

Economic feasibility of renewable energy in Egypt

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Declaration

I hereby declare and confirm that this thesis is entirely the result of my own original work. Where other sources of information have been used, they have been indicated as such and properly acknowledged. I further declare that this or similar work has not been submitted for credit elsewhere.

Graz University of Technology, January 10, 2013

Michael Puttinger

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List of abbreviations

AUC	American University of Cairo
BBOE	Billion Barrels of Oil Equivalent
BOO	Build own operate
Capex	Capital expenditure
CNG	Compressed natural gas
CSP	Concentrated Solar Power
CU	Cairo University
EgyptERA	Egyptian Electric Utility & Consumer Protection Regulatory Agency
EEHC	Egyptian Electricity Holding Company
GDP	Gross domestic product
HVDC	High voltage direct current
kWh	Kilowatt-hour
MENA	Middle East and North Africa
MMBtu	Million British thermal unit
MoEE	Ministry of Electricity and Energy
MSW	Municipal solid waste
Mtoe	Million tons of oil equivalent
NG	Natural Gas
NREA	New and Renewable Energy Authority
OECD	Organization for Economic Cooperation and Development
OPEC	Organization of the Petroleum Exporting Countries
Opex	Operational expenditure
PPP	Public private partnership
PV	Photovoltaic
RDF	Refuse derived fuel
RE	Renewable Energy
TCF	Trillion cubic feet
TDF	Tire derived fuel
TPES	Total Primary Energy Supply
USD	U.S. Dollar
USRT	U.S. Refrigeration Ton

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Kurzfassung

Die gesamte Energieversorgung in Ägypten basiert im wesentlichen auf fossilen Brennstoffen. Diese Brennstoffe sind von der Regierung stark subventioniert und daher für Verbraucher sehr günstig zu erstehen. Der daraus resultierende rapide Anstieg der ineffizient verbrauchten Energie brachte, speziell im Jahr 2012, große Schwierigkeiten mit sich.

Ägypten wurde in den letzten Jahren vom ölexportierenden- zum importierenden Land. Daraus resultierende Zahlungsschwierigkeiten der Regierung an Ölproduzenten aufgrund der explodierenden Subventionskosten, bringen einen Treibstoff- Versorgungsengpass mit sich. Dies hat wiederum schwerwiegende Stromausfälle im städtischen sowie im ländlichen Bereich zur Folge. Speziell während der Sommermonate stößt das existierende System mit dem Spitzenverbrauch an seine Grenzen.

Die große Herausforderung ist nun nachhaltige Lösungen zu finden, welche größtmöglich von fossilen Brennstoffen unabhängig sind. Diese Arbeit dient dazu, einen Überblick über potentielle Möglichkeiten zu bekommen. Einheimischen und nicht ägyptischen Unternehmen und Investoren wird deshalb die aktuelle Energiesituation, gesetzliche und natürliche Rahmenbedingungen, sowie eine Gegenüberstellung zwischen erneuerbaren und traditionellen Methoden der Energiegewinnung vorgestellt, um mögliche Potenziale für die Zukunft aufzuzeigen.

Für folgende Technologien wurde eine derartige Gegenüberstellung durchgeführt:

- Traditionelle Methoden:
 - Dieselgenerator
 - Gasgenerator
 - Gas Turbine
- Erneuerbare Technologien:
 - Windkraftanlage
 - Photovoltaik
 - Solarthermische Energienutzung
 - Biomasse / Energieerzeugung aus Müll

Die verglichenen Variablen dieses Vergleiches sind: vorhandener Markt, wirtschaftliche Einflüsse und eine Kostenbandbreite pro erzeugter Kilowattstunde.

Abstract

The energy generation in Egypt is highly dependent on subsidized fossil fuels. But, especially in the year 2012 the rapidly increasing domestic energy demand (resulting in Oil-consumption) brought new difficulties to Egypt's existing power supply.

Because of the extensive oil consumption, Egypt switched in the year 2008 from an oil exporting country to an oil importer. This brought financial difficulties of the government to the oil supplier, which result in a lack of fuel supply and has further brought massive blackouts. This affect not only isolated operators (e.g. Seaside hotels) but also urban areas (e.g. Districts of Cairo). Especially during the summer months pushes the peak demand to the limit of the installed capacity.

These current problems demand new methods, which should generate sustainable solutions that are mostly independent from the use of fossil fuels.

This thesis aims to give an overview of such potential technologies. Domestic and foreign companies and investors should get a clear view about these technologies including general conditions and obstacles to built such systems. Further, an economical comparison of renewable and traditional generation methods should show solutions.

Following technologies were opposed:

- Traditional Methods:
 - Diesel Engine
 - Gas Engine
 - Gas Turbine
- Renewable Technologies:
 - Wind turbine
 - Photovoltaic
 - Solar thermal
 - Biomass / Waste to energy

The compared variables are: existing markets, economic impacts and a range of costs in Euro per generated kWh.

Chapter 1

Introduction

This work shows foreign and domestic readers a summarized overview of the energy economy in Egypt and further gives a comparison between potential energy possibilities. The main research took place in Cairo three weeks during September 2012 and is mostly based on a collection of data out of a lot of interviews with academics and CEO's of well known companies and institutions which are active in the area of renewable energies [RE] in Egypt.¹

Mr. Sherif Bahnas[3] said in an interview:

"Egypt is a different market, if you are not there, you won't get it fixed"

To provide a maximum realistic and meaningful content of this thesis, it was important for my supervisor Dipl.-Ing. Axel Ceglie Swoboda[28] and me to get data from local Egyptian experts in this specific field.

The main steps of work were:

- Create mind map of possible contents
- Prepare work plan
- Search for similar existing thesis or research results
- Collect company / institution contacts
- Prepare a teaser and inform chosen contacts, organize meetings
- During the stay in Cairo:
 - Finalize meetings
 - Collect data out of personal communications and studies, papers and presentations from interviewees
- Calculation of energy prices for each technology
- Use data collection for contents, finding data out of publications, papers additionally to interview collection

¹The list of Interviewees is included in the Bibliography

Chapter 2

Status quo of the energy situation in Egypt

Key Indicators Egypt [27], (2009):

- Population (million): 83.00
- GDP (billion 2000 USD): 152.36
- Primary Energy Production (Mtoe): 88.19
- Net Imports (Mtoe): -15
- TPES (Mtoe): 72.01

With a population of 83 million, Egypt is the largest market in the Arab world. The total primary energy consumption reached 73.865 Mtoe (million tons oil equivalent) in the year 2009/2010, which is equal to 859,05 TWh (shown in figure 2.2). Natural gas [NG] reaches the biggest share of primary energy in consumption as well as in production. Together with the share of oil products, the fossil part of the primary energy production reaches 96,6%, which means that the current Egyptian energy consists mainly of fossil energy.

The share of renewable energy is low and is in its infancy, but actual difficulties in the fossil fuel sector and upcoming incentives for RE should change this situation.

Figure 2.1 shows the total primary energy production of Egypt: The total primary energy production in the year 2010/2011 was 89,756 MtOE which equals 1043,86 TWh[11].

Figure 2.2 shows the share of the primary energy consumption in Egypt.

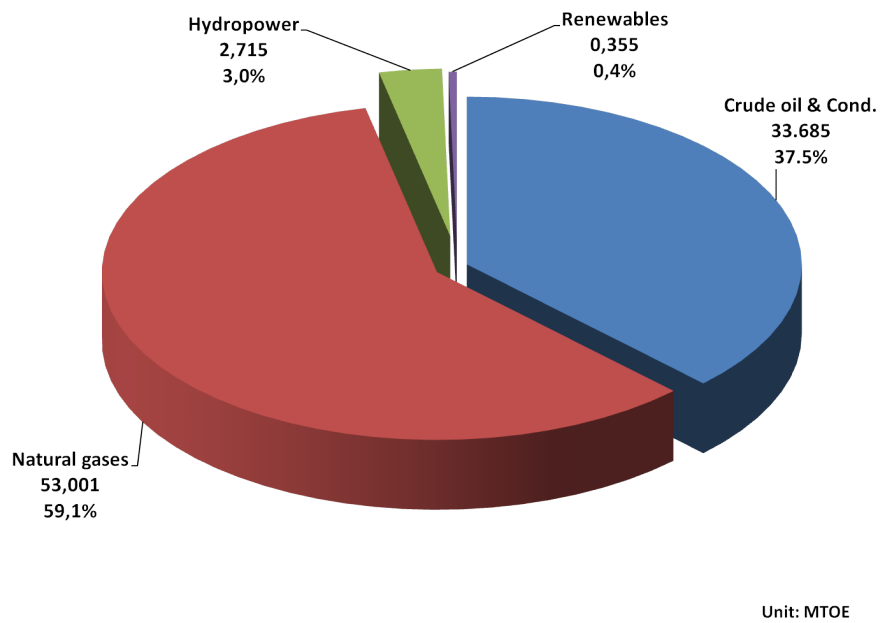


Figure 2.1: Primary Energy production in Egypt 2010/2011, source: Eng. Tawfik Azer [11]

