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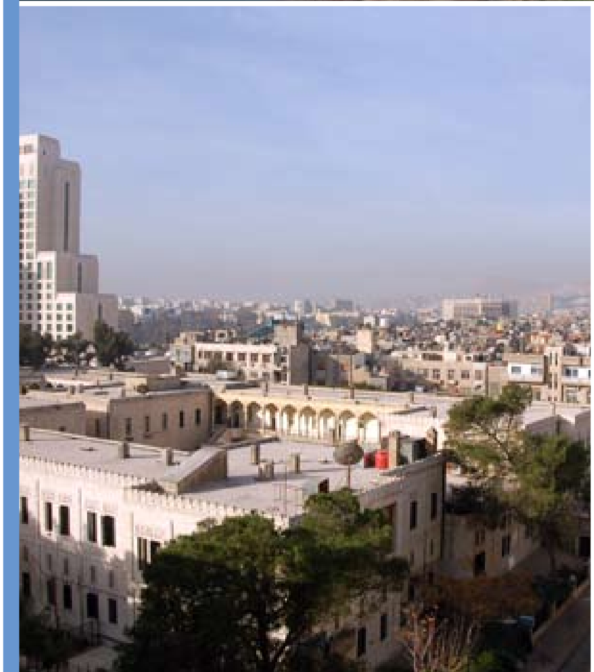

Water and Energy Linkages in the Middle East

Regional Collaboration Opportunities

Middle East Seminar Report World Water Week 2009
Edited by Jakob Granit and Rebecca Löfgren

Background papers by: Michael King and Andy Bullock, George de Gooijer, Jakob Granit, Anders Jägerskog, Andreas Lindström, Rebecca Löfgren, Stuart Pettigrew and Elin Weyler

Seminar contributions by: John Anthony Allan, Mirey Atallah, Mustafa H. Aydogdu, Shawki Barghouti, Carol Chouchani Cherfane, Stephen F. Lintner, Koussai Quteishat and Mengesha S. Woldesemait

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SIWI April 2010

List of Abbreviations

ACWUA	The Arab Countries Water Utilities Association
AfDB	African Development Bank
CAMRE	Council of Arab Ministers Responsible for the Environment
CAPP	Central African Power Pool
COMELEC	Comité Maghrébin the l´Electricitié in the Maghreb Union
DRC	Democratic Republic of the Congo
EAPP	East Africa Power Pool
ECOWAS	Economic Community for West African States
EDF	Electricite De France
ENTRO	Eastern Nile Power Trade Study
EEHC	Egyptian Electricity Holding Company
ELTAM	Egypt, Libya, Tunisia, Algeria, Morocco and Mauritania
FAO	Food and Agriculture Organization of the United Nations
GAP	Southeastern Anatolia Project (in Turkish: Güneydogu Anadolu Projesi)
GCC	Gulf Cooperation Council
GCCIA	GCC Electrical Interconnection Grid
GDP	Gross Domestic Product
GTZ	German Technical Cooperation
GW	Gigawatt
IAEA EEDRB	International Atomic Energy Association Energy and Environment Data Reference Bank
IPCC	Intergovernmental Panel on Climate Change
JMP	Joint Multipurpose Program
JRS	Jordan River System
kV	Kilovolt
kW	Kilowatt
LNG	Liquid Natural Gas
MW	Megawatt
NEPAD	New Partnership for Africa's Development
NTCF	Nigerian Technical Cooperation Fund
NTDC/WAPDA	National Transmission & Despatch Company, Pakistan
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SEC	Saudi Electric Company
Sida	Swedish International Development Cooperation Agency
SIWI	Stockholm International Water Institute
TARWR	Total Actual Renewable Water Resources
TWh	Terawatt-hour
UAE	United Arab Emirates
UNEP	United Nations Environment Program
UNESCWA	United Nations Economic and Social Commission for Western Asia
USD	United States Dollars
WAPP	West African power pool
WSS	Water Supply and Sanitation Services
WWW	World Water Week in Stockholm

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1 Seminar key messages, conclusions and next steps

Transboundary water management and development and access to energy are closely linked to the creation of livelihood improvements, environmental sustainability and regional integration in the Middle East. To be able to reduce poverty in the region, reliable access to water and energy is a must. Without a reliable power supply, water for domestic use, industry, treatment, irrigation and desalination is at risk.

A seminar[1] was arranged during the World Water Week 2009 to explore the specific linkages between development opportunities in transboundary water management and electricity development. The seminar was arranged by SIWI with sponsorship from the Swedish International Development Cooperation Agency (Sida). Technical presentations were made by experts on water and energy from the region and beyond. Panel debates and interaction with the participants allowed for discussions.

Seminar facilitator Mr. Jakob Granit, Project Director at SIWI, concluded that cooperation in the electricity sector is demonstrating promising results. He added that those working to improve benefit sharing over water resources could apply lessons learned from some of the successful experiences from this cooperation. It would be beneficial to explore in more detail how an integrated regional cooperative approach on water and energy could be established to tackle the development challenges that lie ahead in the Middle East. A promising option brought forward at the seminar is to further develop the regional electricity market and connect it with emerging power pools beyond the region that takes advantage of potential hydropower sources.

Seminar key messages and conclusions

- Access to water and energy are crucial for development and improved livelihoods in the Middle East. Evidence presented at the seminar confirms that the supply of electricity can trigger development and pave the way towards industrialisation and other services.
- Rapid population growth and economic development will increase the demands for electricity and the pressure on the freshwater resources in the region.
- Reliable supply of electricity to water supply and sanitation systems will be increasingly important as the resources will most likely be pumped long distances, from aquifers or produced through other means, such as energy intensive desalination processes.
- The region's extensive use of its water resources for irrigated agriculture consumes significant amounts of energy and provides limited economic benefits. Water availability is decreasing, partly resulting from climate change, and adding urgency to reform in the agriculture sector.
- Successful countries in the region are diversifying their economies away from agriculture and are putting in place water demand management systems to save water for high value use.
- The most cost-effective option to meet future electricity demand is to develop and share the region's own resources through power pools and to import electricity from other regions, notably the Nile Basin, the Congo basin, Central Asia and North Pakistan, where major hydropower development opportunities exist.
- The development of hydropower, including irrigation and flood control, in multipurpose schemes that employ best available practice will provide benefits that can be shared at the regional level.
- Hydropower provides future price security and, for countries with indigenous supply, reduces foreign exchange requirements for fuel purchases. The environmental benefits from pollution reduction and lowering greenhouse gas emissions have been well established.

Next steps identified to promote regional integration through transboundary water management and cooperation over electricity

- The transboundary nature of the water resources in the Middle East makes cooperative management of these resources critical. The same is relevant for energy, where co-management of electricity networks will increase the possibilities for each individual country to get access to a larger set of cost-effective energy sources. An integrated regional cooperative approach based on water and energy is needed to tackle the development challenges that lie ahead in the Middle East.
- Many countries already share electricity grids and plan to connect them to regional networks. For example, the Gulf Cooperation Council (GCC) interconnection project and the work on a Mediterranean power pool are in place. Larger regional plans still have far to go before reaching the implementation phase, but dialogues are ongoing throughout the region.
- Cooperation on energy networks exist through bilateral trade agreements and transmission interconnection projects, even in areas with civil strife. This promising emerging cooperation should be analysed to identify successes and failures that can be applied to cooperation on transboundary waters.
- Benefit sharing schemes based on water and energy can promote regional integration that brings stability, provides more opportunities for the small and isolated economies and stimulates growth in larger economies.
- The regional electricity market should be further developed and interconnected with emerging power pools beyond the region and take advantage of opportunities for increased hydropower generation.
- The transboundary water resources in the Euphrates and Tigris, and beyond the region, in Central Asia and the Nile Basin, feature large hydropower development opportunities that can provide cost-effective hydropower for the regional market.
- Strengthening cooperation on both the management of transboundary waters and regional electricity networks within and beyond the Middle East provide good opportunities to reduce poverty and stimulate sustainable development in the region.

