optimum band gap combination of III–V triple-junction solar cells for the highest yearly energy production. They showed that the metamorphic solar cell structure of $Ga_{0.35}In_{0.65}P/Ga_{0.83}In_{0.17}As/Ge$ with transparencies optimized for the standard AM1.5d reference spectrum leads to the highest energy harvesting efficiencies and shows the lowest spectral sensitivity.

The Energy Research Institute at King Abdulaziz City for Science and Technology supported work to increase energy efficiencies of photovoltaic power plants connected to the electricity grid via space-vector-modulated 3-phase inverters using improved solar cell models and control methods using synergies of soft-computing techniques [Varnham et al. (2007)]. Varnham et al. (2007) developed neuro-fuzzy model with a neuro-fuzzy controller and applied it to a plant poorly characterized by the conventional solar cell model resulted in an 8.6% increase in power.

Khan et al. (2009) reported on the development and use of nano materials in low to high-temperature collectors, photovoltaic materials and thin films for direct electricity conversion, novel organic/inorganic matrices, catalytic, solar-induced chemical reactions, solar chemicals and products and building-integrated photovoltaic systems. Advanced material research is performed by KAUST and partners from the US and Europe to develop high performance thin film PV cells for the generation of electricity at competitive cost to fossil-derived electricity. Instead of multicrystalline cells, monocrystalline cells have been conceived to reach higher efficiency in just the same surface area. Khan and Al-Sayed (2008) used selective oxidation for Hydrocarbon desulfurization removing sulfur-containing compounds to an extremely low level for transportation fuels.

Sustainable Water Production

Fresh water production is another area that has been the focus of much research in the GCC region. El-Sebaii et al. (2009) reported improved efficiency by 37% and water production from an active single basin solar still in Jedda when a sensible storage medium of sand material is used.

Gandhidasan and Abualhamayel (2005) presented the use of a renewable method of obtaining fresh water from the atmospheric air in the form of dew from radiatively cooled pigmented polyethylene foils, by modeling and experimentation. A 0.22 L/m^2 of water is collected during a single night of operation in KSA. Producing water from the atmosphere is a new trend for water production in remote humid areas and it may become the least damaging method to Gulf sea water due to increased brine rejected from the multiple water desalination plants on its shore. In addition, soil deterioration influenced by land disposal of brine from water desalination plants is already reported by Al-Faifi et al. (2010) from Salbukh water desalination plant at Riyadh, Saudi Arabia. Soil samples at three depths along transect on both sides of the pond were taken, in addition to, water samples from feed, product, reject and pond showed that, the concentrations of soluble ions were exceeding the allowable limits in most water samples. They reported that the soil pH and the concentrations of soluble ions and other parameters were higher in soils close to the pond which lead to lower permeability, poor aeration and consequently to soil deterioration.

King Abdul-Aziz University and MIT faculty jointly assessed the potential of solar-driven humidification–dehumidification desalination for small-scale decentralized water production. Narayan et al. (2010) found that that among all humidification/dehumidification (HDH) systems, the multi-effect of closed air-open water-heated system is the most energy efficient. For this system, the cost of water production is US$ 3–7/m^3 [Muler-Holst et al. (1998)]. This is higher than that for RO systems working at similarly small capacities (5–100 m3/day); the HDH system has other advantages for small-scale decentralized water production. These advantages include much simpler brine pre-treatment and disposal requirements and simplified operation and maintenance.

Al-Zubari (2003) assessed the sustainability of non-renewable brackish groundwater in feeding an RO desalination plant in Bahrain. The Rus-Umm Er Radhuma aquifer in Bahrain has started in 1984 to feed a reverse osmosis (RO) desalination plant, with an economic life of 25 years. The limiting factor in expanding the RO plant and its rehabilitation is the future feed water salinity. Howari et al. (2008) studied water bodies of United Arab Emirates coastal Sabkhas as potential sites for natural salinity gradient solar ponds. The coastal area of the United Arab Emirates especially in Abu Dhabi is formed of a series of hyper-saline 47%° lagoons surrounded by salt-encrusted flat sabkhas. Such water bodies were proposed to be used by the authors as salinity gradient solar ponds SGSPs to generate economically feasible clean electricity that can be used in desalination plants. Darwish et al. (2008) discussed desalting processes for the purpose of reducing desalting energy and its cost in Kuwait. Darwish et al. (2009) then examined trends in electricity co-generation and water production in Kuwait and Gulf countries. They reviewed the presently used desalting methods and their energy demand, and the correctness of fuel allocation formulas, to determine the most efficient methods to apply and the less efficient ones to avoid. They analyzed fourteen desalting cases of current practice, with and without combination with power generation plants. Their results showed that operating thermally driven desalting systems by steam directly supplied from fuel-fired boilers was the most inefficient practice and the use of the gas/steam turbine combined cycle to drive seawater reverse osmosis (SWRO) desalination plants was the most efficient combination.

Sulaymon et al. (2009) reported experimental measurements on Tigris River water in Baghdad to determine the level of natural organic matter (NOM) and its disinfection by-products formation potential (DBPFP). The results showed that raw water total organic carbon (TOC) levels have a potential to produce concentrations of trihalomethanes (THM) exceeding the USEPA guideline of 80 µg/l during 7 months of the year. Treatment options were tested for their effectiveness to reduce raw water NOM.

Energy Efficient Building Systems and Processes

Energy conservation measures in buildings were focus of research in the last two decade in GCC to develop thermal guidelines or codes for buildings [Aftab and Elhadidy (2002), SAM et al. (2003)]. Aftab and Elhadidy (2002) introduced energy conservation measures for a typical single family house in Dhahran while Said et al. (2003) published a database for building energy prediction in Saudi Arabia.

Much of the work then targeted envelop based solutions to reduce energy losses and the use of efficient systems. Recent work has started to shift towards optimized operation and smart systems and towards green designs that meet ASHRAE goal of zero energy building in the coming decade (http://www.ashrae.org/). Fasiuddin et al. (2010) recommended zero-investment heating, ventilation, and air conditioning (HVAC) system operation strategies for energy conservation and thermal comfort in commercial buildings in the hot-humid climate of KSA. Savings were identified for shopping malls using strategies such as thermostat control, night setback control, time scheduled operation to produce significant savings while maintaining thermal comfort. The Saudi Arabian electricity sector embarked upon a major restructuring program of its electricity sector aiming to achieve sustainable performance through introducing sustainable energy policies for electrical energy conservation in Saudi Arabia [Al-Ajlan et al. (2006)]. Effective development of policies and programs on energy conservation are challenged. Al-Ajan et al. (2006) reports that if only savings on air conditioning are considered, the return on investment is equivalent to 400–500 MW/year of generating capacity—a saving of up to $0.25 billion/year.