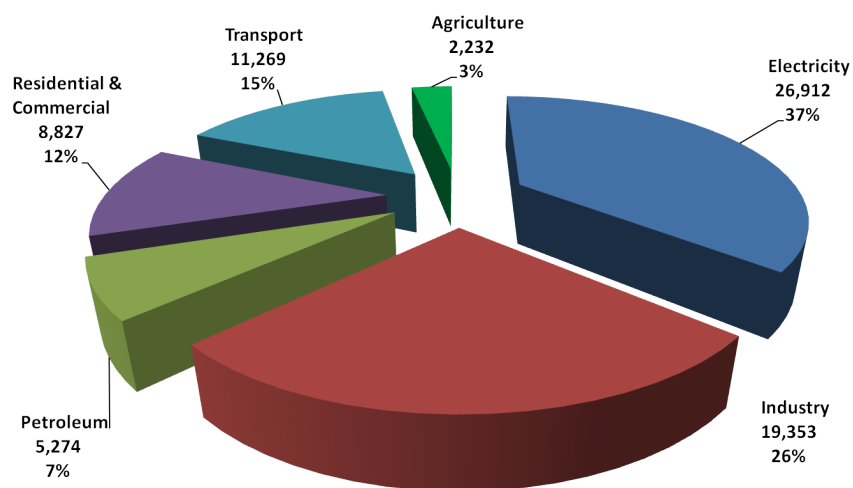


Figure 2.2: Total Energy consumption in Egypt 2010/2011 (Unit Mtoe), source: Eng. Tawfik Azer[11]

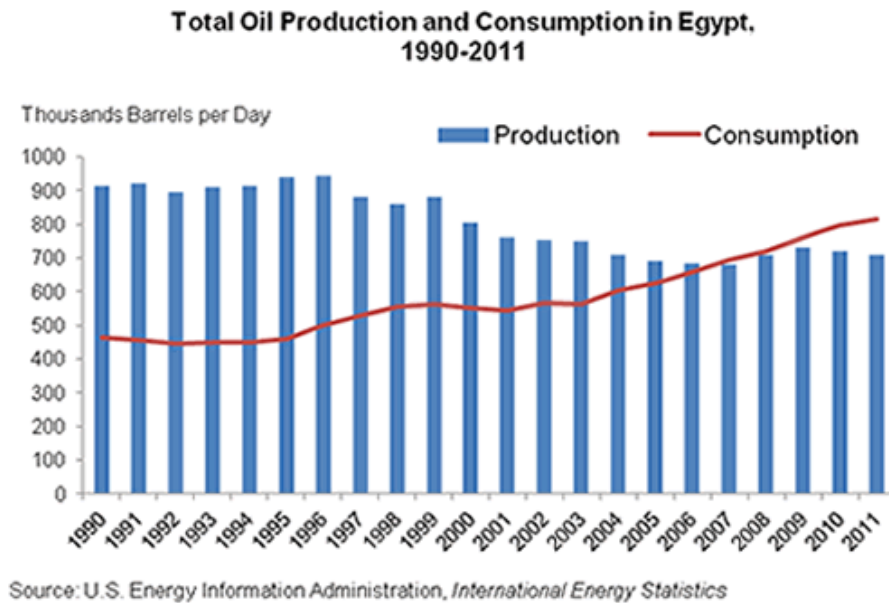


Figure 2.3: Oil Production and consumption in Egypt

2.1 Resources

2.1.1 Oil and Gas

"Egypt is the largest oil producer of Africa which is not member of the OPEC, and the second largest natural gas producer of the African continent." [8]

With the operation of the Suez channel and the Suez- Mediterranean Pipeline, Egypt also plays an important role in international energy markets.

Fuel and NG consumption represents collectively over 95% of the primary resources [10] which contains 49% gas and 46% oil [27]. The energy demand increases hand in hand with the fuel consumption about 7% per year.

Oil

Figure 2.3 shows the evolution of oil production and consumption in Egypt. The oil production reached its maximum in the year 1996 and since that time it decreases annually.

Because of a rapidly increasing energy and oil demand, Egypt switched from an oil exporting country to an oil importer in the year 2008.

In accordance with figure 2.3 the annual petroleum subsidy increased from 5,15 billion€ in 2005/2006 to 8,75 billion€ in 2009/2010 fiscal year. [4]

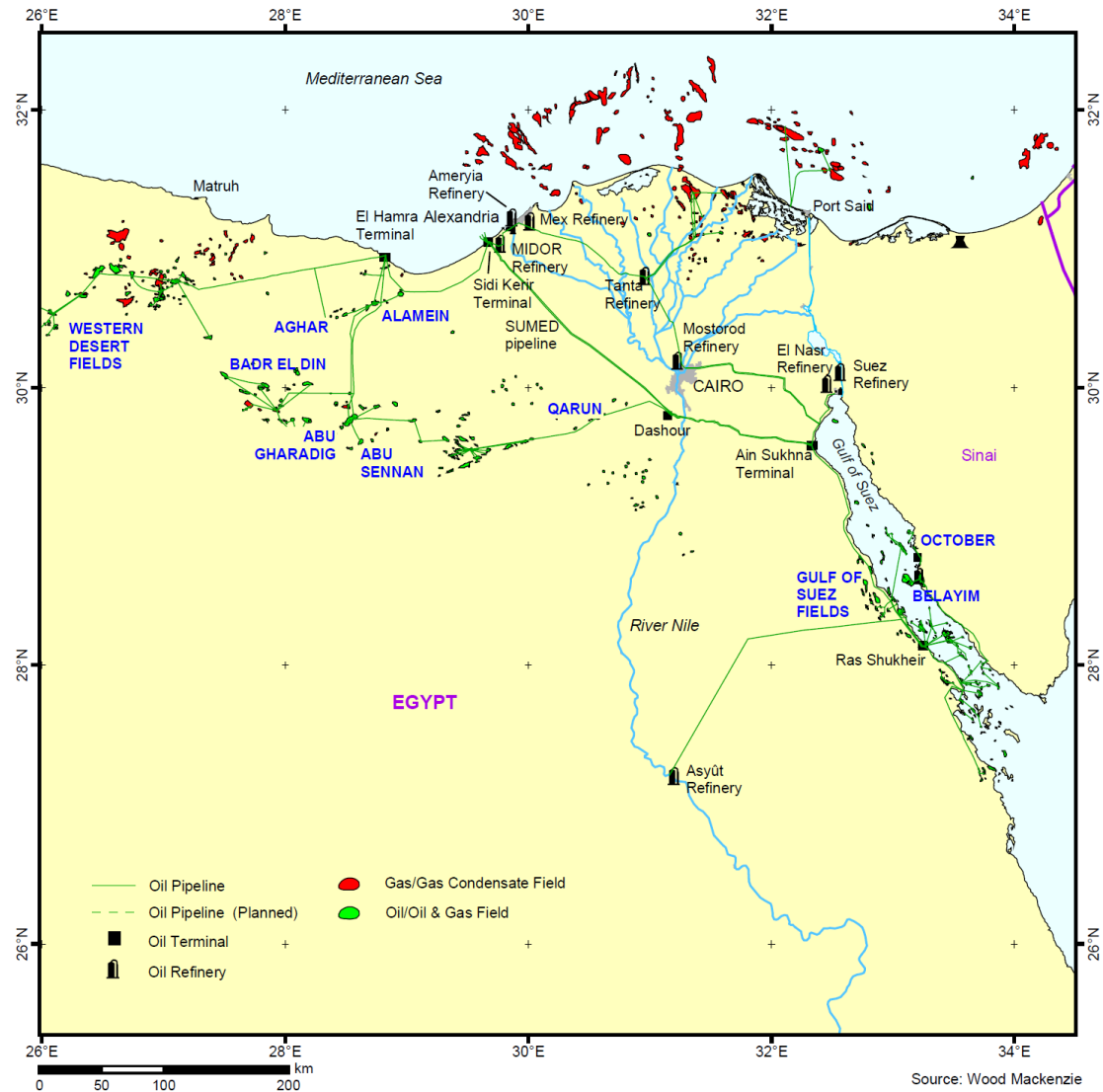


Figure 2.4: Egypt Oil Pipeline Map, source: Wood Mackenzie

In the end of year 2010/2011, crude oil reserves (include condensates) were about 4.33 billion barrels of oil equivalent (BBOE), that is a decrease of about 3,2% to the year before [11]. Figure 2.4 shows the oil facilities in Egypt.

Refining

Egypt has nine refineries with a total capacity of around 680,000 b/d [26].

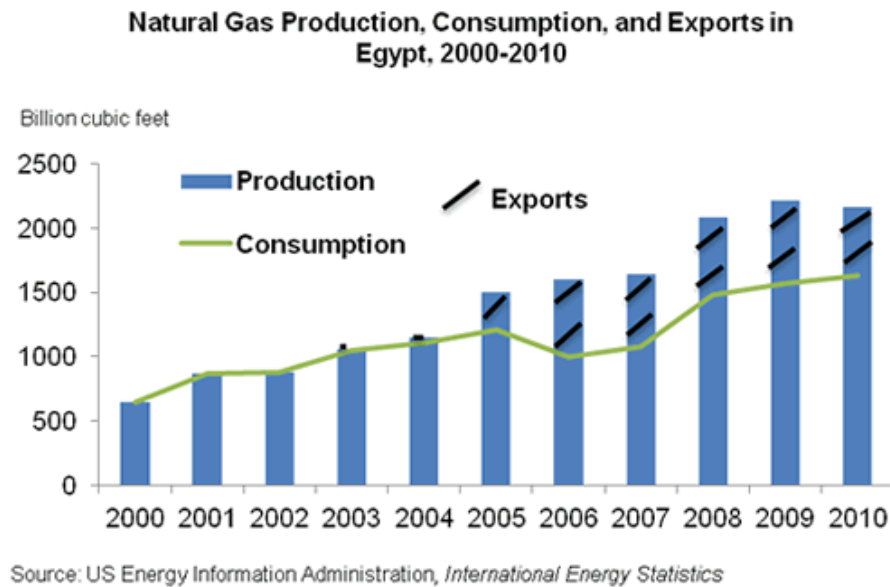
Natural Gas

Figure 2.5: Gas production and consumption in Egypt

The government is pushing to reduce domestic petroleum consumption by tempting to reduce subsidies and promote the use of natural gas.