2 The Linkages between Water and Energy

The Middle East is a region of extremes. Already one of the driest and most water scarce areas of the world, the region is expected to double its population in the next 40 years. The effects of climate change are predicted to exacerbate the situation. While some countries enjoy extreme wealth, others are among the poorest in the world. Poverty reduction and distribution of wealth are of critical importance for regional development. Energy inputs, particularly electricity, are essential to create employment and for industrial activity, transportation, commerce and agriculture. Ensuring available electricity is crucial to provide education, health, gender equality and environmental sustainability[2,3] services. Water management and use for agriculture, domestic supply and industry is closely related to reliable access to electricity.

The region has the highest per capita rates of freshwater extraction in the world (804 m^3/year) and currently exploits over 75 percent of its renewable water resources. The water storage capacity is more developed than any comparable region. Demand for water will continue to rise across the region, due to population increase and economic growth. The agricultural sector is by far the most demanding in terms of water withdrawal compared to any other sector. It consumes on average about 80 percent of the freshwater resources. The Gulf States, dominated by oil industries, still withdraw a considerable amount of available water for agricultural purposes despite only small contributions to GDP (in many cases less than 2-3 percent of GDP).

Electricity powers and moves the production of water-related goods and services that drive the economies in the region. The availability of reasonably priced electricity is a major factor in resolving the interconnected issues of population, poverty, and environmental sustainability. The generation of electricity through hydropower provides a direct feedback loop to water management.

Because electricity may be transported at reasonable cost over long distances, a review of supply options in a specific country or region

Figure 1. Map of the Middle East Region. Hugo Ahlenius, Nordpil, 2008

has to consider outside sources for both electricity generation and transmission options within the region. In some cases, they also should evaluate the potential for importing surplus electricity from outside the region. Moving water is more expensive and less economical than energy. Water transfers between river basins, both at the transboundary level and in-country, are expensive and have both environmental and social impacts that are costly to mitigate. Electricity generated in one basin through hydropower schemes can therefore provide an alternative to distribute more benefits, in the form of energy, from one basin to another without the negative consequences of water transfer.

The 2009 Middle East Seminar "Water and Energy Linkages in the Middle East" at the World Water Week explored the linkages between water and energy in the region. It investigated how cooperation on water and energy issues can reinforce sustainable development, promote regional integration and stability, and explored ways for cooperation in one sector to strengthen the other. The seminar also analysed some promising cooperative partnerships in the energy sector that can serve as an example for effective cooperation over water resources both at the national and transboundary level.

This report is based on two background papers[4] prepared for the Middle East Seminar at the World Water Week 2009 and on the presentations and discussions during the seminar. The Middle East region includes in this report Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates (UAE), and Yemen. The countries in the region (except Egypt) are placed into three groups to reflect their hydrological and/or geographical linkages (figure 1):

- Jordan River Basin
  Israel, Jordan, Lebanon, and the Occupied Palestinian Territories
- Euphrates-Tigris River Basins
  Iran, Iran, Syria and Turkey
- Gulf states / Arabian Peninsula
  Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, UAE, and Yemen

3 Water Resources in the Middle East

The Middle East region hosts five percent of the world's population, but only one percent of the world's renewable water resources. About 60 percent of the available freshwater is in transboundary basins[5].

3.1 *The Euphrates and Tigris River Basins*

Syria, Turkey and Iraq are riparian countries in the Euphrates basin, which has a surface area of 450,000 km^2. The Euphrates River is 2,735 km long. The river rises in Turkey and flows through Syria before entering Iraq where it joins the Tigris and forms the Shatt al-Arab that empties in the Arab/Persian Gulf. The Tigris basin shares the same political boundaries with the addition of Iran as a fourth riparian country. The basin covers about 110,000 km^2 and the river is roughly 1,900 km long. Before the confluence of the Euphrates and Tigris, the Euphrates and Tigris flow within Iraqi territory for about 1,000 km and 1,300 km respectively.

Poor irrigation practices have led to severe salination and land degradation in the basin. The UNEP estimates that over 30 percent of land in the basin has been damaged by salination resulting from irrigation. The Mesopotamian Marshlands in Iraq have become a symbol of the deterioration of the basin. Deliberate political decision by the regime of former President Saddam Hussein to drain the Marshlands in combination with overuse of water in the both the Tigris and Euphrates rivers upstream have significantly reduced water flow to the Marshlands. Recent work to re-flood the area is beginning to restore the livelihoods and ecosystems in the area.

3.2 *The Jordan River Basin System*

The Jordan River System (JRS) is composed of several hydrological units. The Jordan River Basin is of great importance to Jordan, the Palestinian Territories and Israel. Syria and Lebanon also contribute water resources to the basin, but rely much less heavily upon it for water abstraction. The Jordan River suffers from over-extraction, severe pollution and salinity problems. This is especially significant in years of drought.

Considerable dam construction and diversions for agriculture have in effect stopped natural flow in the Jordan River. Only between 5-20 percent of the natural flow is reaching the Dead Sea. The annual flow of the river has plummeted from 1.3 billion m^3 to just 100 million m^3. This has several severe environmental and social consequences, including the formation of sink holes and retreating sea levels.

3.3 *Arabian Peninsula*

Water resources are dominated by groundwater and are over-exploited. Five of the seven countries extract water at rates greater than natural recharge. This has led to salt water intrusion in the aquifers and subsequent lowering of water tables. Agricultural productivity has been reduced substantially.

The oil rich countries on the Peninsula have large desalination schemes to help alleviate the water stress. In Saudi Arabia about 70 percent of the drinking water is provided through desalination plants. As can be seen on next page, all the countries on the peninsula represented in Table 1 (page 9) are using more than 100 percent of their renewable water resources, and in Kuwait that number is above 2,000 percent. The effects of climate change may make supply less reliable. Population and economic growth are expected to increase demand for water. New water governance policies to manage water demand, including e.g. better water tariff systems and raising awareness, are needed.

3.4 *Water and development*

Water is important to national development and it is prominent in the national politics of virtually every Middle East nation. There are strong interconnections between nation states and natural resources. Water is necessary to sustain life, meet health objectives and maintain agriculture and has therefore a very important place in the minds of Middle East citizens. It has played an important role in the development of the early irrigation societies – simply because in the arid areas control over water means control over

Table 1. Precipitation and water use in a selected number of countries in the Middle East (TARWR: Total Actual Renewable Water Resources)

Country	Precip. mm/yr	Total use percent TARWR	Population (1 000 000s)	TARWR Per Capita (2005) m^3/yr
Iran	200	53	70	1,970
Iraq	200	57	26	2,920
Israel	400	122	7	250
Jordan	100	115	6	160
Kuwait	100	2,227	3	8
Oman	100	137	3	340
Saudi Arabia	100	722	25	96
Syria	300	76	18	1,440
Turkey	600	18	72	2,950
UAE	100	1,538	3	49

Source: World Water Development Report 2, UNESCO 2006

development. As a result, the value of water to the entire economy of each individual nation has elevated water to the status of a major regional challenge. It is a challenge with prospects for conflict and cooperation. The consequences of what will happen over the coming years and decades will, however, not be confined within the narrow water sector.

Tackling water's contribution to economic development will undoubtedly depend on the successful management of the available water resources that are regional and shared. Most notably, this includes the Euphrates-Tigris basin, the Jordan basin, and shared groundwater aquifers. To achieve water security, regional political security and stability for its citizens, the Middle East region will have to tackle the governance aspect of water. Interventions can be most effective if they target the regional, national and local scales in unison. Investments in the energy sector are also flagged as critical in order to ensure the region's ability to manage water for productive purposes, desalination and water reuse. Similarly, investments in the region's ability to adapt to climate change and to maintain environmental services at the basin level are critical to ensure long term supplies.