Alnaser et al. (2008) introduced a model for calculating the sustainable building index (SBI) in the kingdom of Bahrain to allow players in the building and construction sector and the energy policy makers on energy strategies to perceive the interest of investors in the kingdom of Bahrain in conducting Building Integrated Photovoltaic (BIPV) or Building integrated wind turbines (BIWT) projects, i.e. a partial sustainable or green buildings. The model allows the calculation of the Sustainable building index (SBI), which ranges from 0.1 (lowest) to 1.0 (highest); the higher figure the more chance for launching BIPV or BIWT. This model was tested in Bahrain and the calculated SBI was found 0.47. This means that an extensive effort must be made through policies on renewable energy, renewable energy education, and incentives to BIPV and BIWT projects, environmental awareness and promotion to clean and sustainable energy for building and construction projects. Alnaser et al. (2008) presented two exemplary cases of transforming two unique large buildings in the Kingdom of Bahrain to sustainable buildings using PV roofs and PV facades, solar heating, and wind turbines. These were the Almoayyed Tower (the first sky scraper) and the Bahrain International Circuit, BIC (The best world Formula 1 Circuit).

Reiche (2010) presented a case study of the carbon-neutral ‘‘Masdar City’’ in Abu Dhabi in an attempt to analyze renewable energy policies in the Gulf countries. Masdar city is presented as a process of ‘‘transforming oil wealth into renewable energy leadership,’’ and with a set the long-term goal of a “transition from a 20th Century, carbon based economy into a 21st Century sustainable economy.” The article identifies the main actors for its implementation, and obstacles to creation and development as well as the policy advancement.

Research on reducing energy use in buildings has shifted to an integrated approach by which thermal comfort sensation models developed for local climates are used to aid policy making related to energy consumption in built in environment. Farraj et al. (2010) conducted an extensive field study during the summers of 2006 and 2007 to investigate the indoor climate and occupants’ thermal comfort in 25 air-conditioned domestic buildings in Kuwait. It was found that the neutral operative temperatures, based on Actual Mean Vote (AMV) and Predicted Mean Vote (PMV), were found to be 25.2°C and 23.3°C, respectively, in the summer season. This knowledge according to the researchers can contribute towards the development of future energy-related design codes for Kuwait.

Sgouridis and Tangible (2010) proposed the introduction of an energy-based parallel currency as a means to ease the transition to energy-conscious living using the Masdar Energy Credit (MEC) system that translates the fundamental aspects behind energy generation and usage into a tangible reality for all users with built-in fungibility to incentivize collectively sustainable behavior.

Research and Development Goals for GCC

Research in the Gulf region is accelerating towards generation of knowledge contributing to sustainability and solving problems of the region. Research addressing policies and implementation of policies at the decision making level is yet to be improved to make use of research data and scientific evidence to develop policies that enhance sustainability and security in the production and utilization of developed forms energy. Regional cooperation among universities and research centers in partnership with industry is expected to increase and the greening of many processed will continue to expand awareness on the sustainable use of resources.

The research is expected to expand in GCC into the following main areas:

1- Energy Supply Technologies

Emerging Energy Supply Technologies for diversifying energy supply in the Gulf countries with proven abundance of alternative energy resources in the form of solar, geothermal, and wind energy. The increased the understanding and acceptance of non-conventional energy sources and the social and global responsibility to contribute to mitigation of climate change adversities will lead to major development in the GCC region and beyond creating valuable jobs for GCC nationals and expatriates from the Arab countries and other countries. Investments in large scale infrastructure for renewable energy generation will demonstrate concern for the global issues, promote commercial exploitation in these technologies, and accelerate change in policies to adapt to the diversified energy supply and to address energy supply and demand challenges.

More research work will tackle development and improvements to energy production that enable power generators to capture more of the power produced and integrate renewable energy sources in the production cycle.

2- Energy and Innovative Water Production Technologies

The increase in fresh water demand beyond the sustainable supply have placed pressure on the existing water sources of many countries in the Middle East and has in some instances to the depletion of the underground water due to unrestrained aquifer water withdrawal. Assessing water desalination approaches for different energy cost and carbon regulation scenarios will be the target of research in the coming few years in order to provide tools of adopting strategies and recommending investments on best water production technologies.

One of the processes of producing fresh water is by extracting moisture from the atmosphere which is considered a huge renewable source of pure water. The atmosphere is a large reservoir of moisture containing 12,900 km^3 of fresh water in the form of water vapor. The extraction can be accomplished by utilizing the absorbency-regeneration characteristics of liquid desiccants. Such a method of producing fresh water is considered ecologically friendly compared to other methods such as desalination by reverse osmosis or by multi-stage flash evaporation which results in two streams: one with a low concentration of dissolved minerals and another stream of highly concentrated salt. The high salt concentration of the discharged stream can have a devastating impact on the marine species and the flora of the sea which has already been observed in the GCC waters. The increased population and demand on water will lead to further research needed to combat adverse effects of increasing Gulf water salt concentration and more research will be done on capturing water from air at competitive costs. Solar driven humidification-dehumidification (HDH) water desalination technologies have become economically competitive in decentralized small-scale desalination applications. HDH technology needs additional research and development for improving system efficiency and reducing capital cost. Currently, the cost of water production in HDH is between US$ 3–7/m^3 which is comparable to RO systems working at small capacities (5–100 m^3/day) with less cost for maintenance and expertise [Narayan et al. (2010)].

Research on hybrid or combined systems that include dual outputs such as generating electrical energy and producing water by recovering heat from power plants, or meeting both space cooling and domestic water needs through capturing water from latent load associated with humidity. In the hot and humid climate of the GCC countries clean fresh water is a scarce commodity, and a comforting surrounding is not naturally available. Researchers would utilize and optimized hybrid systems that can meet the two major needs of occupants to dehumidify air that meet comfort conditions while at the same time have a fresh water supply and effectively meet these needs with low impact on the environment and reduced energy cost. Other work will consider solar assisted liquid desiccant systems that can provide dehumidified air for air conditioning needs and humidified stream for fresh water production. Hybrid desiccant systems integrate a desiccant dehumidifier with a conventional cooling system such that the dehumidifier takes up the latent load and the conventional system can be used for the sensible portion of the load [Ghaddar et al. (2003)]. Hybrid systems offer the advantages of reduced energy costs and reduced equipment size and independent control of temperature and humidity. The technology has been applied to super markets and to large buildings that require large amount of fresh air to reduce the cost of air-conditioning and condensate/frost control. The low dew-point capability of the hybrid desiccant system and independent temperature and humidity control provide enhanced comfort to shoppers and greater protection of frozen goods. Furthermore, incorporation of desiccant preconditioning into such systems allows higher percentage of fresh air in the supply stream. There are many types of available hygroscopic desiccants: Calcium chloride, Lithium bromide, Lithium Chloride, Magnesium chloride, Zinc Chloride and Sodium chloride. Research in this area will tackle effect of selected salts on combined system efficiency, the appropriate operation and control strategies for operation of the hybrid system for small and large scale applications.