The share of natural gas consumed in the transportation sector is rising since the development of compressed natural gas (CNG) infrastructure and vehicles. According to the Ministry of Petroleum in Egypt, the number of natural gas vehicles sold in Egypt has reached 133.7 thousand in the fiscal year 2009/2010[8].

The reserves of natural gas reached about 77.5 Trillion Cubic Feet (TCF) in the year 2010/2011 which is equivalent a decrease from 0,8% on the year 2009/2010. [11]

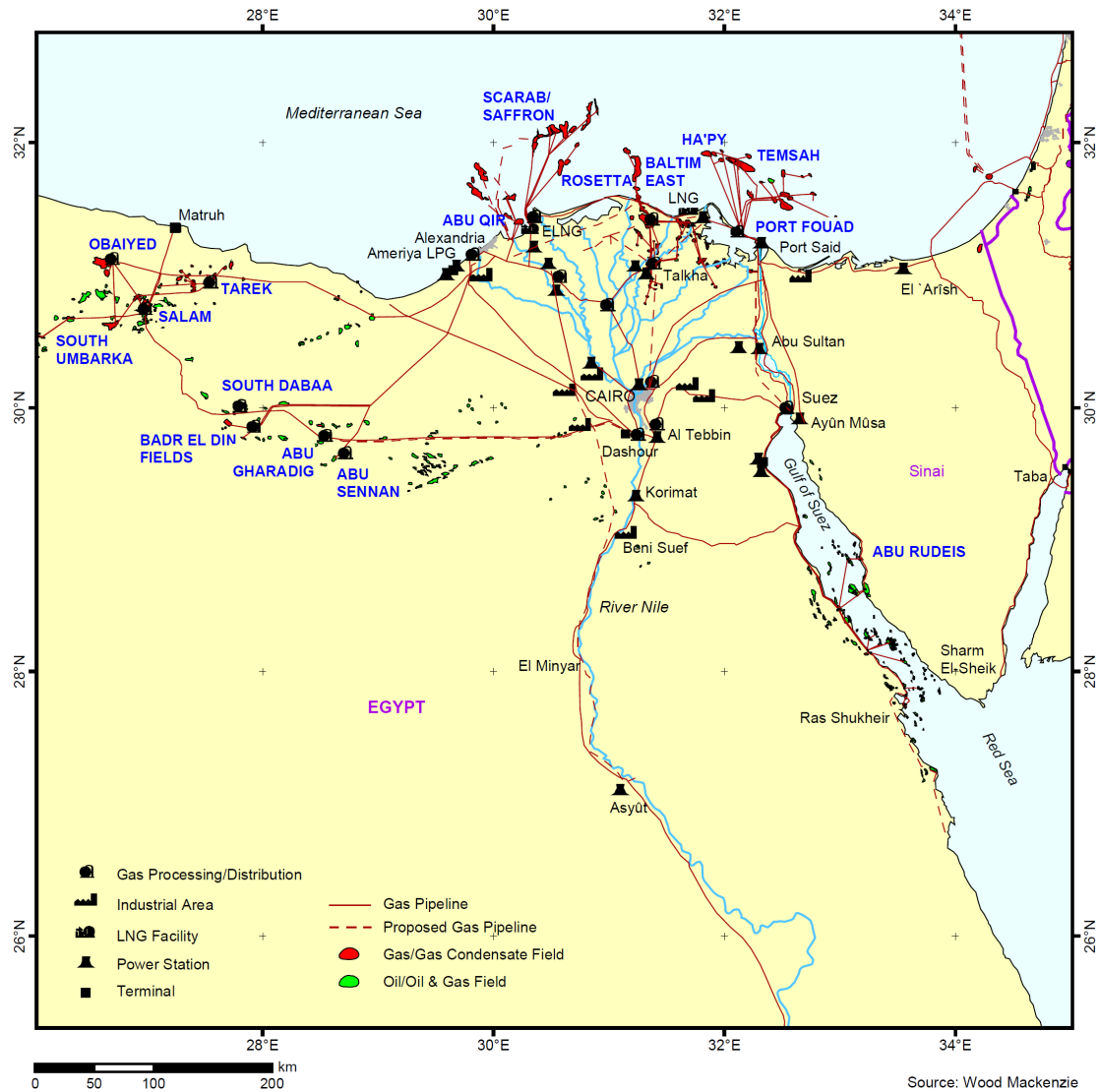


Figure 2.6: Egypt Gas Pipeline Map, source: Wood Mackenzie

2.1.2 Renewable Energy

Egypt has excellent natural resources in wind- and solar energy. (detailed information in Chapter 3)

Hydro power on the Nile is with the Aswan High Dam and some Aswan Reservoir Dams Egypt's third largest energy source after gas and oil. The generation out of hydro power reached with a installed capacity of 2800MW about 85% of the total potential resources of the Nile. [8] Because of this high exploit, hydro power isn't mentioned in the chapters below.

To cover Egypt's increasing energy demand with a big share of RE the Egyptian government signed RE targets.

Renewable Energy targets[6]

1. In Feb. 2008, the Supreme Council of Energy set a target for electricity generation from renewable resources, which will be equivalent to 20% from the total electricity generation by 2020.
 - Wind energy is given the priority as the electricity generation from it reaches 12% (equivalent to 7200 MW)
 - 6% from Hydro power
 - the remaining 2% will be completed from other various renewable resources including solar and biomass energies.
2. In July 2012, the Supreme Council of Energy decided the execution of Egyptian Solar Energy Plan with a total installed capacity of 3500MW by 2027. The plan includes 2800 MW generated from Concentrated Solar Power (CSP), in addition to 700 MW from Photovoltaic (PV), where the private sector is obligated to participate with 67% of the mentioned capacities. The participation ration through the government projects, represented in the New and Renewable Energy Authority (NREA), is 33%.

2.2 Generation of Electricity

Egypt's installed generating capacity reached 26.91GW in 2010, with plans to further expand capacity through additional investments in natural gas, nuclear and renewable energy. Figure 2.7 shows the percentages of the different types.

The total generated energy in 2010 was 138,7 Billion Kilowatt-hours which is equivalent to 22% of generated power in Africa[2].

The daily peak load is 23470MW [5] and takes place during the evening.

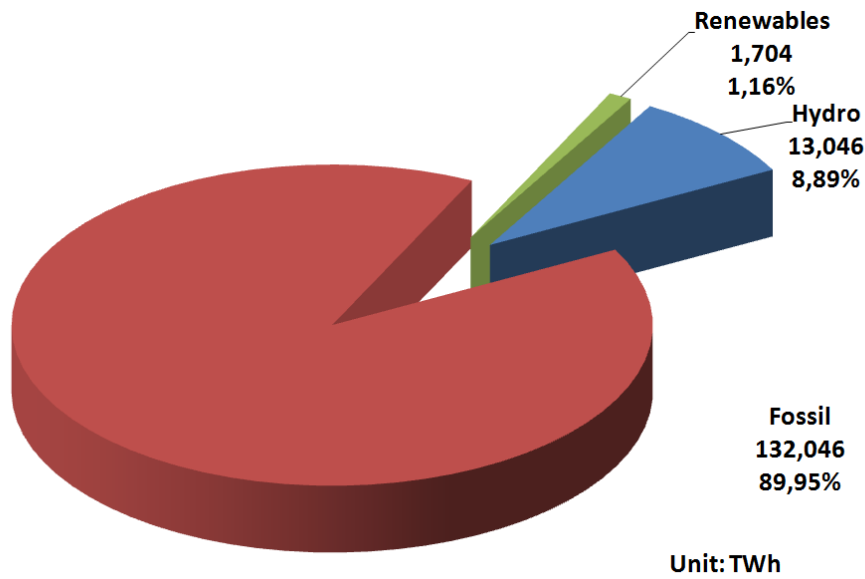


Figure 2.7: Electricity generation in Egypt, source: Eng. Tawfik Azer

2.3 Transmission and Distribution

Only 5 % of Egypt's area are populated, 99,6 % have access to electricity.[27]

Between the areas of high population density along the Nile the main high voltage power transmissions are located. The rural area and some tourist areas at the seaside cover their demands mainly with fuel powered isolated operators.

These decentralised power stations had especially this year major problems with the availability of fuel, which resulted in blackouts e.g. in El Gouna, where five-star category hotels were without electricity up to 5 hours.

Because of these current problems tourist areas started making plans for an ecological tourist sector where the electricity mainly comes out of isolated renewable energy facilities.

Figure 2.8 shows the Egyptian power grid, the main power network is along the Nile. Since 2004 there haven't been mentionable changes which would explain the high percentage of losses.

