RENEWABLE ENERGY MIX FOR EGYPT

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Abstract:

Due to the limited fossil fuel resources, it is expected that their price continues to raise dramatically in the future. On the other hand climate change obliges humanity to react accordingly.
Renewable energy is the favourable alternative to fossil fuels especially because of Egypt's excellent resources of hydro, wind and sun powers. Accordingly a renewable energy share of over 50% till 2050 is considered as a realistic option.
Considering cost reduction potentials which solar thermal power still has, it is expected that solar thermal electricity in co-generation with desalted water will be the most economic option within 10-15 years.

1. INTRODUCTION

The author is of Egyptian origin and resident in Germany. For this reason reference is made to the successful German experience introducing renewable energy to the German grid.
Due to the limited fossil fuel resources, it is expected that their price continues to raise as it did since oil was exploited. On the other hand climate change obliges the humanity to act accordingly. The alternative of nuclear power stations is not favoured because of its potential dangers. The question is; which renewable energy shall be encouraged most?

2. SUMMARY:

Following the example of Germany, to increase the Renewable Energy (RE) share in total electricity production to 20% till year 2020 [1] and to 50% till year 2050 [2], Egypt should target a RE-share of 30% in year 2020 as it has now already 16% (including hydro energy from the dams on the Nile) [3] and will reach 20% in year 2010 [4] (see table I).
Following this logic RE share in Egypt shall increase to about 55% in year 2050.

3. EXPLANATION OF TABLE I:

With a yearly average growth of about 6% [3], Egypt expects to increase its installed energy from 17 GW in 2002 to 50 GW in 2020 and with a smaller increase rate to 120 GW in year 2050. This increase will exhaust the budget if the additional electricity is produced from fossil fuels only. Therefore the target of 55% RE-share is very modest and should be achievable.

As the hydro energy cannot be increased after 2020, the remaining RE share must be covered by wind and solar energy, however, wind alone cannot cover the demand because of its fluctuating character. The good wind areas are all aligned – in wind main direction - on the shores of the red sea which means that a wind still will affect them all together. Leading countries in the use of RE, - like Germany - made the experience, that RE must be generated from different sources to ensure a reliable energy supply. Therefore the key for the solution is a mix of different renewables, otherwise serious supply gaps may occur. At the moment, wind energy generation is the most economic RE after hydro energy. However, solar thermal generation has the great advantage that it can desalinate sea water with the waste heat, giving millions of m^3 of desalted water needed in the near future for the development of Egypt at reasonable costs.

Moreover, planning for the future must also consider the cost reduction potentials which solar thermal generation still has. Analogue to the cost reduction of wind energy in Germany of more than 3:1 within 20 years of application (see fig. 1), one can expect that solar thermal generation will be considerably cheaper than both wind energy and energy production from fossils.

And… its price does not climb up as the oil price does.

The next chapters give calculation examples to prove the necessity of developing solar thermal power stations beside wind energy especially in Egypt. Starting with hybrid operation using sun power during the day and fuel firing during the night and gradually developing heat storage systems to have “Solar Only” operation.

4. RELIABILITY OF RENEWABLES:

Egypt is the only place in the world where both solar and wind potentials are available at a high quality and in the mean time relatively near to the demand of electricity.

It is theoretically possible to produce the whole energy demand of Egypt from wind or from the sun. Here rises the question, which one is preferable?

To answer this question, one must consider a package of several topics:

- Electricity generation costs
- Land area required
- Controllability
- Availability
- Security of electricity supply.

<u>First topic; costs:</u>

Costs are generally the most important factor to decide about an investment. In this particular case, namely dealing with relatively new technologies, one must consider –

beside the costs at the present time – also development of costs in future, e.g. after 20 years.
Starting with present costs we will try to make a comparison between wind energy and solar energy considering the optimal benefits of each.
Assuming a square kilometre of desert, equipped with the most modern and most efficient solar thermal system now available – the "Fresnel" flat mirror technology – working in hybrid operation with a solar share of 35% it will yield per year:

300	GWh electricity at a cost of	0.05	\$/kWh	totalling	15.0 million \$ [5]
		Plus			
13	million m^3 desalted sea water at	0.70	\$/m^3	totalling	9.1 million \$

(combined generation using waste heat, no extra energy needed)

To produce the same quantities (electricity + desalted water) from a good wind park with 4500-5000 full load hours per year, following costs will occur:

300	GWh electricity at a cost of	0.03	\$/kWh	totalling	9.0 million \$
		Plus			
13	million m^3 desalted sea water at	1.10	\$/m^3	totalling	14.3 million \$

(Produced by Reverse Osmosis using electric power)

The total cost of both products together gives 24.1 and 23.3 million \$/year respectively. Thus wind power is only 3% cheaper in the present time.
However, considering the expected future cost reduction in analogy to the cost development of wind mills experienced in Germany, the costs for solar energy are expected to be 0.025 \$/kWh [6] and 0.50 \$/m^3 desalted water totalling to 14 million \$ in about 20 years with an increased solar share of then 75%.
Fig. 1 shows the cost development of wind mills in Germany from 3650 €/kW in year 1982 to 1050 €/kW in year 2001 [7].
As seen the cost reduction flattens down, so it is not expected to have much more reduction in the next 20 years.