3- Energy Efficiency Technologies for Buildings and Processes

Research work is growing on techniques and technologies that improve energy efficiency of building and industrial energy systems, construction materials, consumer goods, machinery, transportation, and other products that store and consume energy. An integrated approach will be followed for tackling the efficiency problem through improved performance and diversify energy sources in various systems, in particular air conditioning and refrigeration systems. The focus areas of research will tackle:

- Optimal and adaptive design of green buildings in different climates which would take into consideration attaining thermal comfort in built in environment at good environmental quality and minimum conventional energy consumption.
- Research and adaptation of technologies toward thermal comfort-based and energy-efficient HVAC systems. Providing the highest comfort level for building occupants and optimizing the system operation to reduce energy consumption are two critical issues for selection of HVAC systems. Natural ventilation, solar control, passive temperature control and day light are applied as common approaches to save energy, and other novel air conditioning systems such as under floor air distribution and displacement ventilation are mainly employed to increase the occupant comfort level. Research work in GCC will tackle advanced control strategies for increasing occupant comfort and decreasing energy consumption in buildings to meet these two requirements simultaneously. The research will focus on the intelligent air delivery system to provide locally the occupants with comfortable and healthy environment based on on-demand control operation Use of sensor and control needs for buildings span a broad range of technical activities where sensors at sufficiently low cost are needed for measuring temperature and humidity as well as power consumption. It is expected that more research will focus on wireless and complex sensor network to make the best use of collected sensor data for optimal operation of HVAC systems.
- Research on modeling, design and optimization of multi-energy systems in buildings will be at the forefront of funding. Cooperation among different disciplines and universities from the region and US and Europe will be the major driver of quality work on advancing knowledge in that area.
- Solar energy applications and use in households and industry to reduce conventional energy consumption.
- District heating and cooling plants to supply buildings cooling and heating needs are another area of development in the GCC.

4- Energy Policy Development

Energy policy development upon review and assessment of current incentive frameworks in the global solar energy market and their potential application to solar energy incentives and policies in the GCC research by economist and energy policy specialists will target developing knowledge of alternative economic and policy approaches that improve energy efficiency and establish a comprehensive understanding of the current state of the art in carbon sequestration and storage from the perspectives of technology, policy, implementation models and applications.

It is expected that more effective and implementable policies will be developed to lower energy consumption in GCC to enable them to formulate strategies that address issues in energy consumption and energy security with diversified sources that meet future needs. Scholarly research identifies effective policies for moderating energy demand and conserving energy for the future will grow. For example, the Dubai Municipality is close to completing and publishing a new building code that will put in place stringent energy, water-efficiency and waste-efficiency requirements on future construction projects and existing buildings alike, but the question of implementation will greatly depend on trained personnel, availability of facilities for testing new materials, and the incentive package associated with the implementation of the policy. The impact of different incentive structures for promoting investments in energy efficiency and conservation need to be modeled and predicted for any produced policy and forecasts of the impact of energy conservation on energy-producing economy should be available to guide investments.

Recommendations on major opportunities of interventions to enhance sustainable energy practices in Gulf Region

There are obvious barriers to the development and implementation of policies that promote the use of renewable energy resources and efficient energy systems. The GCC countries have an opportunity here that other ARAB countries do not have. The accelerated knowledge generation in the region, and the wealth to invest in infrastructure and long term investments in renewable and advanced energy systems, have supported initiatives in renewable energy. The following is recommended to speed policy development:

- Publish information to the public regarding examples of successful implementation and use of renewable energy systems and technologies, their impact, availability and cost benefits.

- Develop policies to provide the environmental price of any system or commodity. Since electricity produced by conventional energy sources is subsidized, renewable and energy efficient systems would fail to be economically feasible unless such policies exist.

- Identify the carbon footprint and the social responsibility to reduce it and contribute to the mitigation of adverse effects of climate change. Talk to the individual.

- Promote energy education and training for the installation, operation and maintenance of renewable energy equipment, by putting more funding on R&D to improve renewable technologies and green buildings and their energy uses.

- Invest in providing tax incentives to the private sector to achieve higher utilization of efficient systems and processes.

- Education is vital to the success in achieving buying into sustainable energy practices and legislations. Introduce interdisciplinary education for energy programs that provide an integrated approach to energy problems and the base for the cooperation of architects, engineers, builders, and managers to address renewable energy technologies and applications, energy efficient building. In addition, develop courses on energy economics and policies, the requirements of laws and their impact on the society, practitioners, and end users of energy efficient technologies.

- Most importantly, adapt renewable energy technologies and energy efficient systems to the needs of local communities in the design of and implementation of projects. Collaborative and major companies in GCC countries hire a certain % of local personnel who are trained and can always provide input about community needs, customs and cultures to the introduced technologies.

- The GCC governments should adopt a requirement for environmental impact assessments or statements for all major energy related projects and products to promote development in the renewable energy sector. Publishing data on emissions will build the culture of socially responsible decisions towards the society and the global community.

  Establish partnerships with international professional organizations that have energy codes and standards such as ASHRAE, IEEE, and ASCE. Successful examples include the cooperation of ASHRAE with the UN to develop codes and appropriate refrigerants to replace ozone depleting ones.

MENA Region

Energy Supply and Alternative Energy Technologies

Renewable energy resources in the Syrian Arab Republic were surveyed by Al-Mahmoud (2001) covering solar, wind and bio-mass resources and their promising applications. The annual average long-term solar radiation on a horizontal plane is 5.2 kWh/m^2/day. The registered annual mean daily wind speed in some regions of Syria reaches more than 13 m/sec and the estimated biogas production of the daily wastes of humans, animals and agriculture is higher than 300 million m^3/year. Hainoun et al. (2010) modelled the national energy chain of Syria and predicted optimal long-term energy supply strategy based on minimizing the total system costs for the entire study period 2003–2030. Their results indicated that the primary energy will grow at annual average rate of 4.8% arriving 68 Mtoe in 2030 and the future national energy system will rely mainly upon oil and natural gas (NG) with limited contribution of renewables and nuclear.