The distribution losses reached 2010 a value of 14,92 Billion Kilowatt-hours[2] which is equal to 10,8% of the generated energy.

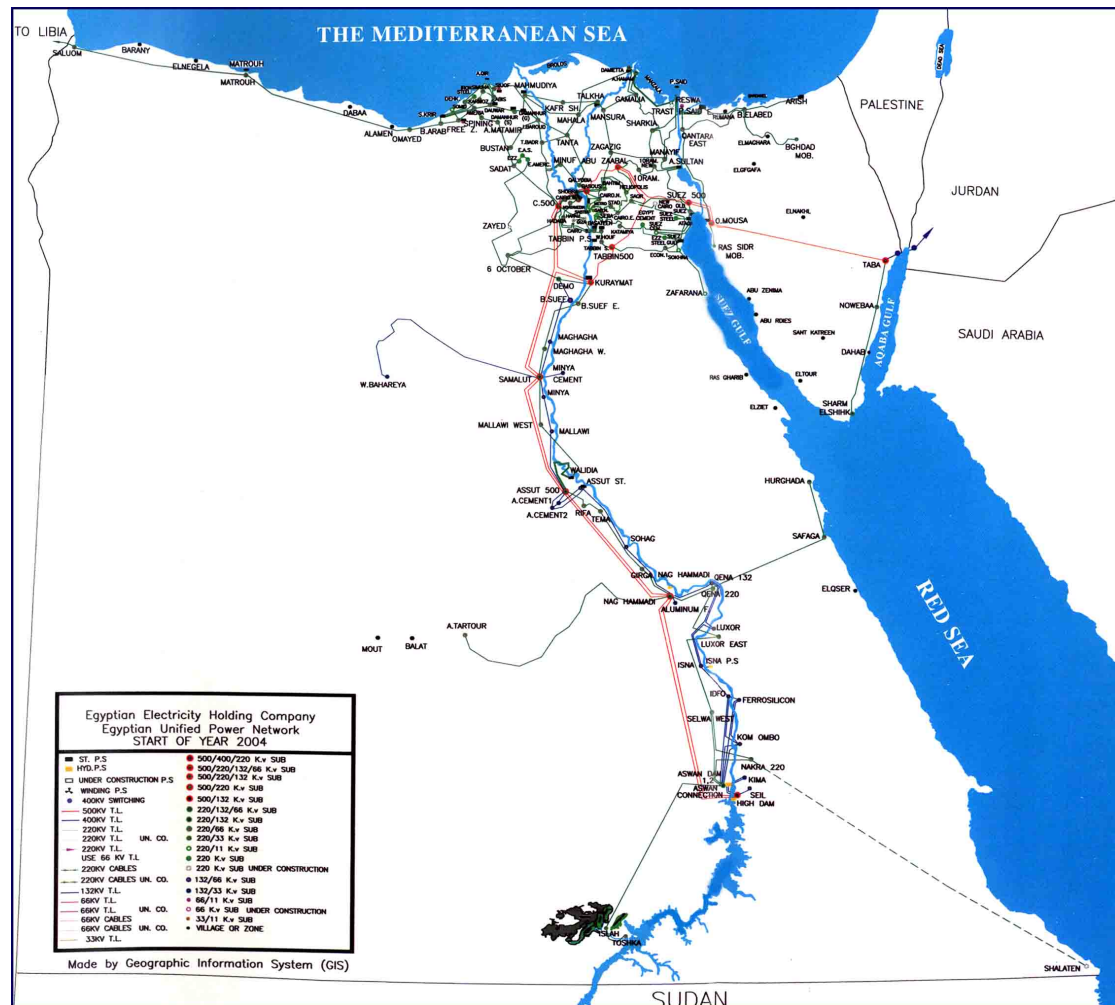


Figure 2.8: Egypt's electricity grid in 2004

Egypt also plays a big role in the DESERTEC project¹, which should provide climate protection by generating power out of renewable sources where they are most abundant. These plans involve in addition to building renewable energy plants, an extension of the grid in Egypt and a HVDC² connection to north mediterranean countries.

Grid costs

The grid costs depend on many parameters, but an expected cost range for the use of an existing grid is between 0,25 and 0,64 €c per transmitted kWh [9].

¹www.desertec.org

²high voltage direct current

2.4 Electricity consumption

The energy subsidies in Egypt have been existing for a long time and were primarily introduced to provide the use of energy (in the form of fuels, electricity) also for households with a lower income.

Further the low electricity costs result in an excessive energy consumption which isn't very efficient.

Ismail Fahmy [12] articulated it in this way:

"When an Egyptian orders a small cup of tea, he puts three spoons of sugar in it and instead of tea with sugar it's sugar with tea, that's similar with energy and subsidies."

The Energy Intensity - the Total Primary Energy Consumption per Dollar of GDP (Btu per Year 2005 U.S. Dollars (Market Exchange Rates)) - in the year 2009 is with 28,384.806 Btu/USD more than six times higher than in Austria. Currently there aren't legal requirements for energy efficiency but in the new energy law such rules are included. The cheap energy prices and the low energy efficiency explains the peak of household consumption in figure 2.9 which shows the share of electricity consumers in Egypt.

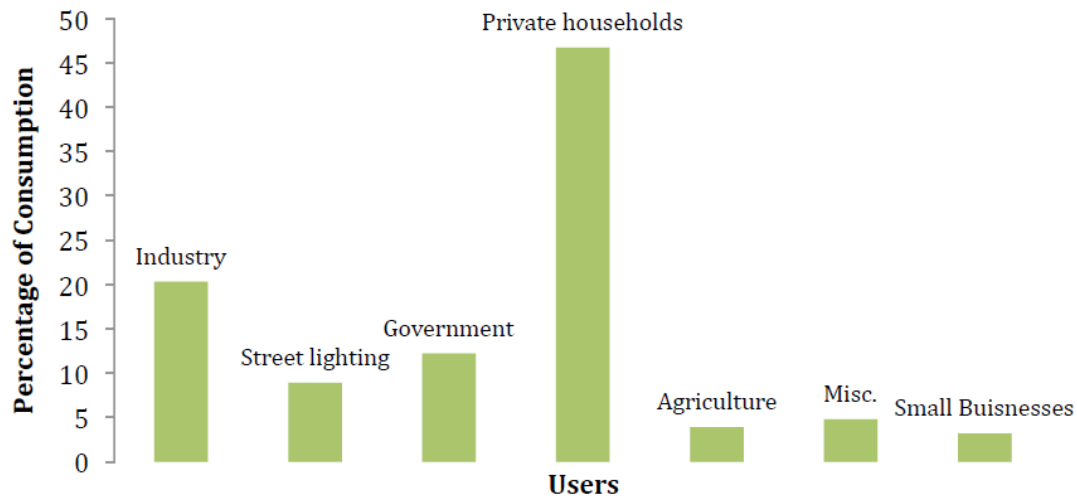


Figure 2.9: Electricity consumption by users according to the Egyptian Electricity Holding Company (EEHC) in 2005, from (Wasielke, 2007)., source: Mohamed Laila, [19]

Figure 2.10 shows the evolution of the peak demand until 2027. Out of the learning curve follows that the current demand gets doubled between 2022 and 2026.

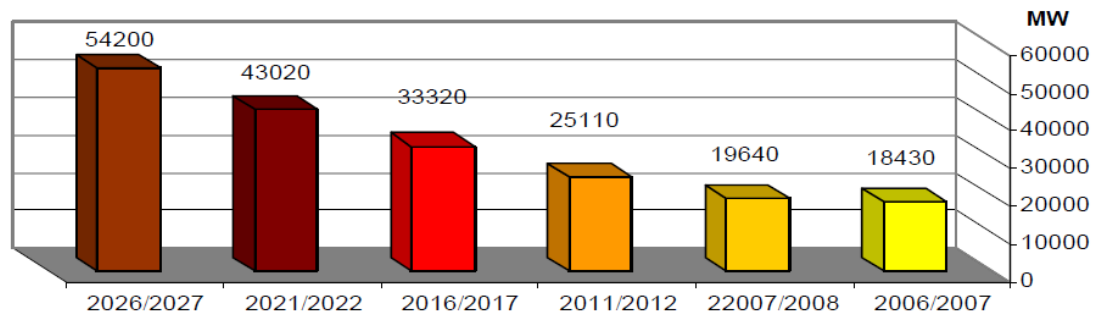


Figure 2.10: Evolution of the Peak demand till 2027, source: Dr. Hafez A. El-Salmawy, EgyptEra [6]

2.5 General Conditions

2.5.1 Players of the Egyptian energy economy

As shown in figure 2.11, the energy economy in Egypt is mainly state owned. For each technology exists an own company which builds and operates particular power plants. Another two different companies organise the power transport and the distribution. The holding company of these organizations is the Egyptian Electricity Holding Company (EEHC)³, shown in figure 2.12, which belongs to the Ministry of Electricity and Energy (MoEE)⁴.