Second Topic; Land area requirements:
Continuing with the example above, 1 km^2 is needed to produce 300 GWh/y solar electricity and 13 million m^3 of desalted seawater. We add 0.1 km^2 for the desalination equipment thus totalling to 1.1 km^2
To produce the same electricity from wind with 4500-5000 full load hours we can calculate with a wind mill density of maximum 7.5 MW/km^2. A higher density will cause reduction of produced electricity from the field. This will give 8.4 km^2.
To produce the same water quantity with reverse osmosis (RO) we will need 8 kWh/m^3 which calculates to 104 GWh. A supplemental area for producing this electricity will be needed which gives 2.9 km^2
The total area needed is 11.3 km^2 which is 10 times as much as for the solar application.
The desert area may be cheep, but looking at this disproportion we have to think about parameters like cable lengths needed and time consumed by maintenance personnel to reach all units in the field.

Third topic; Controllability:

Controllability is the capability to follow the ups and downs of the demand during 24 hours.

Solar-Hybrid power stations, which are the present object of this comparison, are working exactly like fossil fired power stations with the difference that during the day less fuel is burnt because it is partly substituted by the sun heat. Future options are "solar only" power stations with thermal storage allowing continuous operation. In both cases the power station is controllable in the same manner like conventionally fired power stations, backup capacity for the fluctuating solar resource is integrated within the plant.

On the other hand wind is roughly predictable but not controllable and storage of wind power is only possible in rechargeable batteries which are so expensive that they cannot be considered for large applications. For this reason wind farms are working within grids where the control is left to the thermal backup power stations connected to the grid.

Forth topic; Availability:

Availability is the certainty to deliver electricity through the year.

For the reasons mentioned under the third topic, availability is achieved with hybrid solar power stations without any problems. In Egypt it is even advantageous because the electricity demand in summer is about 20% higher than in winter, which is fully consistent with the seasonal trend of the solar energy resource. On cloudy winter days the hybrid solar power station will use fossil fuel or heat from the storage without restriction of availability. The unique solar energy resource of Egypt (up to 3000 $kWh/m^2/year$) and thermal energy storage allows for around-the-clock operation through the whole year like a base load fossil fuel plant.

Wind, however, is subject to seasonal fluctuations. Good wind sites like the Gulf of Suez are highly affected as the site is lengthily extended in main wind direction. This negative effect may be partly compensated by connecting wind parks in different areas, e.g. Red Sea and Northern Coast, taking in account the less favourable wind conditions in the North Coast. Even then availability is not guaranteed, so always free capacities of thermal power stations must be kept within the grid in the background (called shadow power stations). Capital costs of such power station capacities must be taken in account when considering a large scale supply of wind energy in the grid.

Fifth topic; Security:

In summer 2003 several blackouts occurred in USA and Europe, mainly because of failures of transmission lines which lead to overloading and thus tripping of several power stations.

This can be avoided by increasing the available thermal power stations (including solar thermal power stations) connected to the grid, but not by adding wind power. Wind power has in general a destabilising effect on the grid, which has to be compensated by other resources, like hydro power or thermal (solar) power stations.

5. Conclusion:

Controllability, availability and security of electricity supply are as important for a modern society as generation costs. Experience in Germany in summer 2003 - with long periods of wind still - demonstrated the importance of these factors. For this reason experts recommend that the wind share shall not exceed 20% in an electricity grid. Production of desalted seawater from waste heat and the future perspective for a considerable cost reduction of solar thermal power stations makes it essential that they get sufficient support to develop for the future.

**Wind energy is a very good choice in the present, however,
solar thermal energy is essential for the future.**

Table II summarises the advantages of solar thermal power stations compared to wind considering large scale electricity production and present costs.

Fig. 2 shows a sketch for possible constellation of solar field, heat storage and desalination.

To demonstrate the potential of solar thermal power stations, let us consider a solar field of 1000 km² - a square of 32x32 km - it is only 0.1% of Egypt's total area. It is capable of producing 300 TWh of solar electricity, which corresponds to more than 50% of Germany's consumption 2003. Moreover, it can produce 12 000 million m³ of desalted sea water – 20% of Egypt's consumption 2003.