Badran and El-Bassam (2009) introduced the in a case study the concept of integrated renewable energy farms (IREF) with autonomous food production, and high production level of green energy and fresh water. Increased interest with renewable energy systems in Jordan started in its early 2000 with a policy to reduce dependence on fuel and gas imports and the government has set a target of acquiring five per cent of total energy needs from renewable energy by 2015. Jordan, like Syria and Lebanon, has high solar radiation with a mean solar radiation on horizontal surfaces of 5.5-6 kWh/m^2/day compared with that of Europe, which amounts to 3.5

kWh/m^2/day and for about 2000-3000 sunshine hours/year. Badran and El-Bassam (2009) reported that an IREF for the populations living in arid areas of southern Jordan and Badia is planned through cooperative work between Al-Balqa` Applied University and the International Research Centre for Renewable Energy at Hannover.

Mohammed et al. (2010) designed, operated, and tested a parabolic solar cooker with automatic two axes sun tracking system and a programmable logic controller was used to control the motion of the solar cooker. The results of the continuous test showed that the water temperature inside the cooker's tube reached 90 °C in typical summer days, when the maximum registered ambient temperature was 36 °C. Aljundi et al. (2009) analyzed Al-Hussein power plant in Jordan using energy and exergy analysis identifying places and methods where exergy destruction can be reduced for improved performance. Ali et al. (2008) analyzed the tourist commercial sector in Jordan and identified potentials of energy savings in the hotel sector. The study suggested some strategies to help reduce the negative impacts of high energy consumption in hotels. These strategies include better insulation, and enhanced insulation for the hot water reticulation system. Moreover, enhancing and increasing the level of awareness among all hoteliers through a directed and well-designed campaign and offering interest free loans; and activate precise standards and specifications for new hotels. Anagreh et al. (2010) and Jaber et al. (2008) assessed renewable energy potential, at Aqaba in Jordan for space heating and showed that heating systems based on renewable energy, i.e., wind and solar energy, are most favorable, followed by traditional stoves burning petroleum products.

Cantin et al. (2007) presented scenarios of application of energy certification procedure for residential buildings in Lebanon to provide a decision making for the actors of the Lebanese energy policy. Ibrahim et al. (2010) reported on design of a hybrid wind–diesel-compressed air energy storage system for remote areas. Abosedra et al. (2009) investigated the causal relationship between electricity consumption and economic growth for Lebanon and concluded that the policy makers in Lebanon should place priority in early stages of reconstruction on infrastructure development of the electric power sector of Lebanon, as this would propel the economic growth of the country. El-Fadel et al. (2010) studied the Lebanese electricity system in the context of sustainable development and indicated that renewable energy sources are competitive alternatives to current conventional resources. Dagher and Ruble examined the impact of the backup electricity sector that emerged unregulated in Lebanon due to frequent and lengthy power cuts by the Lebanese public utility. They discussed the challenges for CO_2 mitigation providing different scenarios and their economic viability. El Asmar (2008) summarized the development and pilot project on advanced and innovative hybrid solar hot water and air-conditioning system for implementation in Mediterranean countries. The test areas were selected in Morocco, Lebanon, and Jordan. Houri (2006) studied prospects and challenges of using hydropower for electricity generation in Lebanon indicating that hydropower's share of electricity generation will vary between a maximum of 6.9% and a minimum of 1.2% depending on government plans regarding water use.

Chellali et al. (2010) performed wavelet spectral analysis of the temperature and wind speed data over four years for the region of Adrar (27.9 N, 0.3 W, 263 m), Algeria. The results show that significant synoptic oscillations of periods between 2 and 16 days occur mainly in the cold season in both wind and temperature time series. The study reveals that temperature and wind speed co-vary especially at the synoptic and the intra-seasonal frequencies. Mahmoudi et al. (2010) studied application of geothermal energy for heating and fresh water production in a brackish water greenhouse desalination unit for a case study from Algeria. Countries which have abundant sea/brackish water resources and good geothermal conditions are ideal candidates for producing fresh water from sea/brackish water. The main advantage of using geothermal energy to power brackish water greenhouse desalination units is that this renewable energy source can provide power 24 hours a day. This resource is generally invariant with less intermittence problems compared to other renewable resources such as solar or wind energy. A review of the geothermal potential in the case study country was outlined demonstrating success. Himri et al. (2009) presented a review on the use of renewable energy in Algeriag given Algerian's abundant solar, wind resources, biomass, and geothermal and the market for renewable energy technologies.

Omer (2008) assessed wind energy resources of Sudan based on several years data several location blessed with abundunt wind energy and recommending the use of local and small wind energy in rural areas. In Sudan, various designs of wind machines for water pumping have been developed and some designs are presently manufactured commercially. Chaabane et al. (2004) determined Linke turbidity (pollution) factor from solar radiation measurement in northern Tunisia. The correlation between atmospheric turbidity and the local weather conditions shows that this increase is essentially due to the heavy water vapor content of maritime air masses, carried by the north-eastern winds prevalent during the afternoon. A second pollution source is the dust content of the continental air masses carried by western and southern winds prevalent in the morning.

Rashad and Ismail (2002) performed an environmental-impact assessment of hydro-power in Egypt where hydro-power had contributed between 28 and 22% of the total energy produced by Egyptian power-plants, while the contribution of the hydro capacity was between 32.4 and 21.5%. They presented an objective evaluation of the Uswan Dam, based on 25 years of operational data, indicating that it has overall been positive even though it has contributed to some environmental problems that are significantly less than most people originally expected.

Ahmad (2002) presented a simulation study and design of stand-alone PV system to meet electrical energy needs of a family house in Egypt. Mahmoud and El Nather considered the economics of using photovoltaic (PV) technology for developing remote areas in Upper Egypt. The study proved that PV-battery systems can be used efficiently for water pumping at East Owienat: the cost of the water unit pumped by PV systems is much less than that pumped using diesel systems, and the water cost is more sensitive to PV cells' prices. The integration of renewable resources in desalination and water purification is becoming increasingly attractive. This is justified by the fact that areas of fresh water shortages have plenty of solar energy and these technologies have low operating and maintenance costs. Mahmoudi et al. (2009) reported an overview of capacity building strategy and policy for desalination in Algeria and stressed the importance of training and education on renewable energies by outlining the contribution of the Middle East Desalination Research Centre in Algeria. Karim et al. (2010) conducted an experimental study on the salt gradient solar pond stability using particle image velocimetry showing that the instability of solar ponds could be limited by using porous media placed in the lower layer of the stratification.