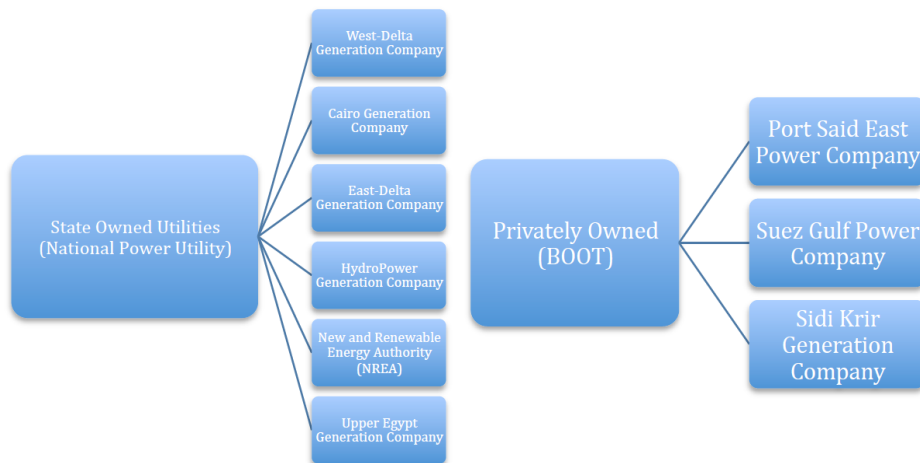


Figure 2.11: Egyptian Electricity Generation Stakeholders, source: Mohamed Laila, [19]

³<http://www.egelec.com/>

⁴<http://www.moee.gov.eg/english/e-fr-main.htm>

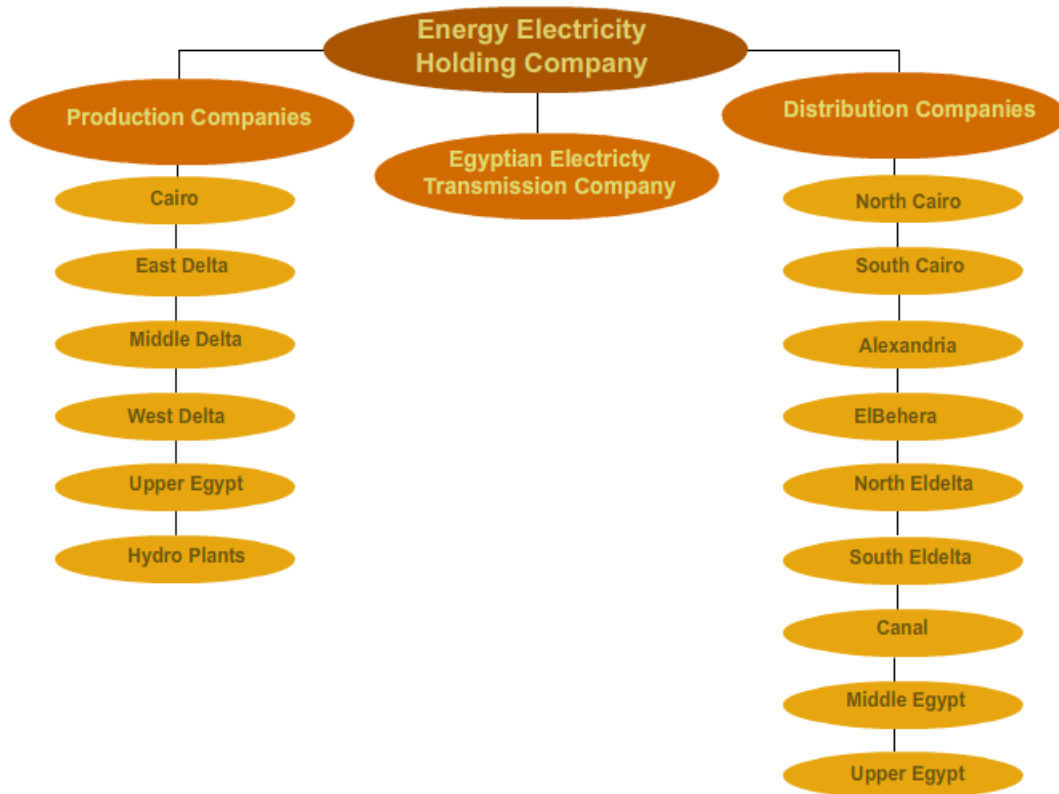


Figure 2.12: Egyptian Electricity Holding Company, source: EEHC

2.5.2 The Renewable Energy Market

The market for renewable energies in Egypt is in early stages, with a huge potential growth in the next years. The change which happened during the Arab spring delayed some developments in this sector, such that there was no mentionable growth in the years 2011 and 2012.

But the good general conditions to build renewable energy projects are still present and for a long term view, the political change brings new possibilities and chances for the renewable energy sector with it.

As already mentioned above, the energy market is mainly state owned but private investors are welcome and can apply for a concession to build and operate a power plant. A soon upcoming feed in tariff for wind power and a "renewable energy" fund should re-activate the RE market, a RE fund will support projects, financed out of saving gas demand.

2.5.3 Obstacles to build renewable energy capabilities

Egypt doesn't need to work on their resources or develop new technologies in RE, the central issue should be the handling of existing obstacles and further minimize the impact of them on new projects.

The main obstacles are:

- Subsidies: People are not used to pay for resources and utilities like water, energy, waste disposal;
Furthermore citizens don't care about energy efficiency, waste separation, RE capacities in households;
Figure 2.13 shows the cheap energy prices in Egypt compared with other African countries.

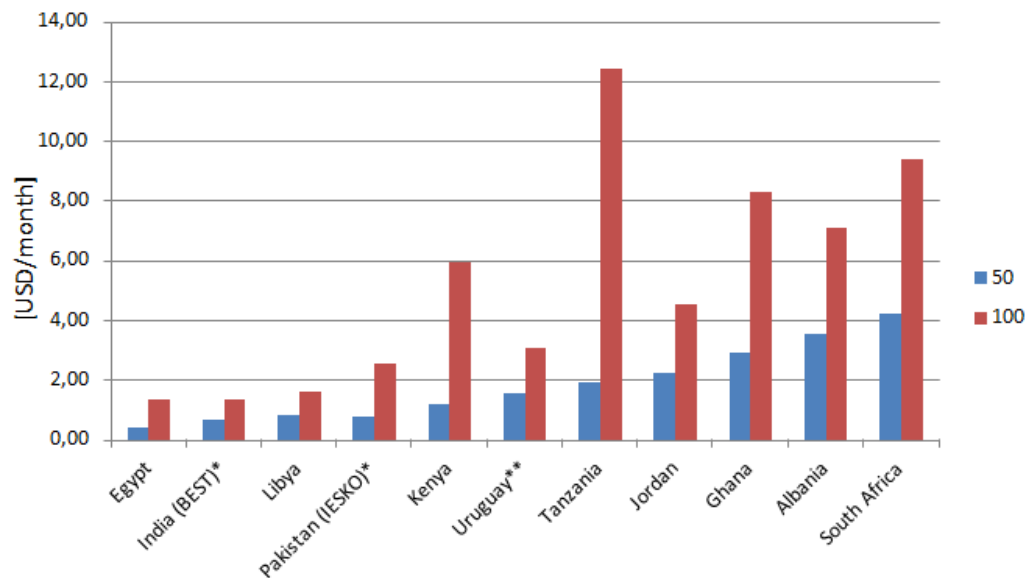


Figure 2.13: Monthly bills at 50 and 100 kWh consumption per month

- Missing market regulation, missing regulated grid connection: Since 2008 a new energy law is prepared which should, among other terms, regulate the grid access. This law has never been signed up until now.
- Limited ability in team working: Because of 60 years dictatorship, a high resistance against co operations remains. Finding synergies and win-win-situations is challenging.

- High interest rates: (overnight deposit rate 9,25% ⁵)

"In Egypt investments aren't feasible under a ROI of 12%[18]."

- Long amortization time: A renewable energy project has an investment contract period between 15 and 20 years (e.g. PV, Wind), on the contrary a hotel at the seaside has an average amortisation time between 3 and 4 years [20].
- Land rights: Most of the desert areas are in possession of the military. NREA selected suitable sights for carrying out wind projects (e.g. Zafarana) to encourage investors to avail such areas for RE projects.

⁵<http://www.cbe.org.eg>, Starting from 28 November 2011

Chapter 3

Economic comparison of technical capabilities

This comparison is mostly based on data out of personal communication with interviewees during the research. It should give an overview of cost range for each technology, but shouldn't attend as a basis of investment calculation. The tables were prepared by own unless otherwise noted in cooperation with Dipl.-Ing. Axel Ceglie Swoboda [28] under following adoptions:

- 1 € = 7,77 EGP (12.11.2012)
- Unsubsidised Gas Price = 3,7 USD/MMBTU (Henry Hub, Nov.12. 2012)
- $1W_{el}=3W_{th}$

3.1 Fossil energy

Shown in in the diagram 2.7 on page 9 fossil energy is by far the most used energy source in Egypt. The reason is clear: Because of the own production of oil and gas in Egypt, the government gives subsidized fuels to the citizen. That fact isn't a good energy efficiency policy and further the population growth brings an increasing domestic energy demand with it which keeps the number of fossil exports smaller and the balance of the subsidies higher.

