North Africa – a renewable power house in the making?

A framework paving the way towards a new power system paradigm

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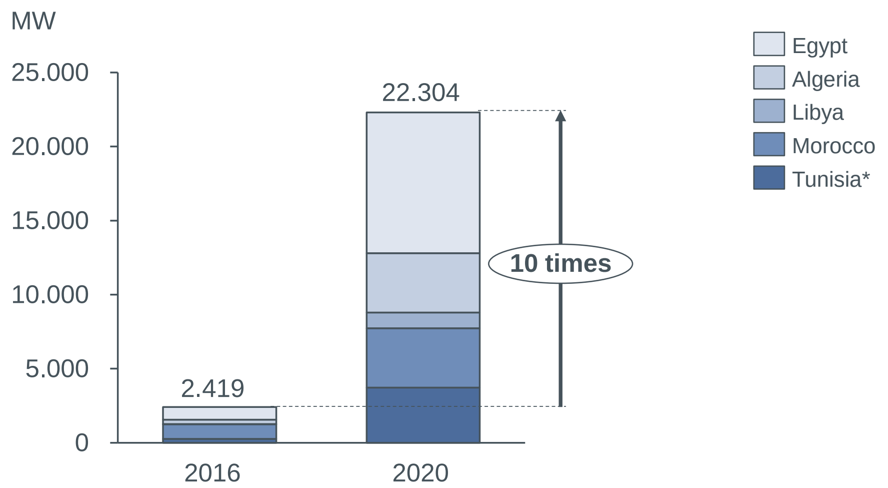
Renewables are taking North Africa by storm

Renewable Energy Sources (RES) have taken the world by storm and are at the core of the energy transformation phenomenon. The appeal of RES is unquestionable as they address at the same time concerns with global carbon emissions and could be used to supply energy in parts of the world still not yet properly served, at hopefully affordable costs. North Africa is no different in this respect and has set a very aggressive growth target for RES capacity build up.

North Africa has an agressive Renewable Energy Sources (RES) agenda

Installed capacity of RES and 2020 targets in North Africa



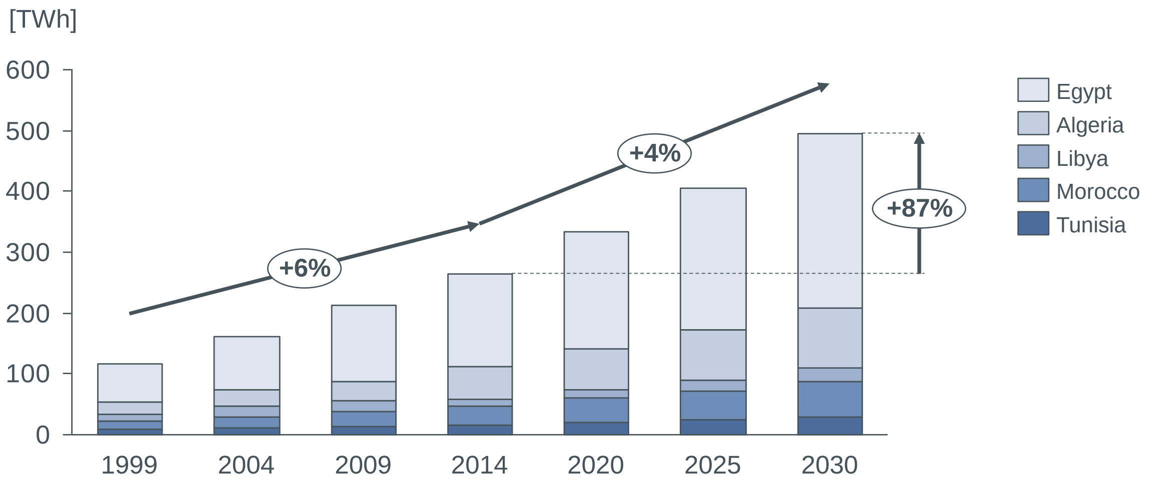
Source: IRENA (2016): Renewable Energy in the Arab Region. Overview of Developments, International Renewable Energy Agency, Abu Dhabi. *Tunisia targets are valid for 2030; RES includes Wind Onshore, Solar PV and Concentrated Solar Power (CSP) plants

Chart 1: Current and targeted (2020) RES capacities in North Africa

The motivation for these countries is also quite clear: as their economies develop further, likewise the access to energy for the population increases causing the domestic demand to grow steadily. The International Energy Agency (IEA) estimates that the demand in these countries will double within the next 15 years.