Ben Yahmed et al. (2009) used biological treatment for an anerobic pilot unit for Jebel Chekir landfill leachate (Tunisia) The treatment system and performance results obtained during this study indicate a significant organic matter reduction was obtained. Ellouze (2009)studied the effect of high ammonia concentrations on fungal treatment of Tunisian landfill leachates (LFL). Assays of a biological treatment of LFL were used in order to detoxify the effluent by selected strains of white rot fungi and an important reduction in the toxicity of the 50% diluted LFL was reported.

Wheida and Verhoeven assessed the limited water resources and their management of the Libyan Jamahiriya recomending that the limited fresh water resources should be given to the human needs of drinking water, tourist activities, and industry, by assuring the quality of life and importing most of the high water consuming food and fodder, particularly the products which can be shipped and stored easily from countries with plenty of water from natural and renewable sources. Kershman et al. (2005) discussed an established hybrid wind/PV and conventional power for sea water reverse osmosis desalination in Libya. The wide range of feasible plant configurations will allow for extension of the scope of research to off-grid stand alone performance analysis of such hybrid systems. The expected nominal power load for the operation of the RO desalination system is 60 kW (net power after recovery), the solar PV system is designed for 50 kWpeak, and theWEC for 275 kWnominal output.

Sustainable Water Production

Water desalination is an indispensable industry for the most of the Arab countries. In the last four decades, the number and capacities of desalination units have increased dramatically in Arab countries (45% Multi-Stage Flash (MSF) and 42% Reverse Osmosis (RO) of world capacity) El-Sadek (2010) indicated that almost all available conventional water resources in Egypt - represented by the Nile water, renewable groundwater, and some scant annual precipitation- have been exhausted. He studied water desalination as a solution for water scarcity in Egypt and demonstrated the significance of seawater desalination for national development in Egypt. Their research concluded that, the water desalination as a conventional water resource should be considered as an imperative measure for water security in Egypt. The future use of such resource for different purposes will largely depend on the rate of improvement in the technologies used for desalination and the cost of needed power. Megahed (2009) studied the feasibility of nuclear power and desalination on El-Dabaa site in Egypt classified in 1997 as a water scarce country. In this regard, he concluded that a nuclear reactor providing electricity to the grid can in principle provide also electricity and/or heat to a desalination plant. Abdel-Rehim and Lasheen developed an enhanced performance solar desalination concentrator system located in Cairo, Egypt that increased fresh water productivity by an average of 18% to conventional solar still. Wheida and Verhoeven (2007) considered the country's water management that requires water policy reforms, with emphasis on supply and demand management measures and improvement of the legal and institutional provisions. They recommended creating authorised water institutions lead by a high-professional staff and enabling them in making the appropriate legislation and decisive measurements to allocate water among consumptive sectors as well as to ensure the protection of the environment. Abdel Dayem and Fatouh (2009) considered experimentally and by simulation a humidification–dehumidification process as an advanced technique to design and construct a solar water desalination system in Cairo and were able to identify more efficient system design among three proposed designs.

Benchrifa et al. (2004) presented a comparative study in terms of levelized water costs for three towns in the south of Morocco using two desalination processes: reverse osmosis and vapour compression assuming energy needs can be delivered by two electricity sources: grid and wind energy. Saadi and Ouazzani (2004) suggested that the use of non-conventional waters such as brackish or lowquality groundwater could be considered to overcome the water scarcity problem in Morocco, especially in interior regions. Desalination of these types of water could be more advantageous than using seawater, as they are less concentrated in salts. Furthermore, desalination of water could provide several benefits: in addition to treatment and valorisation of enhanced quality water in agriculture, it could be possible to valorise economically the desalination residues via salt extraction in extensive evaporation tanks. Wenxiang et al. (2002) published a pre-project study of a nuclear desalination demonstration plant jointly carried out by Morocco and China for Tan-Tan, Morocco under the support of the International Atomic Energy Agency. The plant will produce 8000 m^3 per day of potable water using a 10 MWh nuclear heating reactor developed by China coupled to a high-temperature multi-effect distillation process.

Pollerberg et al. (2009) presented a solar driven process to generate cold water for air-conditioning by parabolic trough collectors and a steam jet ejector chiller. Their investigation shows that the cooling water temperature as well as the cold water temperature has a strong influence on the coefficient of performance of a steam jet ejector chiller. A first calculation of profitability leads to specific cold cost of 0.62 €/kWh in Germany and 0.15 €/kWh in Egypt.

Research in Jordan has put great emphasis on desalination systems that are based on renewable energy sources due to water scarcity in the country. Hadadin et al. (2010) clearly describes the large environmental challenge that Jordan faces today due to the scarcity of water. Jordan's water resources are limited to support population in a sustainable manner. The situation has been intensified by the fact that Jordan shares most of its surface water resources with neighboring countries; their control on water has partially disallowed Jordan of its fair share of water. Current use of water already exceeds its renewable supply. The deficit is covered by the unsustainable practice of overdrawing highland aquifers, resulting in lowered water tables and declining water quality. Omar et al. (2010) proposed a fluidized bed crystallization technology as a feasible method for the reduction of scaling tendency of seawater. Seeded crystallization experiments in a pilot plant fluidized bed crystallizer were conducted. Abdulla and Al-Shareef (2009) indicated that in the absence of run-off sewer systems in most Jordanian rural and urban areas, rainfall harvesting from roads, parking lots and rooftops can increase water supply for various domestic uses and help combat the chronic water shortages in the country. Their results show that a maximum of 15.5 Mm^3/y of rainwater can be collected from roofs of residential buildings provided that all surfaces are used and all rain falling on the surfaces is collected. This is equivalent to 5.6% of the total domestic water supply of the year 2005.

Sahar et al. (2009) documented the experience of the Environmental Research Center at the Royal Scientific Society in stakeholder participation in grey water management (treatment and reuse) in the rural communities of Jordan. The study reveals that the incorporation of input from a broad range of sectors and stakeholders during the project insured cooperative management of the grey water resources and enhanced project quality and ownership. Abdallah at al. (2009) improved the thermal performance and increased production of single solar still by modifying the still absorbing material using uncoated metallic wiry sponge has the highest water collection during day time, followed by the black rocks and then coated metallic wiry sponges. Bdour et al. (2009) discussed several options to achieve sustainability in wastewater treatment in urban areas of the Mediterranean region. The first was by decentralizing the treatment rather than installing expensive sewer systems that combine and increase the volume of the waste. The next involved choosing an appropriate treatment technology for the community where several types proposed included lagoons/wetlands, up flow anaerobic sludge blanket (UASB), and soil aquifer treatment (SAT). There is still a great need in this area for research to improve or optimize the current methods of wastewater treatment.