3.4.1 Agriculture and food

Cropping and irrigated agriculture has been practiced in the Middle East since at least the 5th Century BC. Regionally, more than 85 percent of extracted freshwater is consumed in agriculture. This varies from country to country, but the largest users (including Iran, Iraq and Saudi Arabia) all exceed 90 percent. Israel (63 percent) and Turkey are the only large producers in the region that fall below this level (75 percent).

The region is sensitive to climatic effects on agriculture production and already imports some USD 12 billion worth of food annually. Food imports account for between 10 percent and 35 percent of all imports in the region. The World Food Program in Yemen estimated that in 2008 between 75-90 percent of all food consumed in the country was imported. The major traded food products are basic grains, although individual countries, most notably Israel, are exporters of higher value crops, such as fruit and vegetables. Water use efficiency must be improved. While broadening the skills and knowledge for water use efficiency can improve the productivity within a group of crops, the more difficult issue of where to allocate scarce water resources needs to be addressed.

3.4.2 Water supply, sanitation and health

Access to sanitation is 100 percent in high income countries, and ranges from 90 percent to almost 100 percent in middle income countries. Yemen has the lowest overall access at 86 percent and is also the poorest country based on income per capita. Access to safe water supply follows a very similar pattern. The statistics (per country) differentiate between the diseases related to hygiene, water supply and sanitation (infections through viruses, bacteria and worms), and the diseases related to water management (vector diseases linked to water). Where the contribution of water-related death and disease is small in the high income and the higher middle income countries, this quickly changes in the lower middle income countries, with the highest levels in the poorest country, Yemen, followed by Iraq[6, 7].

3.5 Economy and water resources

Middle East poverty rates have declined over the past three decades. Exploitation of oil resources has led to concentrations of wealth and poverty. The region has comparatively high GDP per capita but there is great disparity between countries as well as within them (see Figure 2). High population growth rates are expected over the next 40 years. As a whole, the region's population is projected to double (Figure 3). This will of course put increased strain on the natural resources. The service sector contributes more to the region's GDP than any other sector (figure 4), whereas agriculture contributes least. Despite the small contribution to GDP, the agricultural sector is by far the most demanding in terms of water withdrawal in all of the sub-regions and compared to any other sector. Gulf States dominated by oil industries still use a considerable amount of water withdrawal for agricultural purposes despite their small contributions to GDP (in many cases less than 2-3 percent of GDP) (Figure 5).

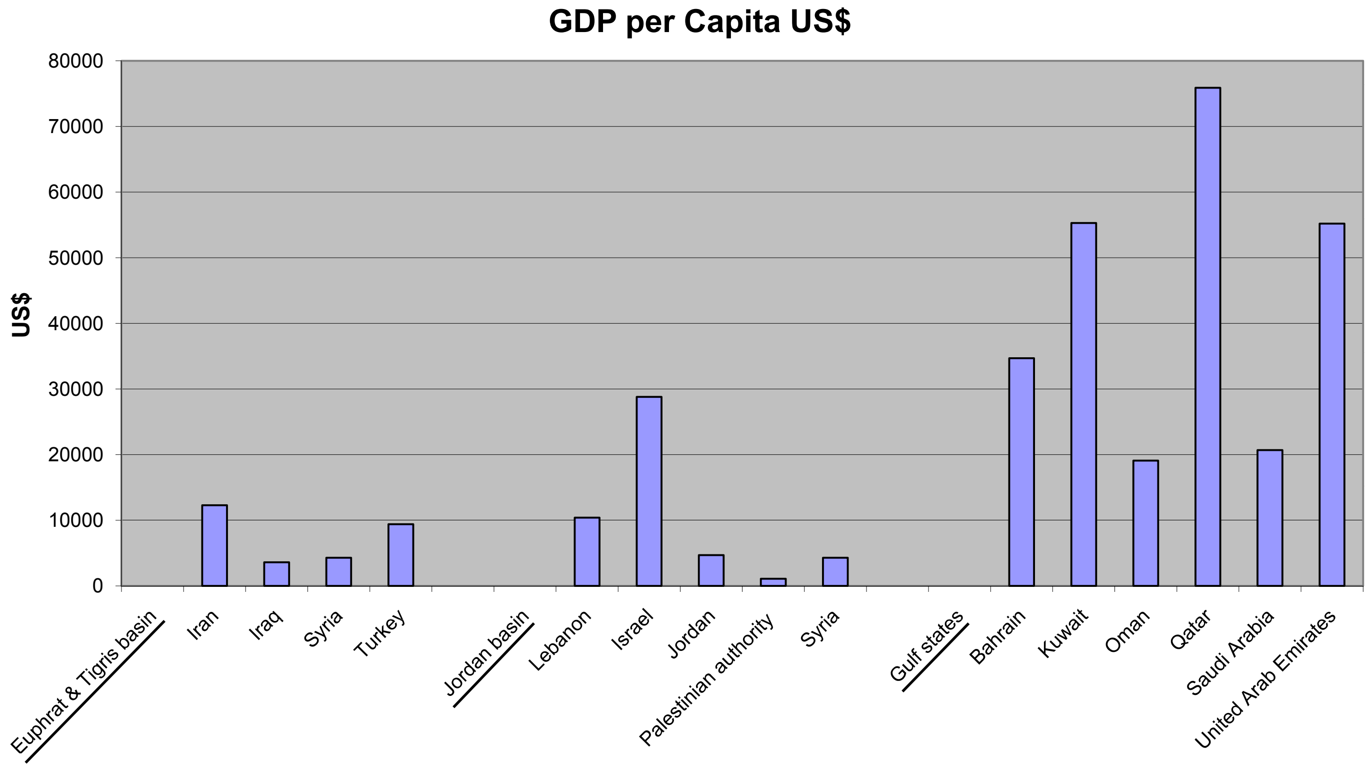

Figure 2. GDP Per Capita. Source: Central Intelligence Agency – The World Fact Book (May, 2008)