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TABLE I COMPARISON GERMANY / EGYPT
AND AUTHOR'S ENERGY EXPECTATIONS FOR EGYPT

Year	2002		2010		2020		2050	
Germany RE share	8%		12.5%		20%		50%	
Egypt RE share	16%		20%		30%		55%	
Egypt total Electricity	17 GW		27 GW		50 GW		120 GW	
Egypt total RE share	2.7 GW		5.4 GW		15 GW		66 GW	
Egypt Hydro share	15%	2.5GW	10%	2.7GW	6%	3.0GW	2%	3.0GW
Egypt Wind share	1%	0.2GW	8%	2.2 GW	12%	6.2GW	17%	20GW
Egypt Solar share	0%	0 GW	2%	0.5 GW	12%	5.8GW	36%	43GW

TABLE II; COMPARISON WIND POWER VS. SOLAR POWER
NOW AND IN THE FUTURE

Topic	Wind	Solar hybrid
Desalination	Only combined with RO	Yes, by waste heat
Electricity costs today	100%	160%
Electricity costs 2020	100%	83%
Elect.+Desal. costs today	100%	103%
Elect.+Desal. costs 2020	100%	71%
Land area usage	100%	10%
Controllability	Uncontrollable	May be used as base load or peaking plant or even as backup for wind power
Availability	Low: operation only within grid	Guaranteed
Security	Low	High
Effect on grid	Potentially destabilising	Stabilising

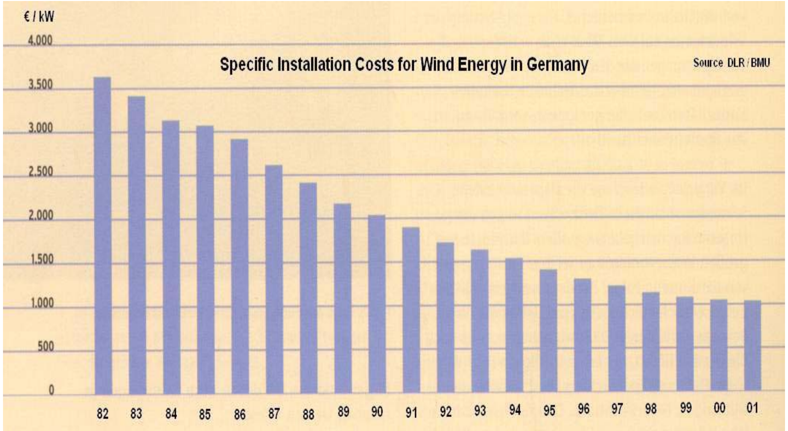

Fig. 1. Specific installation costs for wind energy in Germany

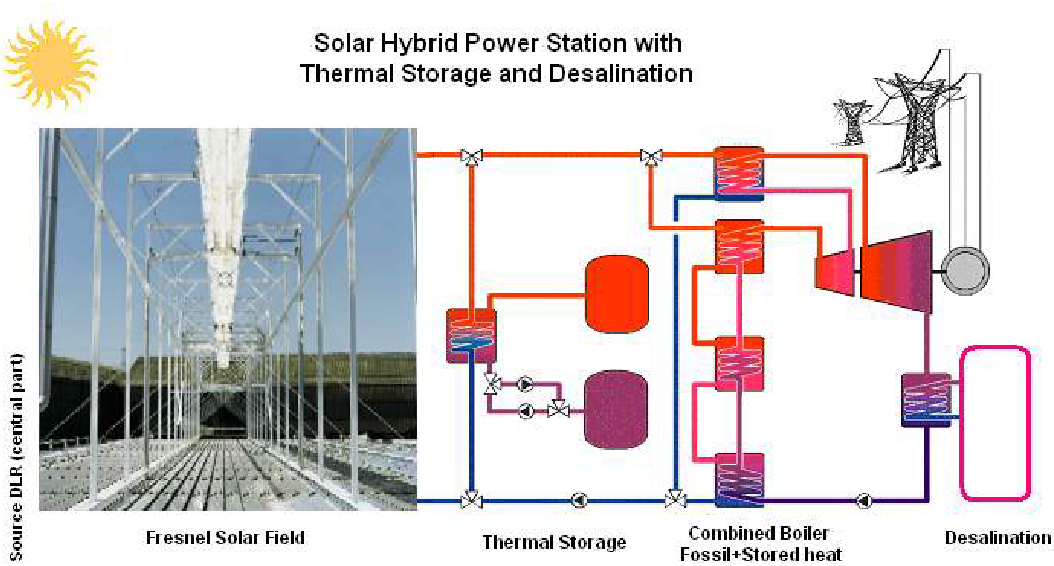

Fig. 2. Schematic diagram of a solar hybrid power station
Using Fresnel flat mirror technology with heat storage and desalination
Source of the Fresnel picture "Solarmudo" [8]

Fig. 3. Fresnel solar field in Australia
Source "Solar Heat and Power Europe" [9]