The calculations of the comparisons between some possibilities of power generation out of fossil energy were made with a subsidized price (2 USD/ MMBtU) and a non subsidized price (Natural Gas price Henry Hub, Nov. 12. 2012, 3,7 USD/ MMBtU). In addition, it is worth mentioning that the international traded gas price isn't a realistic number for consumers. If there would be no subsidy, costs for distribution and transportation are to add. (World market price for natural Gas: 6-6,5 USD/MMBtu)[24]

3.1.1 Gas turbine

Mono Generation:

Calculation parameters:

- Amortization time: 20 years
- Average operating hours: 8000 h/year
- Operation and maintenance: 5% per year from investment
- Steam specification: 180 °C, 8 bar

	<i>fuel</i>	<i>type</i>	<i>power</i>	<i>capex</i>	<i>€/kWh</i>
subsidized	2USD/MMBtu	Kawasaki	8MW	5,15mio €	5,15
unsubsidized	3,7USD/MMBtu				8,8

Table 3.1: Economic facts gas turbine mono-generation (Consukorra)

Co Generation:

The efficiency increases for a gas turbine with the use of an absorption chiller to a value $\eta_{tot}=90\%$ [24].

Calculation parameters:

- Amortization time: 20 years
- Annual operating hours: 8000 h
- Operation and maintenance:
 - Gas turbine: 5% per year from total investment
 - Absorption chiller: 0,25% per year from total investment
- Steam specification: 180 °C, 8 bar

	<i>fuel</i>	<i>type</i>	<i>power</i>	<i>capex</i>	<i>€/kWh</i>
subsidized	2USD/MMBtu	Kawasaki	8MWel	(5,15 + 1,93) million€	1,7
unsubsidized	3,7USD/MMBtu		+10MWth		2,3

Table 3.2: Economic facts gas turbine co-generation (Consukorra)

3.1.2 High speed Gas engine

Mono-Generation:

Calculation parameters:

- Amortization time: 15 years
- Annual operating hours: 8000 h
- Operation and maintenance:
 - Gas engine: based on company- internal data. [24]
- Absorption chiller

	<i>fuel</i>	<i>type</i>	<i>power</i>	<i>capex</i>	<i>€/kWh</i>
subsidized	2USD/MMBtu	Ge-Jenbacher (JGS320-GS)	1MW	450000 €	3,3
unsubsidized	3,7USD/MMBtu				4,5

Table 3.3: Economic facts gas engine, mono-generation. (Consukorra)

Co-Generation:

The efficiency increases for a gas engine with the use of an absorption chiller to a value of 72% [24].

Calculation parameters:

- Amortization time: 15 years
- Annual operating hours: 8000 h
- Operation and maintenance:
 - Gas engine: based on company internal data. [24]
 - Absorption chiller: 0,25% per year from total investment

	<i>fuel</i>	<i>type</i>	<i>power</i>	<i>capex</i>	<i>€/kWh</i>
subsidized	2USD/MMBtu	Ge-Jenbacher (JGS320-GS)	1MWel	(0,45 +0,35) million€	2,5
unsubsidized	3,7USD/MMBtu		+1,3MWth		2,8

Table 3.4: Economic facts gas engine, co-generation. (Consukorra)

3.1.3 Diesel engine

Especially in this year major difficulties occurred in the availability of the high subsidized diesel fuel.

Financing problems of the government brought delayed payments to the fuel producer which followed in running out gas stations and further huge traffic jams in front of them

were part of everyday life. In the past the Mubarak regime was putting pressure on this branch, but with the fall of the dictatorship this pressure decreased and fuel suppliers want to provide their business.

Mono-Generation:

Calculation parameters:

- Amortization time: 10 years
- Annual operating hours: 8000 h
- Fuel consumption: 0,3 litre per kWh
- Operation and maintenance:
 - Diesel engine: 2% per year from total investment

	<i>fuel</i>	<i>power</i>	<i>capex</i>	<i>€/kWh</i>
subsidized	14€/l	1,5MW	386 000 €	6,7
unsubsidized	75€/ l			27

Table 3.5: Economic facts diesel engine, mono-generation. (Consukorra)

Co-Generation:

Calculation parameters:

- Amortization time: 10 years
- Annual operating hours: 8000 h
- Fuel consumption: 0,3 litre per kWh
- Operation and maintenance:
 - Diesel engine: 2% per year from total investment
 - Absorption chiller: 0,25% per year from total investment

	<i>fuel</i>	<i>power</i>	<i>capex</i>	<i>€/kWh</i>
subsidized	20€/l	1,5MWel + 0,9MWth	(0,386+0,4)million €	3,8
unsubsidized	1€/ l			13,1

Table 3.6: Economic facts diesel engine co-generation. (Consukorra)

3.2 Renewable energy

The following listing of different renewable energy technologies are basically classified in:

- Existing capacity
- Natural resources
- Economic facts
- Outlook

To reach the renewable energy targets mentioned in chapter 2.1.2 four implementation mechanisms are determined[6]

1. Projects established by NREA
2. Projects established by Egyptian Electric Transmission Company (EETC) through competitive biddings (BOO)
3. Projects established by Egyptian Electric Transmission Company (EETC) through Feed-in Tariff (FIT)
4. Projects established through construction and operation of renewable energy power plants accompanied by the selling of generated electricity directly to customers

3.2.1 Wind

The wind sector with an installed capacity of 550MW is, after the hydro power, the second largest renewable energy part of Egypt's energy mix. Because wind power is a well known and a high developed technology with an international growth rate of 22,5% [9], Egypt's energy plans include a big contingent of wind power to cover the future energy demand. The targets of NREA for the Year 2020 calculates with 7200MW installed capacity for this technology – which equals 12% of the total electricity generation. This target should be reached with different financing models:

- 33% state-owned projects implemented by NREA
- 66% Private sector projects:
 - BOO (build own operate)
 - PPP (public private partnership)

Natural Resources:

Egypt offers extremely good wind conditions, as shown in the Windatlas, figure 3.1. Especially at the seaside (Region called Zafarana) there are areas with up to 10m/s, but even in some Sahara regions and the Nile delta you can find areas up to 7m/s. For example in Europe wind farms are putting realisations starting at 5.5m/s.

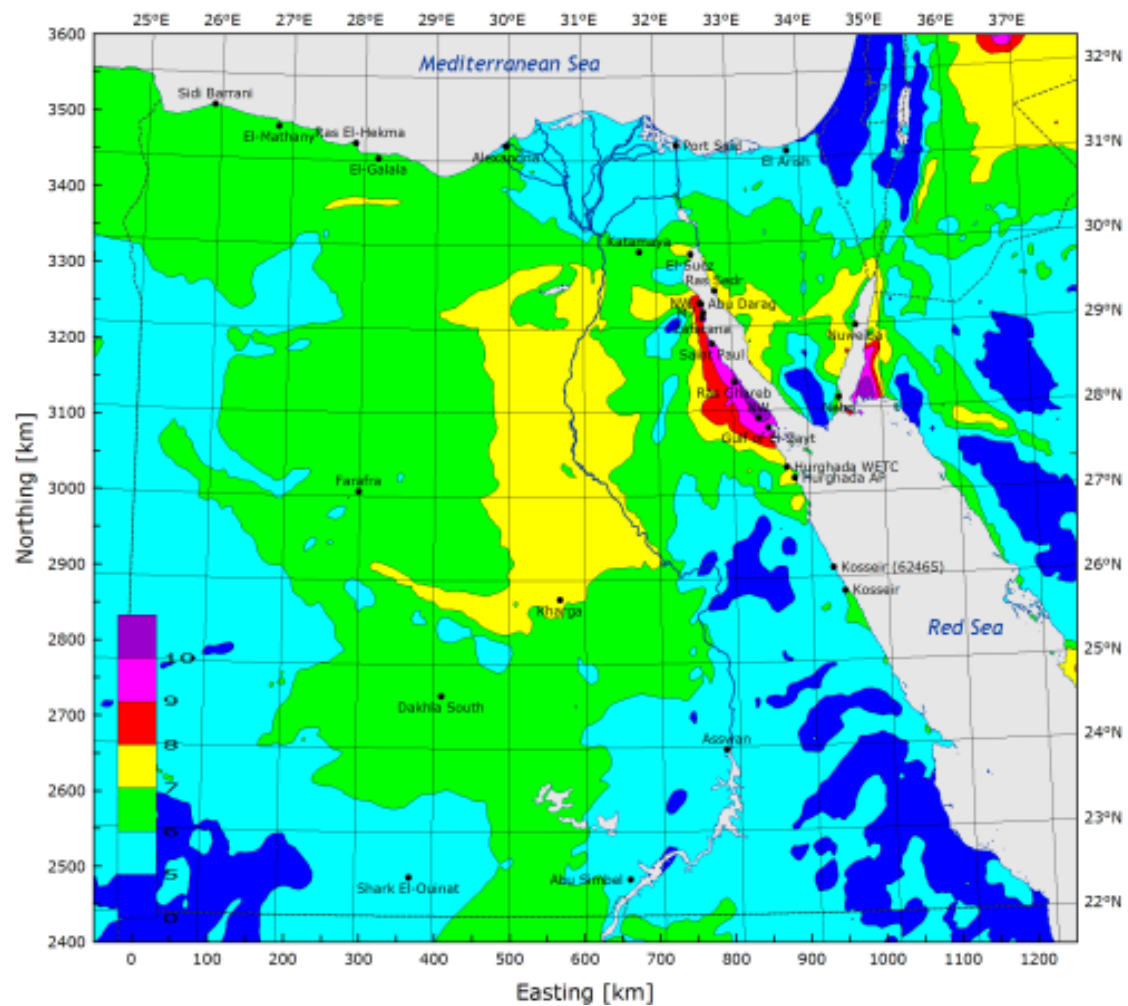


Figure 3.1: Egyptian Windatlas, <http://www.risoe.dtu.dk/>

Economic Facts

	<i>average Windspeed</i>	<i>capex</i>	<i>jobs/kWh</i>	<i>€/kWh</i>
type	7-8 m/s	1,2€/W	15/year	5-6

Table 3.7: Economic facts wind power in Egypt, SWEG [9], Wind power monthly 2010

In March 2010, the El Sewdy Wind Energy Group (SWEG) launched a production of wind towers in El Sokhna area in cooperation with a German company. Further investments for establishing a factory for wind turbines and for blades at 10th of Ramadan were also taken by the EL Sewedy Group.