Trieb et al. (2009) showed the principles and the present state of the art of concentrating solar power technology and explained the option for seawater desalination, either using electricity or steam generated in such plants. Banat and Jwaied (2008) used exergy analysis as performance evaluation tool of desalination processes where the optimal use of energy is considered an important issue. The exergy efficiency of the compact and large units with reference to the exergy collected by the solar collector was about 0.3% and 0.5% but was 0.01% and 0.05%, respectively, when referenced to the exergy of solar irradiance. The exergy efficiency of the flat plate solar collectors in both units varied diurnally and the maxima was 6.5% and 3% for the compact and large units, respectively. The highest exergy destruction was found to occur within the membrane distillation module.

Al-Khatib and Arafat (2009) studied chemical and microbiological quality of desalinated water, groundwater and rain-fed cisterns in the Gaza strip, Palestine. For certain chemical parameters, such as nitrate, a high percentage of water samples from all sources exceeded the limits of the Palestinian Standard Institution and the World Health Organization (WHO). The study reveals a clear superiority of quality for desalinated water, but also the need to adopt better practices (maintenance and pre- and post treatment) in the desalination plants. Water footprint of the Palestinians in the West Bank was studied by Nazer et al. (2008). The consumption component of the water footprint of the West Bank was found to be 2,791 million m^3/year. Approximately 52% of this is virtual water consumed through imported goods. The West Bank per capita consumption component of the water footprint was found to be 1,116 m^3/cap/year, while the global average is 1,243 m^3/cap/year. Out of this number 50 m^3/cap/year was withdrawn from water resources available in the area. Only 16 m^3/cap/year (1.4%) was used for domestic purposes. This number is extremely low and only 28% of the global average and 21% of the Israeli domestic water use.

Energy Efficient Building Systems and Processes

Hybrid air conditioning systems with independent systems of removal of sensible and latent loads have high potential for energy savings, either through optimized operation or by integrating renewable energy sources in the operation. Keblawi et al. (2009) deployed optimized system operation for feasible load ranges of a combined chilled ceiling displacement ventilation system. Ghali et al. (2007) considered the potential for energy savings associate with chilled ceiling and displacement ventilation system for Beirut climate. Ghaddar et al. (2008) developed design charts for combined chilled ceiling displacement ventilation system and Mossolly et al. (2009) used genetic algorithms to compare optimal operation under three control strategies to reduce energy consumption while providing comfort. Ghaddar et al. (2010) reported effect of optimized selection and operation of the combined chilled ceiling system and displacement ventilation on energy cost. Ghali et al. (2008) integrated desiccant dehumidification wheel with air conditioning system for energy savings in Beirut climate allowing up to 30% reduced energy consumption compared to conventional systems. Othmani et al. (2009) compared performance of radiative and convective space heating systems for equal level of thermal comfort during transients. Not only radiative heating systems use less energy, but they also provide thermal comfort in relatively much shorter time. This was considered ideal for intermittent applications.

Abu Qdais et al. (2010) used advanced modeling methods and optimization tools of biogas production process from the digester of Russaifah biogas plant in Jordan. The study considered the effect of digester operational parameters on the biogas yield and demonstrated the effectiveness of model predictions of methane production. The optimal amount of methane was converged to be 77%, which is greater than the maximum value obtained from the plant records of 70.1%. EL-Shimy (2010) reported site optimal matching of wind turbine generator in the Gulf of Suez region in Egypt through improved formulation of the capacity factor. Long-term performance measurements at Zafarana wind farms were used by the authors to validate the optimality of their results.

Messaoudene et al. (2010) targeted studying by modeling and field experiments the effect of ventilation using fans on thermal comfort measured in a typical home in Algerian conditions. They develped a thermal comfort model for transient conditions to calculate an instantaneous thermal comfort index and integrated the model with 17-segment heat balance equations of the human body written for each segment. Their results indicated that even during hot days, an appreciable thermal comfort can be achieved if ventilation at constant air speed is used. They also studied the impact of solar radiation on thermal comfort and showed that a discomfort sensation is quickly felt when a person is exposed to sun fluxes stressing the importance of shading devices.

Sub-Sahara Region

Rujula and Dia (2010) developed an application of a multi criteria analysis for the selection of the most suitable energy source and water desalination system in Mauritania. They studied six scenarios, different energy sources, technologies of water desalination processes and water use. Their analysis showed that the optimal solution is different for each scenario; in some cases the photovoltaic-reverse osmosis option is preferable; in others, the best option is reverse-osmosis powered by wind energy or concentrating solar parabolic concentrator. **Davies (2005)** focused on the potential to link ocean-wave energy to desalination. He reviewed technologies of wave-powered desalination and concluded that along arid, sunny coastlines, an efficient wave-powered desalination plant could provide water to irrigate a strip of land 0.8 km wide if the waves are 1 m high, increasing to 5 km with waves 2 m high.

Research and Development Goals in the MENA and Sub Sahara Regions

This region is characterized with milder climates than GCC region, dense population, and unequal distribution of wealth with substantial population living in rural areas. The region is rich with human resources and trained skilled labor. It is clear that research initiatives are not strategically oriented and do not have a long term focus. The published research in the past few years shows work in critical areas of energy assessment, energy efficiency, desalination, hybrid systems and HVAC efficiency. Universities and scholars work on problems relevant to their localities but with little funding provided to support strategic research efforts. Governmental investments in research at universities are minimal and the primary energy initiatives are supported by the UN and EC countries. Many governments have developed strategic energy initiatives to diversify energy supply and use labeling of energy products or standards for buildings and processes energy efficiency. Renewable energy programs are strong in Jordan, Egypt, and Algeria and are increasing in Syria. Scarcity of water in many countries of this region has also led to an emphasis on desalination research using renewable energy. However, due to the booming energy market in the GCC and the establishment of strong research programs in energy efficiency and renewable energy technologies, education and training in these areas have become attractive for professionals and scholars who either work in the region or have joined universities in the GCC. Research and development is becoming more focused in the strategic planning of key institutions in the MENA region which would like to benefit from the momentum of research and development in North American and European institutions close to the GCC. More researchers from MENA universities apply to major grants by Qatar Foundation, KAUST, ASTF and others in collaboration with faculty in the key GCC universities such as MASDAR, KAUST, Texas A & M Qatar, and others. Recommendations for research and development for the MENA region include the following:

1- Water Desalination Technologies

Water Desalination technologies integrated with renewable resources that are less damaging to the environment will continue to be a main research target. The use of thermo-electric cooling modules operated by PV to condense water from the atmosphere is one of the areas of research. Others include development of more effective membrane technologies that can handle high pressure differences, durable and last longer for reverse osmosis desalination. The energy intensity per kg of fresh water produce needs to be reduced by relying more of renewable resources in large scale productions.