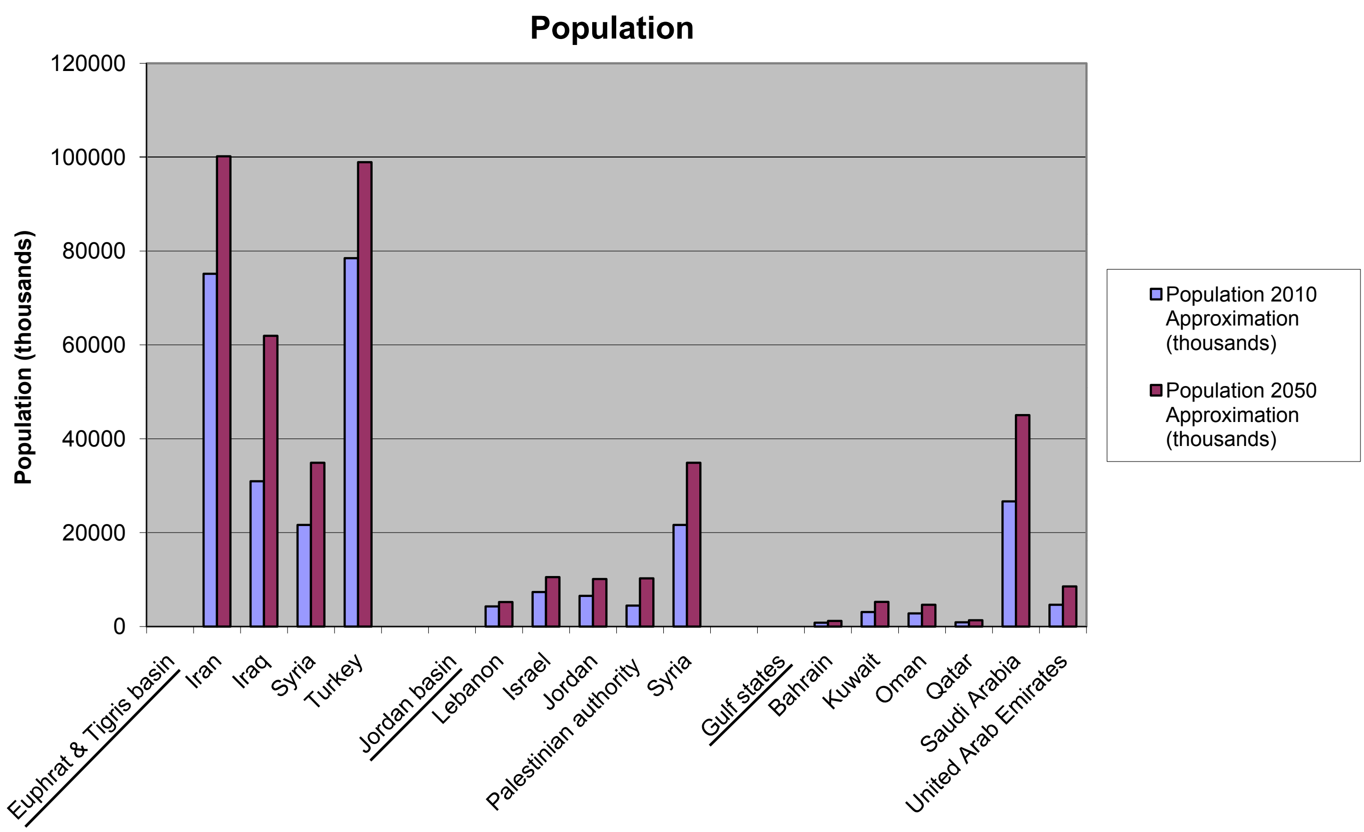

Figure 3. Expected population growth. Source: Central Intelligence Agency- The World Fact Book, UN Data, Population Reference Bureau (May, 2008)

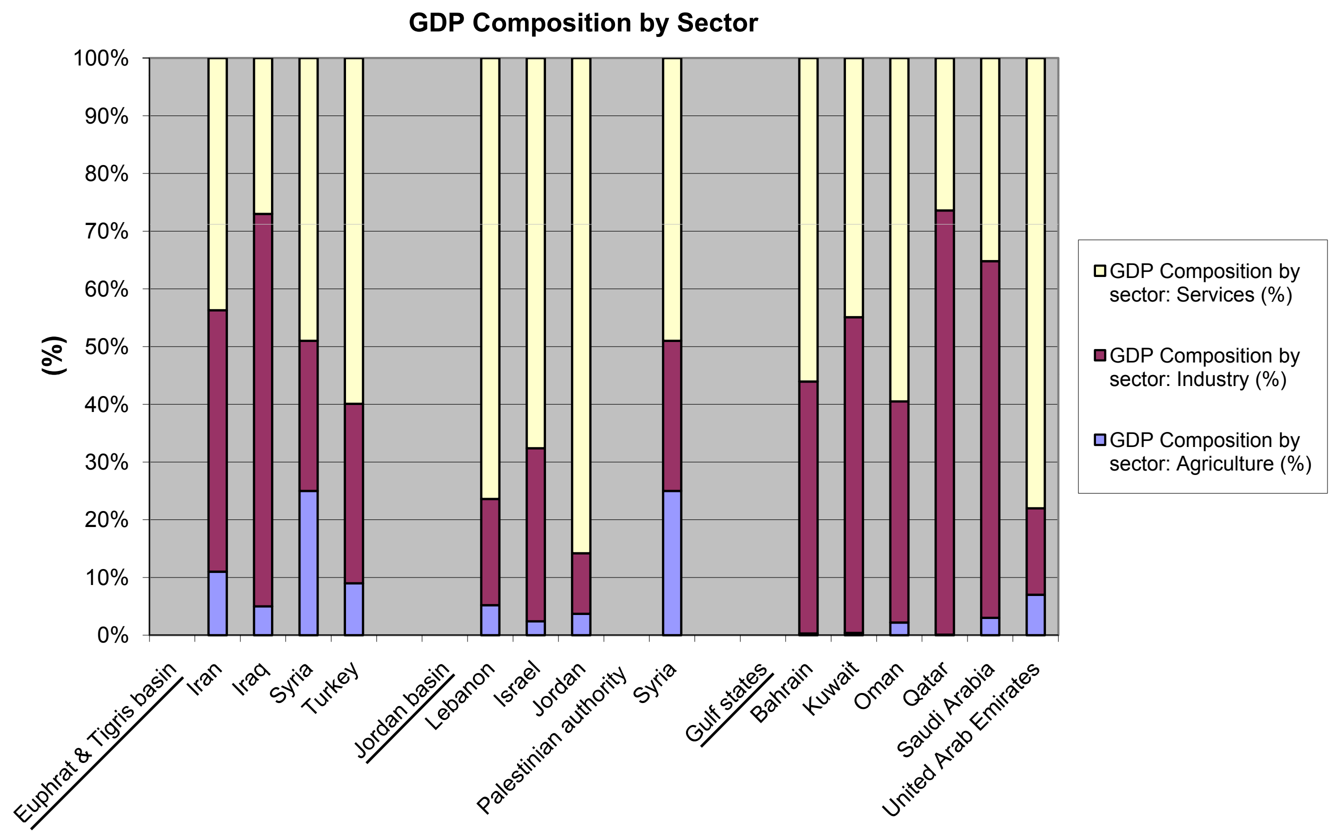

Figure 4. Sector contribution to GDP. Source: Central Intelligence Agency – The World Fact Books (May, 2008)