Electricity demand to almost double until 2030

Electricity consumption in North Africa



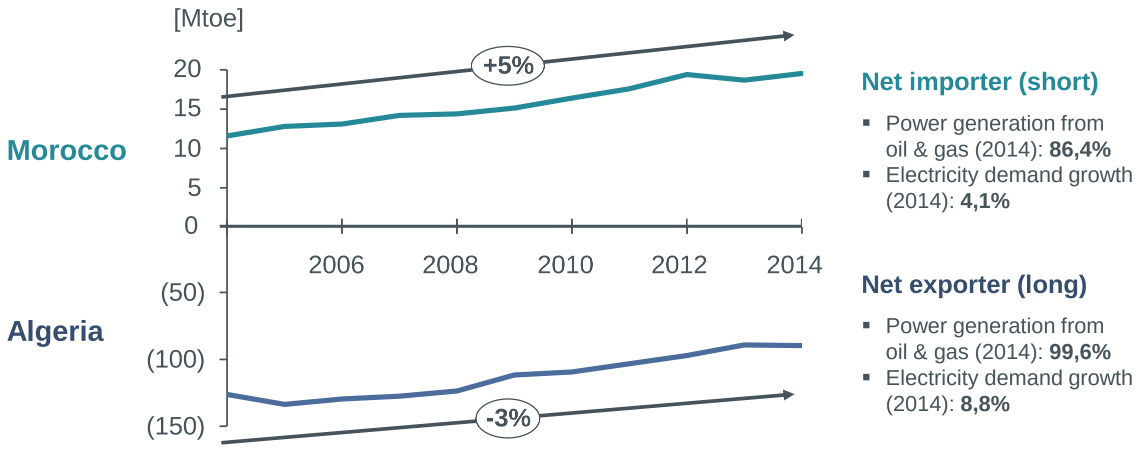
Source: IEA (2015): IEA Statistics Database. International Energy Agency, Paris, www.iea.org/statistics/; IEA (2016): World Energy Outlook 2016. New Policy Scenario, International Energy Agency, Paris; Demand: Electricity Gross Production + Imports - Exports - Losses

Chart 2: Growing electricity demand in North Africa

Another important factor contributing to the interest in shifting to RES is the dependency on costly energy imports to keep up with the ever rising local market demand for electricity. This is not only a problem for "energy short" countries, e.g., Morocco and Tunisia but also, for "energy long" countries such as Algeria and Libya: for these countries a growing local demand means fewer revenues from energy exports. Chart 3 shows the net energy export balance of an "energy long" country (Algeria) and of an "energy short" one (Morocco).

North Africa's demand growth impacts the energy balance of both oil and gas long and short countries

Country's energy net balances



Source: IEA (2015): IEA Statistics Database. International Energy Agency, Paris, www.iea.org/statistics/

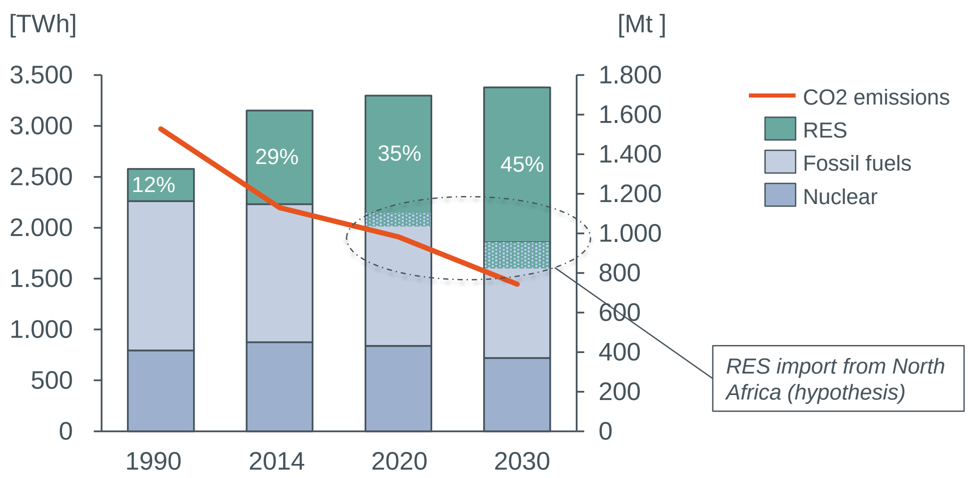
Chart 3: Net energy balances of Algeria and Morocco

For both countries, promoting affordable RES and incorporating it to the grid makes a lot of sense. The question however remains one of what affordable means.

