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REPORT REVIEW

Renewable energy perspectives for the North African electricity systems: A comparative analysis of model-based scenario studies

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ABSTRACT

Prospects for the integration of power markets and the expansion of renewable energy have recently triggered a number of publications dealing with transformation scenarios of the North African electricity systems. This paper compares five studies using economic electricity supply- and demand models to assess possible development pathways of the North African power systems from today until 2030 and 2050. The analysis shows that distinct modeling methodologies as well as different approaches to scenario design and parameter assumptions can strongly influence the studies' results, leading to very heterogenous projections of North Africa's power generation structures as well as the patterns of electricity exchange with other regions, like Europe. Common findings of the studies are that the surplus costs of capital-intensive renewable energy expansion in North Africa can in most cases be offset by avoided fuel costs and avoided investments in conventional power plants. All studies further agree that increased transnational cooperation, notably in terms of market integration and cross-border power exchanges, can bring about important economic advantages for the North African power sector. Renewable energy expansion could also drive electricity exports to Europe, but in integrated power market schemes, such exports only become viable with a very high share of renewable energy exceeding 60% of the North African power demand.

1. Introduction

Electricity generation from renewable energy sources (RES-E) in North Africa has become a prominent topic in the research community. Without doubt, much of the attraction to the issue is owed to the high public profile of the 'Desertec concept' — the idea of large-scale solar power generation from the North African deserts to supply electricity to Europe. The concept, promoted by industry players like the Desertec Industrial Initiative Dii [1] or the Mediterranean power grid initiative Med Grid [2], but also adopted by high-level policy institutions like the Union of the Mediterranean [3], however, remains a subject of controversial debate. Despite a general consensus among experts, that renewable energies will play a more important role in future North African power systems, the detailed scope of RES-E deployment remains ambiguous. Opinions particularly diverge about the following questions: What is the realistic expansion pathway for RES-E in North Africa, i.e. what level of RES-E penetration can technically and economically be achieved at which point of time, and how will a future technology mix — renewable, but also conventional/fossil — in electricity generation look like? To what extent and under which conditions can electricity exports from North Africa actually be realized?

In the last years, these questions have increasingly been taken up by scientific research, which led to the publication of a

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number of studies on North African power system scenarios. As will be shown in this paper, the studies' approaches as well as their results are very heterogenous, and therefore difficult to compare. This was the motivation to carry out a more thorough investigation and systematic appraisal of the publications. Five different studies were analyzed, ranging from relatively brief peer-reviewed research papers to large road-mapping reports from prominent organizations or institutions. In order to present an unbiased picture, a common, uniform comparison methodology was applied to assess the studies' scenario building approaches, modeling methods and model outcomes.

2. History of the North African electricity supply

Before starting with the analysis of the different scenario studies, it is instructive to have a look at the historic development of the North African electricity systems in the past. Over several decades, the entire region, encompassing the countries Morocco, Algeria, Tunisia, Libya and Egypt, has been marked by ever-increasing electricity generation. Annual growth rates averaged 8.9% between 1980 and 1990; 4.5% between 1990 and 2000 and 6.4% between 2000 and 2012. As can be seen in Fig. 1, by far the largest power producer among the five countries is Egypt, followed by Algeria, Libya, Morocco and Tunisia. The proportions of these five countries have not changed significantly over the years, although economic and demographic parameters as well as population growth and per-capita electricity demand vary substantially from country to country.[2]