2- Energy efficient Buildings

Scientists have researched three areas in their studies of energy efficient buildings: the building envelope material, efficiency of the air-conditioning system devices and the use of hybrid air-conditioning systems powered partially/totally by renewable energy resources. Extensive research have been done on the building fabric/envelope such as the proper insulation selection, applying air sealing to the building shell and the use of glazing with dynamic shading to reduce the overall heat transmission across the building. In addition researchers worked on improving the mechanical and operational efficiency of the air-conditioning devices. Despite of all the above mentioned research efforts and the building's design technological advancements; the success in pursuing a zero net energy building was very limited. In fact, the energy consumption in buildings can be further reduced by a substantial margin and it can possibly approach zero, if it is spent only when and where it is needed. One of the key ways to reducing the building energy consumption is to identify the locations inside the building that requires energy resources, such as occupants spots, and then to evaluate the required energy and finally to deliver these resources for a period of time during which they are needed. With the intermittent use of residential building, people are spending less time inside their houses and therefore, the idea of using high thermal capacitance building structure that can keep a uniform space temperature in the presence and absence of occupants does no longer apply when conservation of energy is considered. To transform the concept of residential buildings the following steps need to be considered particularly in MENA region where the climate is mild and building energy systems designs can accommodated these concepts into:

- Optimum physical properties of the residential building construction materials for the insulation, thermal capacitance and moisture absorption should be determined.
- A system of sensors that is capable of tracking the occupants are needed to provide the occupant with the necessary cooling/heating and fresh air only where the occupant is located
- A fast responding delivering system for the heating/cooling is required.
- The use and integration with renewable energy becomes a must with the new concept of building air-conditioning system. The storage cooling/heating systems could use solar energy.
- The practice of architecturally designing the interior of the space has to be rethought to enable the environmental conditions inside the space to be compartmentalized. The environmental compartmentalization of an airplane environment might be an option where each row has its own supply and return air outlet.

3- Hybrid systems that supply cooling needs and fresh water needs.

In the hot and humid climates of the Middle East, where clean fresh water is a scarce resource, and a comforting surrounding is not naturally available we may have two major needs of occupants. These include the need to dehumidify air that meet comfort conditions while at the same time have a fresh water supply. Both needs are proposed to be met by a hybrid system that combines both functions in one unit to effectively meet these needs with low impact on the environment and reduced energy cost. This can be done through the use of the growing technology of liquid desiccant solutions running through a dehumidifier/Regenerator system or combine the dehumidifier with reverse osmosis for water production. On the one hand these special types of chemicals which enter the dehumidifier give us the ability to remove excess water vapor from the air which can be used as fresh water. The continuing rise in energy demand and costs and the associated environmental problems, notably climate change, is causing increased emphasis in finding more efficient ways to condition our closed spaces without having to harm our environment.

Absorption cooling using renewable energy for space heating and cooling will witness major research and development work in the Arab region with emphasis on effective control strategies for distribution of cooling power to the spaces.

Optimized operation of hybrid systems will be another research area that is important for minimizing energy consumption and improving cooling and generation systems' efficiencies

4- Renewable Energy Applications and Product Development.

Research on renewable energy applications will aim to produce and power green (renewable energy) products that reduce reliance on conventional energy, maintain and improve the quality of life, and are affordable to the people in less developed and developed countries. This will open a large green labor market for skilled human resources in renewable energy applications.

5- Energy Education and Training

Engineering, business, sciences, economics and public policy schools are cooperating to provide needed energy education that addresses the preparation of the technical, business, and policy development skills that are and will be highly sought for in the coming two decades. Several specialized programs have been developed at the master level and minors in energy are now part of the undergraduate education. Examples can be drawn from universities in Lebanon, Jordan, Egypt, UAE, and KSA.

Recommendations on Major Opportunities of Interventions to Enhance Sustainable Energy Practices in MENA Region

The Arab countries in the MENA region, despite having a high potential for sustained economic growth and development, have continued in the past decade to have weak economies characterized by income mainly originating from consumer-oriented industries instead of income from productive enterprises. They are dominated by environments of weak national planning and inefficient management of national budgets, rising unemployment and poverty, and increased environmental degradation [IDRC, 2000]. Arab countries began economic reforms to stimulate private investments and to support the transition to a market economy. These reforms have also emphasized the redefinition of national and regional research strategies and the introduction of quality assurance in educational institutions. These discussions have affected scientific research and in particular energy research in universities to be directed towards addressing local and regional problems.

The increase in the number of newly established private universities in the MENA region has forced universities to reposition themselves if they wish to remain competitive in the field of education, to distinguish themselves through research contributions/funding, and to seek local, regional and international partnership from peer institutions. A few private non-profit institutions in MENA region have been more successful in this repositioning than public and for profit institutions, due to the high caliber of the faculty, evident in their research output and performance. Regional cooperation among researchers in MENA and GCC universities will pave the way for building on shared knowledge and for the adjusting to needs and research priorities that serve home countries of both institutions. No longer can Arab countries afford rudimentary, scattered, redundant, irrelevant, non- creative, and un-accountable research projects, despite the impressive number of highly qualified and employed academics and researchers. Greater financial resources need to be allocated to support research in competitive situations...

One challenge is to have research support come from the industry or to have enterprises and companies spin off from universities. This goal is more reachable in GCC countries where governments and universities have already partnered with US and European institutions to reform funding concepts. University faculty must redefine their roles in initiating ideas and linking their research to the development of their country. Another challenge has to do with incentives available to faculty members to continue their focus on knowledge generation. Retention of highly qualified and productive academics in science and technology, in the MENA region, is another issue these countries face. Many faculty members are seeking opportunities to join GCC universities that provide much higher salaries and professional opportunities. These issues can be resolved by reforming university policies to allow bilateral faculty exchanges, and to encourage collaborative research work. Additionally, the field of renewable energy and energy technology research is multi- and interdisciplinary and requires integration of skills from different fields-- from basic sciences, various engineering disciplines, and economics, and policy. Faculty members should be encouraged to change their approach to work so as to focus on long term projects that will lead to the advancement of knowledge and to the strategic development of new programs. This also requires another area of development in universities– that of supporting staff in research management and in the management of multi-million multi-year grants. Administrative support for research projects is lacking in many research institutions, specifically in the managing of paper work, intellectual property, online resources, finances, hiring and signatory structures that enables principal investigators and creates the research culture. Universities need to be encouraged to establish grants and contracts offices to provide the administrative support for external funding support. They should establish international programs and relations offices that aim to extend student and faculty exchanges and provide opportunities for initiating cooperation at the graduate level.

