15. Symposium Energieinnovation, 14. bis 16. Februar 2018, Technische Universität Graz, www.EnInnov.TUGraz.at
ISBN 978-3-85125-586-7 DOI 10.3217/978-3-85125-586-7

A SOCIOECONOMICAL WIND ENERGY APPROACH IN EGYPT, UTILIZING TAILWINDS FROM A FAST MOVING EUROPEAN ENERGY ECONOMY.

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Introduction

Egypt´s energy economy is in transition. In the midst of an economic crisis following a devaluation of the currency about 50% over night at the end of 2016, and inflation rates exceeding 30%. Fuel prices and electricity rates are highly affected by this devaluation and even strengthen the governmental strategy to cut off the omnipresent energy awareness opponent, “Subsidized fossil fuels”, with the last price increase happened during summer 2017, where e.g. Diesel price raised about 55%. [1]

Egyptian electricity market

Nearly 99% of Egypt’s population have access to electricity, which is mostly dependent on fossil fuels. Natural gas and other conventional fuels have always been considered the most dominant sources for electricity generation in Egypt and would be for many years to come. They, in addition to hydropower and non-commercial fuels like biomass, represent the bulk of energy resources in Egypt. The share of renewables is remarkably low as it is still below 2.5% in terms of total installed capacity and only 0.8% of generated electricity. With the cut of subsidies for fossil fuels, energy prices are rising fast, both the direct fuel prices as well as the dependent electricity rates.

Wind energy in Egypt

Compared to sun-based technologies, the wind sector of Egypt has been neglected so far mainly due to the high investment costs and the lack of know-how. In contrast to solar energy, wind speeds vary significantly between different parts of Egypt. Since the energy output of a wind turbine is very sensitive to wind speeds (its power output is proportional to the cube of the wind speed), it is necessary to know the exact prevailing wind conditions before installing a wind system.

Egypt has already installed 600MW of electrical wind power plants. Its first and biggest wind park was installed in 1999. Unfortunately, a large share of the installed capacity is no longer in operation due to lack of maintenance. The insufficient local know-how in repairing and maintaining such turbines makes this an expensive venture for the government which is operating the plants. Currently, further 120MW of wind power is in construction which represents the first private wind park in Egypt, additionally 220MW are in pipeline.

Wind resources in Egypt

Figure 1 shows a graphical output of the available “Egyptian Wind Atlas”. [2] According to this map, Egypt offers a lot of potential sites with high wind speeds in the Gulf of Suez in particular. However, there are also many areas which should be investigated in depth. This is especially the case for local thermal wind systems which exist around the Red Sea as well as near several Oasis regions but are not well documented. As a result, there are many uncertainties in this atlas, especially in rural areas.

Nonetheless, very promising sites for utilizing wind energy in sites other than the coastal regions of the Gulf of Suez have been identified around the Nile Valley sides near El Minya and the western area of Luxor, including Kharga, Dakhla South and Bahareya Oasis.

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Since the energy output of a wind energy systems increases with the cube of wind speed, it is recommended to measure the wind speed at potential rural sites. The sensitivity of wind energy production is demonstrated in the following example: 15% less wind speed can lead to more than 50% less energy output. That means that when decisions about the feasibility of wind energy are to be made, good wind data of the exact site are necessary. Therefor an evaluation of the existing wind atlas, shown in Figure 1, is part of this analyses. Especially rural areas, were less considered in the development of this wind atlas and show differences to available wind resource data. [2] Thus a case study is in operation with a local manufactured wind pole, evaluating the wind atlas at a potential site.

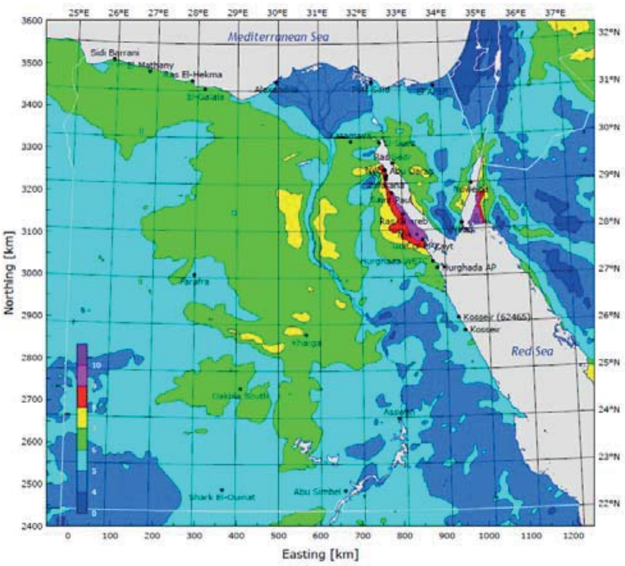

Figure 1: Wind atlas of Egypt, mean wind speed 50m o.g.l. using mesoscale modelling [3]