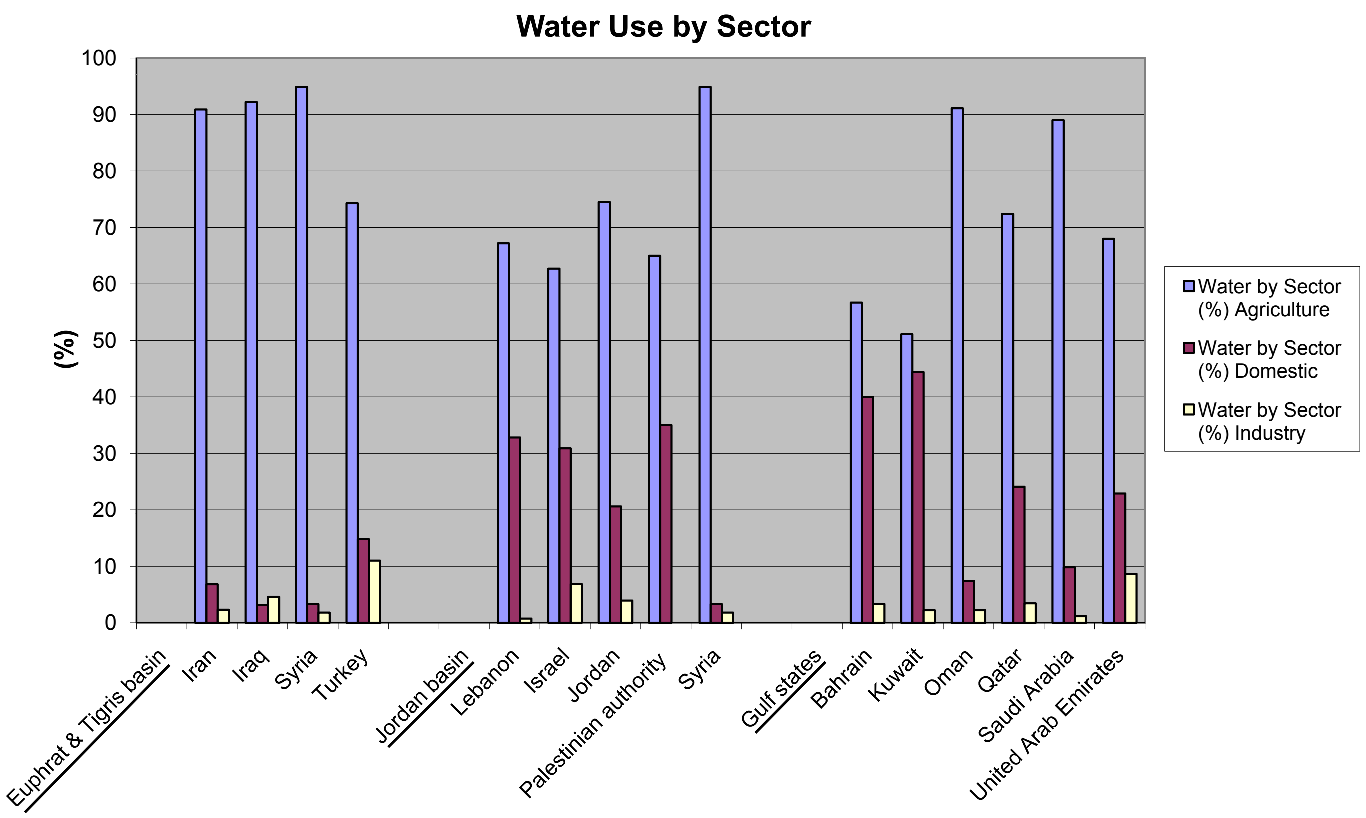

Figure 5. Percentage of water use per sector. Source: FAO Aquastat, Israel/Palestine Center for Research and Information (May, 2008)

3.6 Water and climate change

The Middle East is one of the most vulnerable regions in the world to the impacts of climate change. The mean temperature is predicted to increase as well as the variability of rainfall. Climate models are showing divergent results when analysing changes in amount of rainfall. According to the IPCC[8], most models predict minor changes in rainfall. Still, even slight increases in temperature and small changes in precipitation will have major impacts on the highly water scarce region. The average temperature will, according to most models, increase between 1.2 and 3°C. This will increase the evaporation rate and therefore decrease the portion of available water from rainfall and surface water which also affects the recharge of groundwater. An increase of 1°C is likely to increase agricultural water demand by 10 percent. The increase in temperature is expected to be larger during winter than during summer.

To be able to adapt to climate change, it will be important for the countries relying on water intensive agriculture in the region to diversify their economies in order to make them less vulnerable. According to a study done by the FAO[9], the average cost to the economy of a baseline climate change scenario in the Middle East region is predicted to be about 1.9 percent loss of GDP. Under a high climate change scenario the loss is predicted to be 3.5 percent, mostly due to a loss of arable land and threats to coastal cities. Food import will need to increase.

4 Energy in the Middle East

At the regional level, hydropower forms the quintessential link between water and energy. Water resource management, irrigation, supply, and treatment all place demand for electricity to be able to operate on the local level. Electricity also links basic natural resources, i.e., water and fossil fuels, and delivers the goods and services that provide the basis for the economies of the world. The availability of reasonably priced electricity is a major factor in resolving the interconnected issues of population, poverty, and environmental sustainability.

The current availability and future potential of electricity supply in the region depends on 1) in-country fossils fuels, 2) hydroelectricity, 3) renewables, and 4) wealth, as wealth allows for imports of fuels or electricity. The overall energy balance (supply/demand) will also be affected by the extent to which demand side management can be applied to reduce total energy consumption and the region's ability to increase supply through renewable energy sources, such as solar and wind power.

4.1 Energy, water and development

Water and energy are both closely linked to development. In the Middle East, there are specific regional conditions that are important to consider in the context of water and energy linkages. For example, it is important to consider the differences between access and availability, which doesn't always go hand-in-hand. Variation in access to water and electricity between urban and rural areas, especially in Egypt, Oman and Yemen is another area that requires attention since it is is often hidden in statistics showing country availability. The region is also burdened by conflict, which has destroyed and damaged infrastructure for both water and energy. Iraq, the Occupied Palestinian Territories and Lebanon are particularly affected. The same countries are also affected by insufficient supply, problems of operation and maintenance and financial constraints. Often, access to a network exists, but the network only provides intermittent service provision of water or electricity[10].

Table 2. Relationship between population, economy and energy use and resources in the Middle East. Sweden is added for comparative reasons.[11]

Country	Population million	Population per km²	GDP total USD billion	GDB/cap USD	Electricity use kWh/cap	Indigenous energy resource
Bahrain	1	987	29	35,900	15,570	Gas, Oil
Egypt	78	77	326	4,200	1,300	Gas, coal, hydro
Iran	71	42	872	11,763	1,800	Gas, oil, hydro
Iraq	24	55	102	3,600	1,300	Gas, oil, hydro
Israel	7	290	201	28,245	6,500	Gas
Jordan	5	58	32	5,410	1,440	Nil
Kuwait	3	119	152	42,500	16,800	Gas, oil
Lebanon	4	354	49	12,700	2,800	Nil
Oman	3	13	73	27,900	4,304	Gas, oil
Palestine	4	620	5	1,100	NA	Nil
Qatar	1	69	117	96,275	21,750	Gas, oil
Saudi Arabia	24	12	636	24,936	3,700	Gas, oil
Syria	17	93	99	4,870	1,600	Nil
Turkey	72	91	937	13,450	2,100	Coal, hydro
UAE	5	30	201	40,040	13,700	Gas, oil
Yemen	19	35	61	2,560	174	Nil
Sweden	9	20	385	28,400	15,665	Hydro

4.1.1 Agriculture and rural development

Many areas in the Middle East are dependent on groundwater for irrigation as well as for water supply. During the 2009 WWW Middle East Seminar, it was noted that intermittent electricity supply increases the cost of production and will reduce the productivity of the region's agriculture[12]. This will affect the development of the rural areas in the region and have implications on food security and sustainable livelihoods. The impacts of climate change are likely to increase the need to pump groundwater for irrigation, which will also amplify demand for reliable electricity supply.

4.1.2 Water supply and sanitation

To provide adequate water supply and sanitation services (WSS) requires access to water and relevant infrastructure. Dependent and reliable energy sources are as important for WSS delivery. High performance and service delivery depend on consistent sources of electricity. Unreliable electricity availability can affect the water quality as fluctuating pressure and loss of pressure in pipes draws in outside contaminates into the pipeline networks. Cost recovery in the WSS systems are affected by interruption of electricity when supply becomes intermittent.[13]

4.2 Economy and energy availability

In broad terms, Middle Eastern countries may be classified in: nations that have substantial petroleum / gas resources that provide energy and relatively affluence (e.g. Qatar); nations that have strong indigenous renewable and non-renewable energy sources (e.g. Iran); nations that are primarily dependant on hydropower (e.g. Turkey); and nations with no significant indigenous energy resources (e.g. Syria). Table 2 provides a comparison between basic economic parameters, such as average income, population, and availability of indigenous energy resources. Data is taken from the years 2007 to 2009, as available[14]. Comparative data for Sweden has been added to put the range of statistics for the Middle East region into perspective. Clearly, energy consumption is highest in the richest of the Middle East countries, i.e. the Gulf States (with the exception of Yemen). This in turn correlates directly with a high level of oil resources combined with small populations. Consumption rates in the countries of the Jordan River Basin and in the Euphrates and Tigris River Basins are similar, with the single exception of Israel, which reflects its more developed industrial and commercial base. In general, lowest consumption occurs in countries with no or minimal indigenous energy resources (oil or hydro), and these are also the poorest countries. This reflects the general consensus that poverty alleviation depends on access to improved health (including clean water) and education, and that these are heavily dependent on access to reasonably priced and adequately reliable electricity. This relationship is the driving force behind rural electrification programmes to improve access to electricity.