Outlook

The targets promise a huge increase of wind power but will be hard to reach, as mentioned in chapter 4.

A 200 MW Wind farm in Co-operation with KfW (Kreditanstalt für Wiederaufbau), EIB (European Investment Bank) and the European Commission in the area of Gulf of Zayt is under implementation.

Future Projects in the public sector with Japan and Spain are under preparation as well as in the private sector with e.g. Italgen Company.

Local installer companies e.g. Taqa Power [1] waits with projects until feed in tariffs are signed.

3.2.2 PV

The current photovoltaic sector in Egypt is very small but cheap prices have thrown a new light on this market.

Except some small isolated PV-projects in the desert, you find PV mainly in street lighting systems and telecommunication stations. These facts allow the small number of total installed capacity which is about 10MW[13].

Natural Resources

The annual direct normal solar irradiation ranges are between 2000 kWh/m^2 and 3200 kWh/m^2 (shown in figure 3.2), rising from north to south, with a relatively steady daily profile and only less variations in resource. Such conditions come from 9-11 hours of sunlight per day, with few cloudy days throughout the year[22]. Thus, Egypt offers excellent conditions for varieties of solar energy technologies.

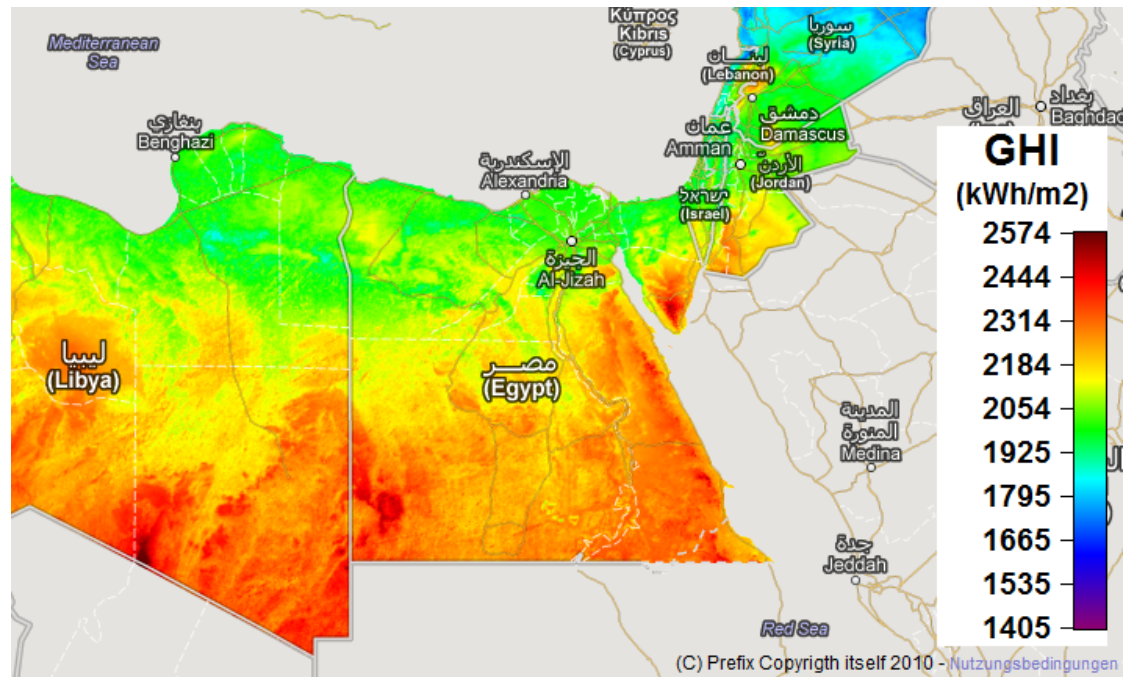


Figure 3.2: Solaratlas, Global Horizontal Irradiance/Irradiation, www.solar-med-atlas.org

Economic Facts

Calculation parameters:

- Amortization time: 20 years
- Panel degradation: 0,5% per year

<i>power</i>	<i>capacity factor</i>	<i>capex</i>	<i>opex</i>	<i>€/kWh</i>
100kW	1600 Wh/W/year	1,5€/W	2%	6,9

Table 3.8: Economic facts photovoltaic in Egypt

Mr. Sherif Bahnas [3], general manager of the factory Sun-prism, is the only producer of PV-panels in Egypt with an average production of 5-8MW per year. Because of the current market situation in Egypt he exports about 98% of his production to Germany and only 2% aren't leaving Egypt. As shown in the Solar-Atlas, figure 3.2, it isn't that small because of missing natural resources.

Most of the components for this manufacturing (photovoltaic cell, front glass, film) are imported because of quality difficulties of home-made parts.

Figure 3.3 shows the expected job creation for PV. It compares commercial and utility

facilities with residential systems. The big difference of job creation comes from construction and installation of the much smaller sized residential systems.

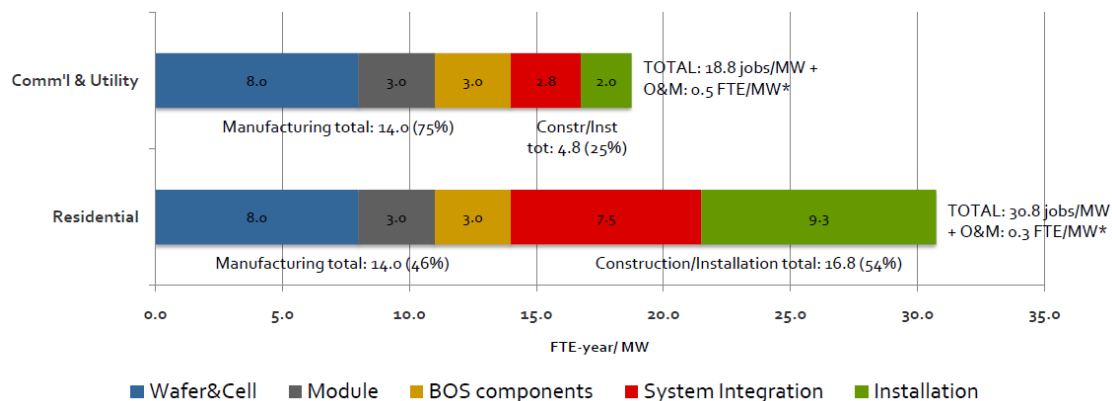


Figure 3.3: Jobs/MW PV, Source: Navigant Consulting, 2010 scenario

As usual there are two different concepts for the use of Photovoltaic:

- Isolated operator:

The main obstacle of isolated operators is energy storage, especially in Egypt where the peak load takes place in the afternoon and not at midday. A range for Battery prices e.g. from a Chinese Company¹ is about 700-800 €/kWh for lithium ion batteries.

- PV as fuel saver:

The expectation for the photovoltaic sector in Egypt is high, and especially for small decentralised energy systems. The "fuel saver" principle could be a feasible supplementation for example for Hotels at the seaside which cover their current electricity demand with diesel engines.

Mr. Emad Ghaly[15] said in an interview:

"With the actual situation in Egypt, you also have to calculate the availability of fossil fuels and further add resulted prices to the normal costs."

Outlook

Mr. Mohamed Abdel Hai [16] presented some projects and expects the future potential for PV more in a summation of residential small projects which should bring a cost reduction compared to one large scale project.

¹www.calb.cn

One project in preparation is to implement 1000 MWp with reams of small power stations on roofs. Tools to finance such projects e.g. a feed in Tariff for PV should come up soon.[16]

3.2.3 Thermal solar

< 80° Celsius

Mr. Khaled Gasser[14] expect huge growing in the solar thermal sector:

"Solar thermal is the most feasible solution now."

Currently nearly all installed water heaters in Egypt are running with electricity or gas.

A replacement by solar water heaters would result in huge savings of the government's subsidy bill for electricity and gas. Furthermore job creation and a slow down of the annually increasing energy consumption will be the consequences.

Economic Facts

Comparisson for hot water production (60° C):

<i>Turn key price</i>	<i>capacity factor</i>	<i>lifetime</i>	<i>average costs</i>
600€/m ²	850 - 1100 kWh/m ² /year	25 years	2,4€/kWh thermal

Table 3.9: Economic facts solarthermal (Sekem Energy)

Conventional system: 80l boiler, 1,5kW, 5 €/kWh electricity price

<i>Turn key price</i>	<i>capacity factor</i>	<i>lifetime</i>	<i>average costs</i>
200€	80%	15 years	7,9€/kWh thermal

Table 3.10: Economic facts conventional installed Systems 80l Boiler

Outlook

An initiative named Egypsol will establish solar water heaters in the red sea tourism area and will cover the hot water demand of 30% of the existing 220000 rooms. The expected business of number is more in the area of double digit million €[14].