Case study and evaluation of the existing wind atlas

As already mentioned, Wind is a very complex affair and theoretical models often show certain uncertainties. Therefore, every wind observation on a special site needs a wind measuring facility for a certain time frame. Within this study an on-site analyses in the Fayoum Region is made. A 30m mast is mounted in this region in the middle of Egypt. The Region was chosen due to the following reasons:

- The geology of this area with hills and lakes lead to a high horizontal gradient of wind speeds caused by the local orology
- Valuable existing meteorological stations are at least 20km away
- No weather stations in the near of this region were considered in the first wind atlas
- Fayoum is connected to the national grid and has a high energy demand and therefore would be a suitable region for wind power utilisation in case of a shown feasibility with measured wind speed

The wind measuring is currently in operation and planned for another 4months collecting data of one year. Due to high costs of wind analyses an own measuring project was planned within this study. An autonomous data logger on microcontroller basis was developed which can stream data on a server. The metal mast is fully manufactured in Egypt with local welding workshops. The concept and analysis is based on the Measnet "Evaluation of site specific wind conditions, 2009" [4] and was in cooperation with Austrian wind measuring specialist "Verein Energiewerkstatt".

Measured data is:

Table 1: Measured parameters of installed data logger

Parameter	Wind speed height1, 20m	Wind speed height 2, 30m	Wind direction	Temperature	Solar radiation
Sampling rate	1Hz	1Hz	1Hz	0,1Hz	0,1Hz

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All input data is stored locally with a certain sampling frequency. Ten minutes' mean values are calculated and transmitted to a webserver every 10 minutes. Additionally, also standard derivation for every 10 minutes' mean value is calculated and transmitted.

Figure 2: Mounting sensors on locally manufactured 30m measuring pole

To compare measured wind speeds with Merra data, a wind shear exponent (Hellmann exponent) has to be calculated and further the measured wind speed in 30m height over ground level, o.g.l. is interpolated to the Merra output height of 50m o.g.l.

Equation 1: Calculation of the wind shear Exponent: [4]

$$\alpha = \frac{\ln \frac{v_{Z1}}{v_{Z2}}}{\ln \frac{z_1}{z_2}}$$

$\alpha \ldots wind\ shear\ exponent$

$v_{Z1} \ldots wind\ speed\ measured\ at\ height\ 1\ [m/s]$

$v_{Z2} \ldots wind\ speed\ measured\ at\ height\ 2\ [m/s]$

$z_1 \ldots measurement\ height\ 1\ above\ ground\ level$ [m]

$z_2 \ldots measurement\ height\ 2\ above\ ground\ level\ [m]$

Interpolating the measured 30m mean values on the 50m height of Merra data:

Equation 2: Calculation of a wind speed in certain height with Hellman wind shear exponent [5]

$$v_H = v_{Href} \cdot \left(\frac{H}{H_{ref}}\right)^{\alpha}$$

$v_H \ldots mean\ wind\ speed\ \ at\ height\ H\ [m/s]$

$v_{Href} \ldots wind\ speed\ measured\ at\ height\ H_{ref}\ [m/s]$

$H \ldots\ height\ [m/s]$

$H_{ref} = measurement\ height\ H_{ref}$

A comparison of the monthly data already shows big differences in the absolute mean value between Merra data and measured wind speeds. For the correlation of seasonal effects are the following months outstanding. It´s awaited that the maximum mean wind speeds happen during spring. Also the feasibility analyses is getting finalized with a one year measuring period. –However due to the relatively low wind speed it is very likely that a wind energy system does not show feasibility at this site. As a first wind

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speed analyses in this region the output is useful for further investigations. For an economical better scenario, other promising sites should be targeted, –Anyway the difference also shows the importance of wind measuring before a significant feasibility study can be realized.

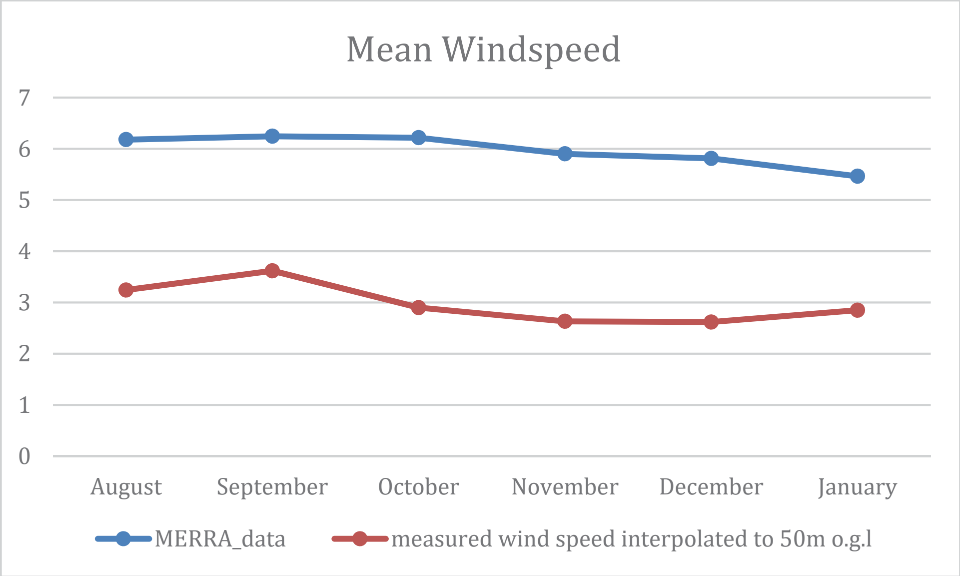

Figure 3: Difference in monthly mean values of monthly mean wind speeds on 50m o.g.l.; measured wind speeds at 30m height are therefore interpolated on 50m height with the Hellmann exponent