Some recommendations towards enhancing sustainable energy practices have already been addressed by governments in the region. They include creating frameworks for cooperation among Arab Universities with solid and meaningful partnerships for faculty and student exchange, supporting long term interdisciplinary research programs in energy with multiple partners from various countries, funding mobility grants for faculty of universities in Arab countries, and identifying and promoting research programs that address local needs but have global importance. However, an increase in major investments for renewable energy resources for electricity generation, the development of renewable products, and the availability of research funding from GCC and EU to partners from the MENA region will lead to accelerated development, affordability, and the adoption of sustainable energy practices.

The private sector and universities are responding with new urgency to prepare skilled labor for the green energy market for projects, building, and products. Change towards sustainable energy practices is being accelerated through green universities and through energy and research education. If universities support sustainable energy practices, they must invest in making their campuses green, and involve students in these initiatives. Students who live the green building experience will tend to change their attitudes and practice green living after leaving the campus. The promotion of sustainable energy practices can also be promoted through green business practices and green projects.

Several examples were provided in the introductory section about the creation of structures and competitions to engage and support entrepreneurs who are developing products that enhance sustainability and impact development in the society. In addition, the implementation of policies such as that of the Dubai Municipality new building code will force international and regional companies to abide by strict standards for future construction projects. This will increase the demand for trained personnel in green technologies with a deep understanding of integrated approaches to building design from concept to actual construction. It will increase the demand for professionals trained in advanced methods for implementing smart building designs.

The MENA region can provide a pool of trained, skilled, professionals to join local and international firms to develop and implement projects in the GCC and in their own countries. Adapting advanced technologies in the new local climates requires the engagement of universities in the process to ensure proper adaptation of technology. In addition, social scientists, policy experts, and energy technology experts should be able to cooperate and understand the process by which the knowledge of sustainable energy practices and data can be transformed into acceptable policies by the general public and the under-privileged population. Civic responsibility is becoming a major component in university curricula where students are engaged in community projects that improve the quality of life in the society and the understanding of its problems. Civic engagement must become an integral part of the promotion of sustainable energy in future societies.

The MENA region can no longer afford energy waste in all of its sectors. The increased interest in green technologies and population awareness will enable the green market to grow. This market is still in its infancy and will need governmental and research institutions and the support of universities to provide facilities for testing products, labeling and certifying systems. Many governments have been adapting their policies and introducing new energy policies with tax incentives and loans for green products. The widespread market of solar water heaters in Syria, Jordan, Tunisia, and Algeria is a result of a governmental effort in cooperation with research centers, with the support of UNDP.

Development of Energy Policies

The accelerated, but uneven, economic and human development in the Arab region associated with the scarcity of water and the degradation of the environment has led many countries to reform their economic, environmental and energy policies. Investments in the region by international companies and the complexity of the various policy standards will lead to the further development of energy related policies, including labeling, standards, taxation, and incentives for promoting energy efficient practices, in addition to incentives for entrepreneurs developing renewable energy products and services.

Arab countries have also begun addressing the diversification of, their energy generation resources even though they may have plenty of oil and gas resources. Some GCC countries are investing in nuclear power to generate energy; other countries are investing in renewable energy generation. The energy market is expanding and policies that address these issues collectively are needed.

The development of policies for energy generation and use require careful consideration of local materials, climate, culture, and business practices to make sure that the developed policies are implementable and can be supported by local governments. The implementation of policies needs the commitment of many stakeholders, and investment by the government to provide accountability.

Impact on Human resources Development and Mobility in the Arab Region

Human resources must be developed to meet these changes and to affect the move to an expanding market driven economy for sustainable energy products and services. Mobility from and to countries that have the wealth to invest in the emerging green market will increase the need for skilled energy experts, scholars, academics and economists. Energy focused education in engineering and economics majors will be in high demand, and universities will have to develop programs that prepare the students to meet these needs in a more integrated multi- and inter-disciplinary way than ever. Academic programs must address local problems and provide more hands-on experience through open ended projects that involve teams of students. Programs should be based on developing students' critical thinking skills and be more innovative if they are to enhance the expansion of the green energy market. More funding should be available for those types of programs that can partner with the industry to work on energy problems and allow students to think ahead about the future. Governments, particularly in the MENA region (of economies not derived from oil and gas revenues), need to grasp the urgency of upgrading their educational perspective and direct resources towards building these programs in the public and private sector. Governments and universities' resources must go towards creating an atmosphere geared to releasing the employment generating capacity of the private sector to small-sized enterprises.

The GCC is expanding beyond its local labor capacity and it is already attracting skilled labor from the MENA region and from Asia. GCC investors may find an opportunity to expand their investments for private power generation in MENA countries. They could operate in a structure similar to the EU where projects are developed outside its borders. The benefits of bringing human resources together from across the region has resulted in an accelerated research agenda for Europe and the Arab countries thus reducing the brain drain in critical areas like sustainable energy. As a result, there will be a major impact on climate change and benefits to the global community.

Closure and Recommendations for Enabling the Green Market

The green market can be easily created in the GCC region considering the affordability of green products and the wealth of some countries. Strategic energy-related strategic decisions must now be taken by GCC governments to investing in the green energy products market from generation to end user to the manufacturing of green products. Compliance with energy standards and policies can be enforced on businesses and international companies providing services or implementing projects. In addition, the general public has the wealth to afford new renewable products if awareness and civic responsibility campaigns towards improving the environment are financed. However, in the MENA region the challenges are far greater, due to the same factors that hindered development in these countries-- weak economies, political instability, bureaucracy, corruption, lack of appreciation of long term benefits, lack of labor unions, and the inability of thinking strategically in the national interest. The change requires major reform of many policies to expand the green market. It may result from external pressures to be competitive in the global market or from capacity building through UN and EU projects, or from internal pressures from educated professionals who are entrepreneurs and would like to invest in the renewable energy market and energy efficient products. Success and expansion of the green market depends strongly on the presence of energy policies and taxation systems that favor green solutions, human resources with the needed skills to develop the green market, public and research facilities that can provide certification of locally and imported energy products, educational interdisciplinary programs that prepare energy professionals and entrepreneurs to promote and market energy services, access to public domain online data and information needed for the assessment of energy products-including climatic and solar data and bench-marked energy service prices, and public awareness campaigns that are based on locally generated data for the practice of sustainable energy. The governments of Arab countries need to move strategically towards sustainable energy practices and towards supporting businesses and education in that area. Targeting support of energy education of the middle and lower class populations may lead to better results by preparing individuals for new job opportunities that will open up in these new areas.

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