Looking at the electricity mix by source (see Fig. 2), it becomes apparent that electricity generation in North Africa is still substantially based on fossil fuels. Today, the dominating source of power generation is natural gas (in 2012: 75% of total North African generation). Since the 1980s, natural gas has continuously increased its share in the generation mix, pushing the formerly predominant, but inefficient and expensive oil[3] based generation to the second position (in 2012: 15%). All countries are striving to reduce oil usage in power generation, be it for reasons of cost-cutting (Morocco, Tunisia and Egypt are net petroleum importers [4]) or to save greater quantities of this strategic fuel for export (in the cases of the net oil exporters Algeria and Libya). The shift in the fuel source, from oil to natural gas was eased further by important investments into gas extraction and transmission infrastructure that many gas-rich North African countries carried out in the 1990s in order to promote pipeline-based gas exports. These upgrades also helped to channel more natural gas into the domestic power sector, which has seen a boom in gas power plant projects in the last two decades. The share of coal in the North African power mix (in 2012: 4%) stems exclusively from Morocco, which, being the only North African country without any noteworthy hydrocarbon resources, had introduced steam coal power plants back in the 1980s, in order to diversify its electricity mix. Hydropower in North Africa (in 2012: 4%), for the most part, is supplied by Egyptian Nile river hydroelectricity and Moroccan hydro power plants. Due to lacking expansion potential, and as other energy sources accelerate production, the proportion of hydroelectricity in North Africa's power mix is set to decline. Non-hydro renewables, hardly noticable in Fig. 2, have only recently entered the North African power systems. Today, the bulk of non-hydro RES-E generation comes from wind farms, with Egypt, Morocco and Tunisia being the most important producers of wind energy. In 2012, their aggregated wind electricity production amounted to 2.8 TWh, representing about 1% of the total North African power generation of 289 TWh.

Today, as a result of nationally oriented energy policies, the North African power systems are fragmented into five separate electricity markets, mostly ruled by monopolistic state utilities. Despite certain efforts to increase regional cooperation and even the desire to form integrated power markets in the future [5], the internal exchanges of electricity between the five North African countries are still hovering at a level close to zero [6]. Somewhat more significant are the electricity exchanges between North Africa and its neighboring regions Europe and the Middle East. In 1997 and 1998, the first electricity interconnectors were built between Morocco and Spain and between Egypt and Jordan. Over the past 15 years, the exchange of electricity across these power links has shown a net import balance of North Africa, which on average meets around 1% of its demand from abroad (see Section 5.4).

3. Trends, influencing factors and uncertainties of North African power system development

Forecasting the future of North Africa's electricity generation based on historic developments is certainly imprecise, but the observations outlined above nevertheless give some indications about likely trends in the near term. One of the trends with the highest inertia is certainly the growing electricity demand, which, as the developments of the past have shown, is still far from saturation in North Africa. Although exact growth rates are difficult to predict, the trajectory in Fig. 2, suggests a general continuation of the demand increase. A second, very certain pattern concerns the stagnation of hydro power in the North African power mix. Furthermore, liquid fuels (fuel oil, diesel) are also set to decrease their contribution to the North African electricity mix: old, inefficient power plants of this type will continuously be replaced by more efficient gas power plants.

Much more uncertainty is associated with the question of the extent to which non-hydro renewable sources can penetrate into the North African power systems. The favorable worldwide conditions for RES-E technologies (falling costs, improvements in technology) and the immense potential of solar and wind resources in the region speak for an accelerated RES-E expansion in the region, clearly going beyond the current 1% contribution to the North African power mix. The recent proliferation of renewable target announcements by North African governments [7] additionally underscores the generally positive prospects for RES-E in the region. However, doubts remain as to whether the ambitious policy targets can actually be realized as scheduled — especially in light of the current political and economic difficulties following the Arab Spring. A further open question concerns the choices of RES-E technologies. Wind power, photovoltaic (PV) and concentrated solar power (CSP) are expected to be the leading renewable technologies for bulk power generation in North Africa. However, their exact proportions in the future renewable mix are still a matter of speculation.

The same goes for the conventional fuel mix. While natural gas is set to gradually replace oil-based electricity generation, uncertainty remains about the future of coal in the North African power mix. Morocco already operates coal-fired power plants, but for instance Tunisia, suffering from declining natural gas reserves has also been deliberating the usage of coal for electricity generation [8] — although no final decision on this technology has been taken, yet. Whether carbon-intensive technologies will actually garner support in the region will certainly also depend on the future stance of national governments towards climate policies. Finally, many North African countries have also displayed nuclear ambitions in the past [9] — which, despite the Fukushima disaster and the recent political upheavals, have never fully disappeared [10]. A likewise highly

[2] Electric power consumption per-capita (2011 data, World Bank): Morocco 830 kWh, Algeria 1090 kWh, Tunisia 1300 kWh, Egypt 1740 kWh, Libya 3930 kWh. Per-capita consumption in the EU is 6030 kWh.

[3] In this article, the term 'oil' stands for all types petroleum-based liquid fuels (e.g. heavy fuel oil, light fuel oil, diesel) that can be used for power generation.