Utilizing refurbished wind turbines

Wind turbines for electricity generation are available in different sizes for varying purposes. While the largest scale wind turbine clusters (wind farms) show a very slow development in Egypt due to high investments, smaller scale solutions increasingly seem to be an option for suitable sites. Wind power in Europe is developing very quickly based on the European energy goals and the intensive subsidisation available in many European countries. At the end of the subsidisation period, the used wind turbines are often replaced by bigger and more powerful ones. This offers the opportunity to prolong the life-cycle of the used windmills, by exporting them to countries like Egypt after suitable refurbishment. This approach would result in a reduction in the investment costs, while local personnel could be trained for doing necessary maintenance works, thus further gaining local added value. In particular, the replacement of existing large-scale diesel generators can be targeted as a very feasible sector, as shown in Figure 4 on an example with a large scale water pumping system.

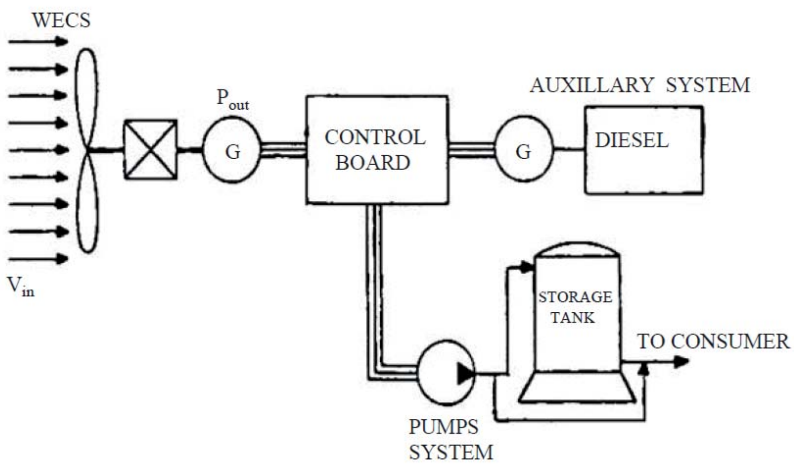

Figure 4: Electrical Wind System for an isolated operator, in this case combined with a pump system [6]

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Results and Conclusions

From a socioeconomically perspective, a recently published study from IRENA show that wind power requires less labour in development, construction and maintenance per plant in comparison to photovoltaics, which in principle makes this technology less interesting from a job-creation point of view. However, the fact that it needs more local employment and has a lesser share in manufacturing and procurement jobs, as shown in Figure 15, is an advantage in local added value. The use of refurbished wind turbines which is linked to training and educational activities has potential to generate additional green jobs.

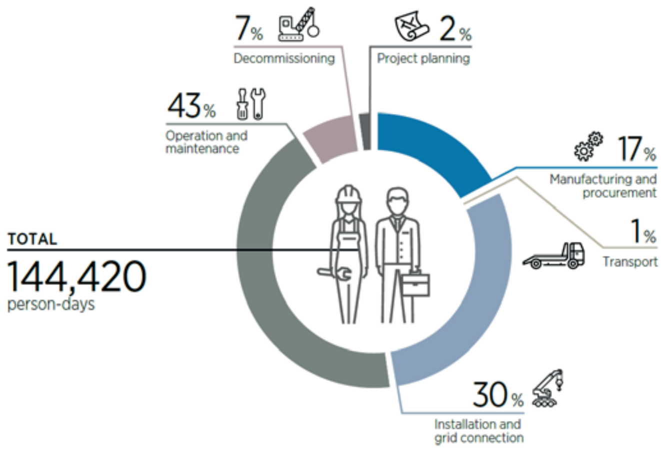

Figure 5: Distribution of human resources required along the value chain for the development of a 50 MW wind farm, by occupation, [7]

Economically, the replacement of existing large scale diesel generators, which represent the most affected sector of the last price hikes, can be targeted with such approaches. The systems with single or combined diesel generators are still very common and have been identified especially in rural areas for large scale irrigation- or in the southern red sea for tourism purposes. Still, the fluctuating framework conditions like governmental restrictions on imports and energy generation does not make the assumption to a game changer and require a detailed case study including efforts in lobbying and international cooperation's.

Aside from technical feasibility, the framework conditions for commissioning and erecting such turbines are still challenging. The import into Egypt of used machines and materials is generally forbidden by law, so the import of used wind turbines would have to be arranged with special governmental support.

Regarding the erection of wind plants, the current height regulation limits the maximum blade height to 120m.

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