According to a study by the Fraunhofer Institute, renewables alone (wind, PV and Concentrated Solar Power – CSP) could meet the whole electricity demand of North African countries[1]. In the long run, as a by-product of a successful widespread implementation of a RES strategy, North Africa could eventually become a net exporter of electricity to Europe given its geographical proximity. It also represents a perfect fit for Europe's ambitions to get more green energy and thus less carbon emissions. The study suggests that imports of green energy could help Europe achieving its aggressive emission targets.

Successful RES implementation in North Africa may represent an opportunity to export green energy to Europe

EU's electricity generation and CO_2 emissions from power generation



Source: IEA (2016): World Energy Outlook 2016. New Policy Scenario, International Energy Agency, Paris.
RES: Generation from bioenergy, wind, geothermal, solar PV, CSP, marine and hydro power plants

Chart 4: European electricity generation and related CO2 emissions

Solar as the most promising bet

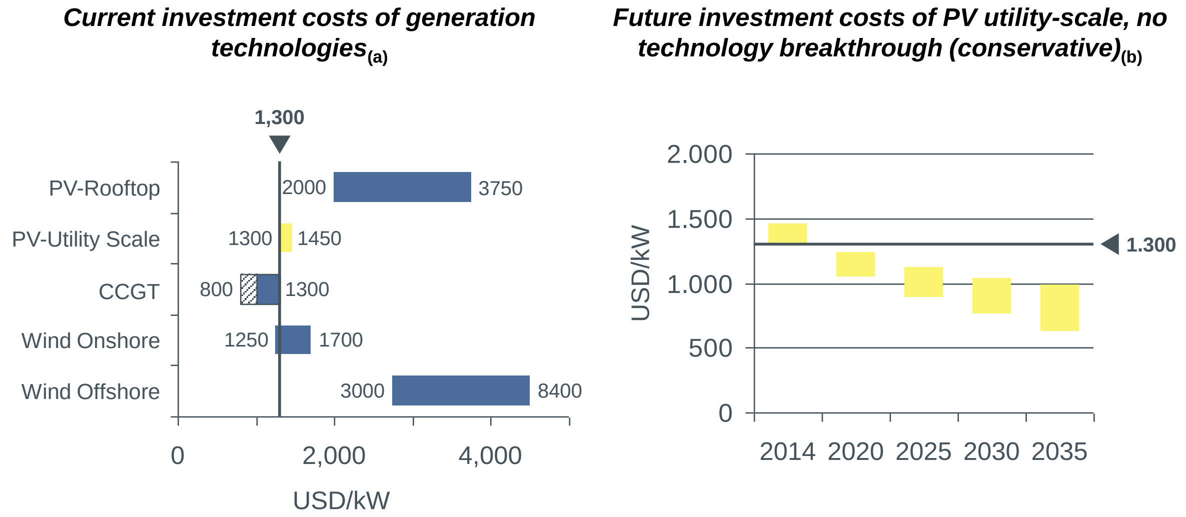
Thus far the greatest challenge for an increase in the penetration of RES in the supply mix is economics: RES is not yet competitive at a large scale and deployment is still heavily dependent on costly subsidies which create in turn an array of other complications not only for countries' budgets but also for the balancing of electricity markets where merit order is the rule, or still risks for investors for when subsidies fade out of the system.

Solar technology has been supported by public policies over the last decade, enabling quick deployment around the world. This support contributed significantly to the growth of PV markets, setting the right conditions for benefits of economies of scale. With growing markets, opportunities to improve the efficiency of supply chains have led to cost reductions, which are expected to continue into the future with the increasing market scales.

[1] Fraunhofer ISE (2016): Supergrid study. Approach for the integration of renewable energy in Europe and North Africa. Fraunhofer Institute for Solar and Energy Systems ISE, Freiburg.

As the market for PV grows and technologies keep on evolving things are indeed changing. In PV power for example, some projects are already competitive vis-à-vis fossil fuels on a specific capital cost basis, meaning more efficiency on a $/kW of installed capacity.

As technologies keep on evolving, RES are getting competitive against fossil fuel generation



Source: (a) LAZARD (2016): LAZARD's Levelized Cost of Energy Analysis. Version; (b) Fraunhofer ISE (2015): Current and Future Cost of Photovoltaics. Long-term Scenarios for Market Development, System Prices and LCOE of Utility-Scale PV Systems, Fraunhofer Institute for Solar Energy Systems ISE, study on behalf of Agora Energiewende; Graph (a) for utility scale units 100-600 MW

Chart 5: Current investment cost of current generation technologies and expected evolution of investment cost of utility-scale PV

In this capital efficiency game, North African countries enjoy a great comparative advantage, as the sun shines more: direct solar irradiation levels are on average two times higher than in northern Europe.