For countries that are not heavily endowed with hydrocarbon resources, it should be recognised that wealth is, to a significant degree, enhanced by access to electricity, rather than the reverse. Thus access to electricity is a critical factor in improving quality of life and prosperity.

Within the region, there are three groups of countries:

- Countries with petroleum reserves, which yield sufficient wealth to purchase clean water and for advanced health and education programme (the Gulf States except Yemen).
- Countries with adequate indigenous hydro, coal, and natural gas resources to achieve a reasonable level of economic development and quality of life (e.g. Turkey and Egypt). The hydropower resources are, however, in many cases located in transboundary river basins and hence the development of those resources entails some form of cooperation with the riparian countries.
- Countries without indigenous energy resources (e.g. Yemen and Jordan) which could benefit considerably from access to reasonably priced electricity via transmission interconnections and power trading arrangements.

4.3 Energy demand outlook

In order to put the potential contribution of hydropower and imports to the region in context it is relevant to look at current and projected electrical demands for a long term horizon of year 2030, i.e. 20 years into the future. This outlook does not take major demand management into account, nor does it consider possible major transformational implementation of renewable energy such as solar or wind. However, these renewable sources will be needed to complement conventional technologies in meeting future demands.

Projected demands in 2030 are approximate and only intended to provide an indication on the order of magnitude of the minimum energy requirements for the new generation. These are based on specific forecasts from available references. For other countries, an average annual growth rate of 3.5 percent per year has been assumed, which is less than median or typical values used in planning studies for developing countries, and thus may be considered a low estimate. Demand is assumed equivalent to the total electricity supply in a country, which includes any imports. If one assumes an average capital cost of USD 2,000 /kW, the total corresponding

Table 3. Energy demand in the Middle East (TWh)[15]

Country	Present / recent demand	Demand in 2030
Bahrain	11	30
Egypt[16]	123	407
Iran	156	370
Iraq	33	77
Israel	44	105
Jordan	8	18
Kuwait[17]	52	145
Lebanon	11	25
Oman	12	21
Palestine	4	9
Qatar	17	26
Saudi Arabia	87	156
Syria	27	64
Turkey	152	360
UAE	74	191
Yemen	4	9
Total	822	2010

investment would be in the order of USD 4 trillion. Comparative values based on an average growth rate of 5 percent are 50 percent higher. This illustrates the major infrastructure and investments which will be required within the next two decades, and the dramatic effect that would result from higher growth rates.

4.4 Present contribution of hydroelectric generation

The region primarily depends on indigenous or imported fossil fuels for power generation. However, hydroelectric generation makes an important contribution in certain countries. This is usually associated with multipurpose applications, such as flood control and irrigation, which are also important to the economies of these countries. In fact, for some projects, such as the High Aswan dam in Egypt and the Thawa Assad project in Syria, these non-hydro benefits provided the primary justification for the construction of the hydro project.

The availability and use of significant hydroelectric resources is directly dependant on the water resources of the region in which the country is located. All countries in the Euphrates and Tigris River Basin (Iran, Iraq, Syria and Turkey) have significant hydroelectric generation supply and potential. However, the countries that are located in the Jordan River Basin (Israel, Jordan, Lebanon, the Palestine Territory), and the Arabian Peninsula (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, UAE, and Yemen) have minimal water supplies, and no hydroelectric generation potential. Egypt benefits from substantial energy generation on the Nile and will have access to upstream hydropower from Sudan and Ethiopia if cooperation moves forward. Both Lebanon and Egypt have developed most of their in-country hydro resources. Six countries have significant hydroelectric resources or potential for additional hydro development (see Table 4).

Hydropower contributes more than 12 percent to the total electricity supply in the region, and much of this generation is multipurpose, providing other social and economic benefits. The countries with the best opportunity to develop and use hydropower in transboundary river basins, and reduce fossil fuel dependency in the future, are Iran, Iraq, Syria, and Turkey (Egypt can be included in this discussion due to its present major hydro development). These future options are reviewed in the following section. An important component to be noted is the extent to which present and future hydro are part of a water management and supply system, primarily for irrigation and agricultural production.

4.5 Future generation needs and supply options

The approximate estimate provided above indicates a total future need for a further 200-300 GW, or 1,200 to 1,600 TWh, of new electricity supply by 2030. Future supply additions to countries in the region can be divided into four categories:

1. Indigenous oil and gas will supply 100 percent of the needs of individual countries.
2. Indigenous coal and hydro will provide part of the needs of individual countries.
3. Generation deficit will be met by imported fuels and/or interconnections within the region.
4. Imports from outside the Middle East Region to supply a Middle East backbone grid.

If it is assumed that the Gulf States (excluding Yemen) and Iran and Iraq can provide for future needs from oil and gas reserves, the total future requirement shrinks to about 700 TWh. Based on available information on indigenous fuels and hydro resources, and assuming maximum development of hydro, and assuming the nominal lower 3.5 percent growth rate for countries for which forecasts were not obtained, the projected additional need of approximately 180 TWh to be met by imported fuels, or electricity over transboundary interconnections.

Component	**Potential supplyTWh**
Countries with 100 % oil/gas	490
Oil/gas partial supply	330
Hydro	160
Coal	0
Wind/Solar	40
Import	180
Total	1200

If a growth rate proceeds at 5 percent, the requirement for imports would rise from 180 TWh to about 600 TWh.

The above distribution assumes:

- All countries with very large oil and gas reserves will meet all future needs with thermal energy. Iran and Iraq can in addition develop some hydro to increase fuel exports.
- New hydro is primarily in Iran, Iraq and Turkey on transboundary river basins.
- There is no significant surplus coal in the region.
- Egypt is planning for major wind and solar renewable energy[18].

The import component therefore represents the future projected deficit that cannot be met from indigenous fuels or renewable re-

Table 4. Middle East countries with hydro generation[19]

Country	% Hydro energy of total load	Installed capacity MW[20]	Energy generation GWh	River basin
Egypt	15	2,800	15	Nile
Lebanon	9	190	1	Jordan
Iran	7	5,045	11	Euphrates-Tigris
Iraq	20	2,200	7	Euphrates-Tigris
Syria	41	2,100	11	Euphrates-Tigris
Turkey	26	7,600	40	Euphrates-Tigris

sources. The assumptions for hydro are a maximum, in that actual development will be heavily dependent on financing, which in turn may be affected by issues such as those transboundary ones being generated by the implementation of the GAP (South-eastern Anatolian Project) in Turkey, including the implementation of the Ilisu project in Turkey, immediately upstream of the Syria and Iraqi border. The actual viable limit will probably be less, thus increasing the "import" component.

4.6 Interconnections and power trading

Cross-border interconnections and power trading are already an important part of the electrical supply system in the region, and further interconnections are underway. Planning initiatives are also underway for long distance grids and power pools, such as the Mediterranean Power Pool.

4.6.1 Regional collaboration and political considerations

The implementation of interconnections and power trading arrangements provides both economies in the supply of electricity, but also provides a mechanism for improved cooperation between countries. At the same time, grid interconnections can provide some liabilities and constraints to the participants. Some of these political benefits and liabilities are outlined below. In this context, political impacts refers to those that enhance or degrade political relationships between countries or participants[21].