$\geq 80^\circ$ Celsius

The market for concentrated solar is actually very small, but it is to expect that if further bigger projects are in pipeline, there will be a price decrease similar than it happened to PV.

Existing Projects:

- Kuraymat 140MW Integrated Solar Combined Cycle Power Plant. -Total capacity 140MW, included solar share of 20MW, operating since July 2011
- Kom Ombo 100MW Solar Thermal Power Plant Project, -under construction

Economic Facts CSP (Concentrated Solar Power):

Because of the small existing market it's very difficult to get the costs for a CSP system. In accordance with REN21 [25] the energy costs of an average CSP project are between 18.8 and 29€/kWh (depending on storage capacity)

Table 3.11 shows economic facts of a combined power plant using hot water for power generation and water desalination.

<i>type</i>	<i>power</i>	<i>water specification</i>	<i>storage</i>	<i>€/kWh</i>
MES, multi effect solar with steam turbine	1MW	95 ° Celsius	24 hours, min. 7200h/a hot water storage	15
	10MW			7
	100MW			<5

Table 3.11: Economic facts MES, source: Witt Solar

3.2.4 Solar cooling

The current Egyptian cooling energy demand is mainly covered by decentralized compressor air conditioners. Thus, in this sector exists a huge energy efficiency potential.

Economic Facts Absorption Chiller

<i>capex</i>	<i>opex</i>	<i>cooling-capacity</i>	<i>steam spec.</i>	<i>€/kWh</i>
1,93mio€	0,25%	2000USRT ≐7MW Th.	180° C, 8 bar	1,4

Table 3.12: Economic facts solar cooling in Egypt

Compared to electric chiller:

A cost estimation of an electric chiller with produced energy from a gas turbine results in a price of 11,6 €/kWh calculated with a gas price of 2 USD/MMBtu.

The costs for cooling capacity are highly dependent on the demand size. An estimation shows, that compressor chiller up to the capacity of 700 USRT are cheaper. At a higher capacity absorption chiller are the cheaper solution.[28]

The big difference is the necessary equipment. While compressor chiller are relatively compact and only need electrical connection, absorption chillers need cooling towers, tubes and pumps.

3.2.5 Waste / Biomass

Every year during autumn there is the anniversary of the "black cloud", when farmers in the whole Nile-delta burn their agricultural waste, because they don't know what to do with it otherwise. This leads to a shrouded Cairo in a dark mixture of the usual traffic and industry exhausts and smog from e.g. burned rice straw.

These unused biomass offers energy resources as well as the recycling and use of waste. In 2010, Egypt generated 21 million tons of municipal solid waste (MSW) and the annual MSW generation growth is about 2%. Moreover, 6.2 million tons of industrial waste, 0.2 million tons of hazardous waste, 28,500 tons of medical waste, and about 25 million tons of agricultural waste were generated in the same year[23].

MSW contains 55-60% of organic waste. Because of its relatively high moisture content and its low calorific content, a Waste to Energy plant is compared to actual low electricity prices hardly feasible [23].

Other concepts like Refuse Derived Fuel (RDF) –"waste to fuel" or Tire Derived Fuel (TDF) are coming up and enjoy a high potential. The cement industry has already started to burn biomass, because of increased fuel prices during the last years. The conditions for RDF and TDF in Egypt are good, the sunny and dry weather in Egypt allows an easy drying process which results in a higher calorific content for the same raw material as in Europe. [12]

Economic Facts

Table 3.13 shows the costs of a waste incinerator. It is calculated for a lifetime of 15 years without fuel costs. If cooling capacity is needed the numbers from table 3.12 on page 26 are to add.

Waste Incinerator (only):

<i>capex</i>	<i>fuel</i>	<i>steam</i>	<i>opex</i>	<i>€/kWh thermal</i>
1,155 million€	1 ton/hour	7t/h	0,5%	1,7

Table 3.13: Economic facts waste incinerator

Jobs

The informal sector collects about 80% of the recyclables (plastic, paper, etc) from the MSW which creates 7 jobs per ton/day[28].

Outlook

The missing standards and regulations make it difficult to use these resources. The first challenge is to formalize and liberalize this sector and currently there are some movements: Egyptian Junior Business Association (EJB) started with plans to found a "Waste union" which object is this purpose.

However a leading Egyptian producer and distributor of milk and juice products Juhayna² made plans for a biogas plant for a cattle farm.

²<http://www.juhayna.com/>

Chapter 4

Outlook

4.1 Chances for RE

It is a fact that a sustainable energy supply with a big share of RE is part of Egypt's future energy policy. The comparison in chapter 3 shows that some possibilities are currently feasible and it's mainly a job of Egypt's new government to open this market and prove with a high domestic content the benefit of the Egyptian economy.

Opportunities that this becomes reality are:

1. Remove Subsidies
2. Publicise possibilities out of RE to citizens
3. Create financing tools and well legacy conditions for investors

Remove subsidies

The first steps have already happened with higher electricity prices for the industry. To get an understanding from citizen and avoid political difficulties it needs the right public information and prearrangements of the government. In other countries with a similar subsidy system (e.g. Iran) a remove of the subsidies had been successful with voucher or limited subsidies for people whose existence is dependent on cheap energy prices (e.g. Taxi driver). The switch to higher energy prices followed in a high interest for energy efficiency and renewable energy. –The Iranian concept has already been presented to the actual government [21].

Publicise possibilities out of RE to citizens

To bring Egypt to a sustainable democratic community it's necessary to arise public interest in renewable energies. If Egypt pushes now to play a key role of RE in the MENA Region the existing companies which are active in this field would benefit and a new industry sector could arise. To get domestic know how in the area of RE, there are movements to organize trainings and courses (e.g. AUC).

In the universities of Cairo RE is an important topic and some institutes are also active in the research of new possibilities. (e.g. AUC, Ehab M. Abdel-Rahman [7], department of Physics, developed a "Thermal acoustic engine" which reached already 30% efficiency, but also research in existing technologies are in the scope of duties).

To raise awareness for environmental protection and "green energy" among tourists and tourism employees, a project called "Green Star Initiative" was founded within the scope of the Public Private Partnership (PPP) programme of the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). A first pilot destination for this concept is El Gouna where among other terms a significant reduction of energy and water consumption and further an increasing use of renewable energy¹ should be made.

Create financing tools and well legacy conditions for investors

A main financing tool which is missing so far is the feed in tariff. In a personal interview with Dr. Hafez [6] the expectations from most of the specialists I asked about the feed in tariff get approved that this financing model for wind power will come during the first quarter of 2013.

Also upcoming in the beginning of 2013 is a master plan for renewable energy prepared by Lahmeyer International [17] (client: KfW) where a calculation of the exact tariff among other terms is part of it.

A second tool which will also come is a "Renewable Energy Fund" which will finance projects. The idea is to use the saved money of gas consumption with such RE capabilities and support by this fund new projects. This fund should cover the deficit gap between the RE cost and market prices. It is part of the new Egyptian electricity law and will come up in 3-5 Years[13].

4.2 Expectations for RE in the next five years

Egypt is in the midst of the Arab Spring, so far tremendous changes have happened and a lot more of them will follow. The switch from dictatorship to democracy needs time to emerge and further efforts to come to fruition.

"A spring doesn't make a summer automatically"

¹<http://www.elgouna.com/pdf/Green-Star-Factsheet.pdf>



Figure 4.1: A spring does not make a summer automatically

While political modification moves forward the energy consumption grows annually and will be doubled in the next twelve to twenty years.[18]

Mr. Mohamed Abdel Hai [16], General Manager of the Renewable Business Development MEET said in a personal interview:

"The government has to do something and must react on the current difficulties, otherwise we have big problems already during the summer 2013."

The comparison shows that renewable Energy has already come close with the average costs to some capabilities running with unsubsidised fossil fuels. Considering the availability of this fuels and the dependence on this industry, renewable energy is additionally feasible.

This study also demonstrate that there is a huge potential in energy efficiency. This could result in an increase of the effectiveness of existing capacities (e.g. Co-generation, absorption Chiller) as well as the promoting of energy efficiency to all consumers.

Dr. Mohamed Salah Elsobki mentioned:

"Demand Management is a power sector resource. A megawatt saved through demand management is as good as a megawatt of Generation Capacity[10]"

The answers of the interview questions "Where will be the market for RE in 5 years?, Will the RE targets be reached?" which I asked all my interviewees were different.

Eng. Emad Ghaly and Dr. Mohamed Salah Elsobki estimate:

"Half of the wind targets for the year 2020 are realistic to reach.[15][10]" (equivalent to a new installed wind power capacity of 3050MW till 2020).

Dr. M.S. Elsobki expected further:

"Basically the market is able to absorb 4000 -5000MW photovoltaic during the next five years, but at the reality point of few this number can come down to 1000MW PV[10]."

Dr. Tim Hoffmann mentioned:

"Reaching the targets is possible, but challenging[17]."

Mr. Ismail Fahmy said in the interview:

"Cause of actual problems with the production and consumption of energy, targets are possible to reach[12]."

4.3 Conclusion

In conclusion, the Arab spring brought huge changes for Egypt and the economy will benefit from it, especially in the energy sector further changes will arise which will be followed by a new and big potential for renewable energy.

"Egypt is the gate to Africa", and if Egypt manages to use its huge natural resources in these fields, it could gain a key role in this economic sector and Egypt could further become the gate to a sustainable energy economy in Africa.

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