Benefits

- The government-to-government cooperation that is required for the legal, economic and organisational linkages may also serve as a vehicle or springboard to improve cooperation in other areas. The intergovernmental cooperation to develop agreement on legal and commercial terms (e.g., power sales and purchase terms), rules for operation and maintenance of the lines, and provisions to ensure the required levels of security of supply, require that working relationships and communication between parties are developed.
- Such cooperation mechanisms may be particularly important where participants have a history of mutual conflict. Transboundary supply arrangements usually incorporate a level of mutual dependence, which require effective procedures to resolve differences. This can even apply to the avoidance of military conflict, and to avoid risk to shared infrastructure.
- Social and environmental issues must be included in all large-scale programmes and stakeholder views need to be taken into account in the planning and approval stage. In the case of interconnections, this requires that all participating countries provide sufficient democratic intervention to ensure that such projects are not stalled in one participating country[22].
- Multicountry interconnections should provide opportunities for capacity building at the professional level, and better distribution of economic benefits than single power projects.

Liabilities

A shared infrastructure transmission project inevitably requires participants to take responsibility for the security of the whole, which may create some political liabilities. These may relate to areas such as:

- Potential for restrictive practices employed to ensure security of interconnection lines, such as using line routing to displace opposition groups;
- Possibility of the interconnection being used for political leverage on a partner country (i.e. using the line as a hostage);
- Vulnerability to threats from dissident groups (again, using the line as a hostage).

Regional collaboration on water and electricity

Initiatives are taken in the region to collaborate on electricity issues. The Council of Arab Ministers Responsible for Electricity (CAMRE) is working towards an interconnected Arab electricity grid and natural gas pipeline network to link production sites to consumer locations in the region. The Arab Countries Water Utilities Association (ACWUA), an initiative founded by UNESCWA and GTZ assist utilities in improving service delivery, develop performance standards and ensure large capital investment programmes and resources are well managed. It is a forum for exchange of best practices, benchmarking and training and capacity building[23].

4.6.2 Interconnections within the Middle East region

The following subsections outline the present status and proposed planning from interconnections that could have an impact on future power supply within the region and from outside the Middle East. Most countries in the region have established interconnections with neighbouring countries. These do not constitute power pools; however they provide the physical and commercial systems for the interchange of electricity. These include the following existing pairings:

Bahrain – Saudi Arabia
Iran – Turkey, Iraq
Iraq – Syria
Jordan – Palestine
Lebanon – Syria
Palestine – Egypt
Saudi Arabia – Bahrain, Yemen
Syria – Iraq, Lebanon, Turkey
UAE – Saudi Arabia
Yemen – Djibouti

The GCC interconnection project[24]

The major interconnection programme in the region is the GCC[25] interconnection project, which is being implemented in three stages:

- **Phase 1** – interconnection of the northern systems – completed in 2009
    - Kuwait
    - Saudi Arabia
    - Bahrain
    - Qatar
- **Phase 2** – internal interconnection of the national grids for UAE and Oman
- **Phase 3** – interconnection of the Northern and Southern systems – scheduled for 2011. Extension to:
    - Oman
    - UAE

The project will be operated as a power trading facility and its sole purpose will be to exchange and trade electrical power. The cost of the project is USD 1.4 billion[26]. The primary economic justification for the GCC interconnection project was its ability to reduce cost in the reserve requirement (or reserve sharing). This provided enough benefits to yield a less than 2 year payback period for the 1.4 billion dollars invested in the project.

Saudi Arabia – Egypt interconnection

The electricity utilities of the Kingdom of Saudi Arabia (Saudi Electric Company-SEC) and Egypt (Egyptian Electricity Holding Company-EEHC) have completed a feasibility study of an interconnection between the two country national grids. They are now proceeding with the implementation of the project with the preparation of tender documents for the various components[27].

The purpose of this interconnection is to provide Egypt and the Kingdom of Saudi Arabia with the necessary flexibility to share their capacity and trade energy in a commercial manner during normal operation and to provide mutual back-up assistance during emergency operating conditions.

4.6.3 The Mediterranean power pool

This project has been under discussion and development since the 1960´s. The project would link power grids from Spain to Morocco, pass through North African countries to Egypt, continue though the Middle East countries to Turkey and Greece and then link up with the European grids.

The goal of this ongoing Mediterranean ring project would be to interconnect electric power transmission grids among the countries and regions that encircle the Mediterranean Sea. This, in turn, would increase energy security in the entire region, enable more efficient power flows at lower costs, and reduce the quantity of power plants required to meet rapidly increasing demand for electricity in the southern and eastern Mediterranean regions[28]. A major direct benefit would be from reserve sharing, which would reduce new generation and capital investment requirements.

The European Union nations have taken the lead in assisting the Mediterranean region in its quest to be interconnected to the European grid. The objectives of such a huge system of electric power interconnections include:

- Provide increased levels of energy security to participating nations.
- Defer or avoid construction of new power plants by importing/exporting electric power among nations.
- Balance the load and the demand for electric power across the region.
- Cut back on the primary electricity reserve requirements within each country.

Organisational aspects would be complicated as grids from the two regions have very different standards and characteristics. European networks use high voltage lines, with high consumption and consumer density, and have predictable load patterns. By comparison, grids along the North African coast are typically lower voltage grids, serve fewer loads, are concentrated in highly urbanised areas, and are strung out through the countryside at lower voltages.

It is relevant to note that a number of the North African linkages are already in place or near implementation. The North Africa Power Pool includes Egypt, Libya, Tunisia, Algeria, Morocco and Mauritania[29]. These are now interconnected, except for Mauritania, and are referred to as the ELTAM interconnection. Studies are underway to move to a 400 or 500 kV voltage level to increase interchange capabilities. The western interconnection from Morocco to Spain was completed in 1997.

4.6.4 Supplies from Northern Africa

River Nile power Pool

This is a developing concept that would link Egypt, Sudan, Ethiopia, Kenya, Uganda, Eritrea, Djibouti and Somalia. Ethiopia has major potential in developing hydropower and is planning exports to Ethiopia, Djibouti, Egypt and Kenya.

Ethiopia has extensive hydro resources with more than 1,100 MW currently under construction (Takese – 300 MW, Gilgel II – 420 MW Anabeles – 460 MW)[30]. A further committed and under construction project is Gilgel III, 1,870 MW. This project was to be the source for exports to Kenya in 2012, however construction is delayed and current planning is to provide export power from Gilgel II[31]. Information on future potential hydro sites suggests that there may be a further 8,000 MW of hydro that could be developed in Ethiopia[32, 33] (see below). Sudan and Djibouti also have significant hydro resources that could be integrated into a North-South Nile power pool.

Supplies to the River Nile power pool will depend on power sharing arrangements that will result from the implementation of the East Africa power pool, and an eventual pan-Africa grid, that is envisaged by the study on infrastructure development in Africa, that will be initiated shortly[34]. The energy sector component of this programme will look at opportunities for cooperation between existing and developing power pools across Africa[35]. These interconnections and power trading arrangements may be expected to create competition for surplus power deliveries from Ethiopia and Sudan, and the Congo.

East Africa power pool

The planning studies and consultative processes for development of the East Africa Power Pool (EAPP) will soon begin[36] between the EAPP partners, which include Burundi, Democratic Republic of the Congo (DRC) Egypt, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda[37].

The two major components of the study are:

- To assess opportunities for power generation and interconnection between power pool members at the level of a power system master plan.
- To develop and recommend a grid code for the pool members.

ENTRO Nile study

A further study, currently at the tendering stage, will identify and evaluate hydro sites on the Blue Nile/Abbay in Ethiopia. These studies will feature an an Strategic/Sectoral Social and Environmental Assessment (SSEA) methodology [38], which includes formlating a portfolio of cascade development scenarios that accounts for the topographical and geological conditions along the main stream of Blue Nile/Abbay, in addition to overall development objectives (Power Generation, Irrigation, Flood and Drought Management, and Water Savings, etc.)[39].

A number of major multipurpose projects have been identified in previous studies, including:

Site	Capacity MW	Energy GWh
Border	1,200	6,000
Mandaya	2,000	12,100
Beko Abo	1,200	12,600
Karadobi	1,600	9,700
Total	**6,000**	**35,000**

The primary purpose of these projects would be for power export.

4.6.5 Power from Congo

The concept of developing the Grand Inga scheme on the Congo, in the Democratic Republic of the Congo, continues to be of interest because of the size of the project and its potential for regional power supply.

The existing Inga 1 and 2 projects have an installed capacity of about 2,000 MW, and development of Inga 3 would add 3,500 MW.

The Grand Inga project would have an installed capacity of 39,000 MW, approximately equivalent to 1/3 of the total capacity in Africa. Power could be supplied to South Africa and other countries. One proposal is to connect to the Mediterranean or North African grid.

Feasibility studies by EdF, financed by the AfDB, indicated that power supply to Egypt was viable. Transmission could be via the Central African Republic and Sudan, or via Uganda. Total cost was stated as USD 80 billion[40], of which approximately 50 percent is for the hydro plant and the balance for the transmission infrastructure. Transmission distance to Cairo would be in the order of 3,500 km.

4.6.6 Power from the East

A further potential electricity supply source is from Central Asia and Pakistan. There are a number of major hydro sites that have been identified in the region. Several are moving towards implementation, most prominently in the Amur Darya and Syr Darya river basins.

Central Asia[41]

Country	Project name	Capacity MW
Kyrgyzstan	Kamabarata 1	1,900
	Kamabarata 2	240
Tajikistan	Rogun	3,600
	Sangtudinskaya	2,220
	Dashtigjumskaya	4,000
	Nijne-Kofarnihon	120
	Ayini	190
	Yavan	222
	Fandarya	183
Kazakhstan	Moynak	300
Total		**10,975**

The overall distance from the Central Asia sites to Tehran would be in the order of 1,500 km (a 400 kV transmission line could cost up to USD 400-500,000 /km).

North Pakistan

The northern areas of Pakistan have a power potential of more than 50,000 MW. Of this, over 15,000 MW has been identified on the Indus River, and its tributaries upstream of Tarbela. Some of this potential is provided by the following identified hydro sites[42].

Project name	Capacity MW
Diamir Bashra	4,500
Dasu	3,700
Pattan	2,800
Thakot	2,500
Spat Gah	545
Chornala	385
Bunji	5,400
Total	**19,830**

The distance from the Indus projects to the Gulf area would in the order of 2,500 km.

The Central Asia-South Asia regional electricity market

The planned development of a regional electricity market for the countries of Tajikistan, the Kyrgyz Republic in Central Asia and Pakistan and Afghanistan in South Asia is relevant to the possible supply of power from this region to the Middle East. Studies have considered power transfers of 1,000 MW and the construction of a 400 kV line to connect these countries[43]. Development of the northern Pakistan hydro sites in the Indus basin could provide the basis for a regional power pool to include the Middle East.

4.6.7 Summary of power options for 2030

The projected electrical energy deficit for the region in 2030 is in the order of 200 to 600 TWh. This projected deficit accounts for indigenous supply from oil/gas, and potential hydro, wind and solar energy. This projection assumes that each country develops its available resources, which may be optimistic due to likely financing constraints and the reality that some hydro projects may not be feasible or economical. This estimated deficit does not assume that oil/gas rich countries will export energy to other countries in the region.

Consequently the options to meet this deficit are:

1. Sharing electricity from thermal generation using oil and gas fuels in the Gulf States (excluding Yemen), using extensions to the GCC interconnection that are currently being implemented.
2. Import of electricity from outside the region, i.e. hydro from the Nile Basin, the Congo, and from East of the region (Central Asia) and Pakistan.
3. Import of fuels, such as coal from India or South Africa, or gas (Liquid Natural Gas (LNG)) from the Gulf States, and maximal use of renewable energy, such as wind and solar, where economical.

The real availability of energy will depend on a variety of variables. Programme strategic assessments and project feasibility analysis will investigate the potential supply options analysing a range of factors including project lead times, cooperation, dependence on outside factors, acceptability and price. Balancing energy demand with supply in 2030 will require a combination of these basic options.

The sharing and import of electricity outlined in the first two options would require a power pool and interconnection infrastructure throughout the Middle East. This means that an operating entity would have to be established for the ownership and operation of the line, including commercial operations. It would also demand that the transboundary water resources assets are cooperatively being developed to make use of the significant hydropower potential in the Nile, Congo, Euphrates and Tigris and Central Asian basins. Efforts to achieve a cooperative regime is undergoing in the Nile Basin through the Nile Basin Initiative. Other major basins, such as the Congo, Euphrates and Tigris basins and the Amur Darya and Syr Darya, however, are lagging behind.

The potential delivery costs of power to the Middle East from sources outside the region, will likely include generation costs in the range of 3 to 6 cents/kWh plus a transmission/wheeling charge of at least 3 cents for 1,000 km delivery[44]. For comparative purposes, based on today's costs, delivery into the region would therefore cost at least 6-8 cents/kWh. This suggests that, if this option, i.e. major imports of electricity from outside the region, is to be part of the long term supply plan, concrete planning would have to begin very soon.

The proposed Mediterranean power pool would probably not provide a significant source of energy, as its objectives are related to reserve sharing, power trading, equalisation and security of supply. It would, however, facilitate movement of electricity in the area, and could be incorporated as part of a Middle East backbone grid.

The third scenario assumes that future demand increases in countries without major oil/gas reserves will be compensated for by in country generation using imported fuels. Primary alternatives would be coal from Richards Bay, South Africa or from India, and LNG from the Gulf region. This third option will be the highest cost alternative with in-country generation costs probably above 10 cents/kWh.

5 Examples of Integrating Water and Energy at the Regional Level

5.1 Desalination in the Middle East

Desalination of sea water has become a substantial source of water in the Middle East. It has been a very expensive way of producing potable water, but with increasing scarcity of other water sources, the development of new technology and availability of energy, it is emerging as part of the region's solution to deliver water to its growing population in the future. Some countries in the region, such as Qatar and Kuwait, rely on desalinated water for up to 100 percent of domestic and industrial use[45]. Desalination is still very energy intensive and the energy cost accounts for up to 50 percent of the operation costs.

At present, desalination in the Middle East is dependent on fossil fuels. Research is being conducted on how to move towards use of more renewable energy sources, such as solar, wind, wave and geothermal. Developments in solar collectors, and the current trend of increasing costs for fossil fuels could lead to solar energy becoming a feasible and cost-effective option within the next ten years[46].

5.2 Red Sea – Dead Sea water conveyance study programme

The Red Sea – Dead Sea water conveyance study programme was initiated by Jordan 2002, and is now a joint programme between Jordan, Israel and the Palestinian Authority. The Dead Sea is presently sinking by approximately 1 metre per year and faces vast environmental degradation. The study programme will look at ways to improve the Sea's ecosystem health, cultivate hydro electricity and generate desalinated water for use by Jordan, Israel and the Palestinian Authority. The programme will investigate the feasibility of reversing environmental degradation of the Dead Sea region by transferring water from the Red Sea to the Dead Sea. The study programme looks at technical, economic, financial, environmental, social and institutional issues. The feasibility study is to be completed mid-2010 with World Bank Facilitation and will then be analysed by the three beneficiaries[47].

5.3 The South Eastern Anatolia Project – GAP

The GAP project in Turkey is a multipurpose project for the development of the South-eastern Anatolia region in Turkey. The Euphrates and Tigris River systems are the dominant features of the region's hydrology. The GAP covers nine provinces in Turkey and will, among other things, include development initiatives on hydropower, irrigation, infrastructure, communication, forestry, health, education, cultural heritage, tourism and social aspects. The objectives of the GAP are to eliminate regional development disparities, improve living standards, and contribute to social stability through increased economic growth and employment opportunities. When it is completed it will include 22 dams, 19 hydropower plants and 1.82 million ha of irrigated land[48].

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