Some fundamentals still have to keep evolving

However for a real revolution in the supply of affordable solar power in North Africa to take shape, some things must happen.

a. Solar economics has to continue on the downward trend

Already competitive in some cases, solar technology needs to improve further. Continued technology evolution is key to improving the economics of photovoltaic (PV) solar electricity generation. Today's PV panel technologies, i.e., crystalline silicon and thin film, have efficiency levels in the range of 15% to 20%. New technologies such as multi-junction cells are expected to improve efficiency levels to 30% to 40%. Beyond the conversion panels other PV systems parts such as the balance of system, non-module and inverter hardware, installation costs, and soft costs will continue to fall further as the convergence towards best practice cost structures accelerates under increasing competitive pressures[2] .

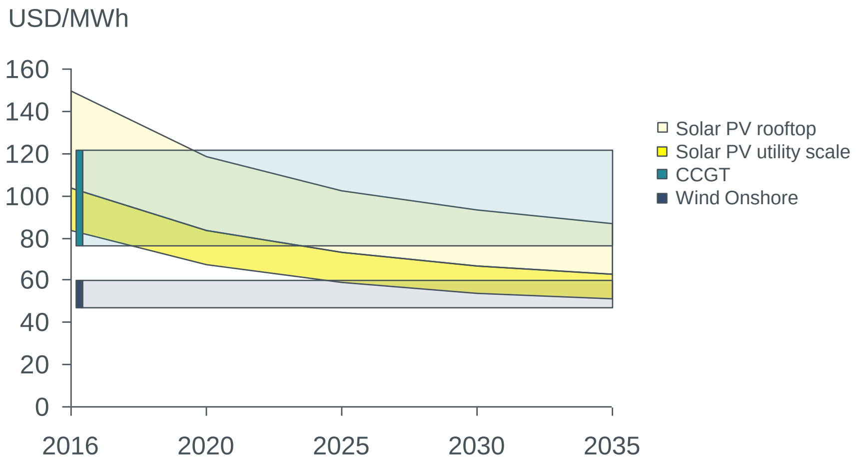
[2] IRENA (2016): The Power to Change: Solar and Wind Cost Reduction Potential to 2025. International Renewable Energy Agency

This continuous reduction of PV systems costs, thus of the $/kW of installed capacity, will eventually make it competitive against the most efficient fossil fuel generated kWh or, in other words, will reach “grid parity” independently from subsidies. Some analysts reckon that solar may become the single most competitive source of energy within the next 5 years.

For the Egypt market, Fraunhofer ISE expects costs for utility scale PV dropping below generation from Combined Cycle Gas Turbine (CCGT) plants already before 2020[3].

Efficiency improvements will make Solar PV competitive against efficient fossil power generation

Example of LCOE for Solar PV compared with LCOE of CCGT and wind in Egypt



Source: Fraunhofer ISE (2016): Electricity Cost from Renewable Energy Technologies in Egypt. Fraunhofer Institute for Solar Energy Systems ISE, Freiburg. Illustrated values 2016 for CCGT and Wind onshore

Chart 6: Electricity investment cost by RES technology

Finally, it is important to note that, with increasing RES integration in the power systems, conventional fossil fuel-fired power plants are less requested to cover demand, while their fixed costs remain the same. The LCOE (Levelized Cost of Energy) of conventional plants increases thus with higher RES integration, which improves the case of RES generation. At a certain level of RES integration, subsidized RES is profitable whereas conventional power plants are not anymore, with a risk of closure for economic reasons. Conventional power plants are however still required in the system as backup for volatile RES generation. Eventually, they will need specific support mechanisms (i.e. CRM, Capacity Remuneration Mechanisms) to remain economically viable.

In these circumstances, the policy and regulatory frameworks need to be developed in a balanced way, between RES and conventional generation, preventing any double subsidizing and securing the best affordable energy for the consumer.

b. Prepare the grid first so supply local demand with new RES sources then to trade abroad

Experience says that the grid will have to evolve to be able to supply the domestic market which has not been planned for the massive new capacity that shall come on stream. The

[3] Fraunhofer ISE (2016): Electricity Cost from Renewable Energy Technologies in Egypt. Fraunhofer Institute for Solar Energy Systems ISE, Freiburg; Illustrated values 2016 for CCGT and Wind onshore

Fraunhofer Institute[4] reckons that North Africa will need to add about 63.000 km of AC lines alone by 2050, on top of the existing 24.000 km lines, to be able to cope with the growth in local demand.

Connecting RES to well-chosen locations could help in some cases decrease the requirements in transmission grid capacity. But in general, RES integration requires more transmission grid to transport energy from remote areas to consumption centers. The grid architecture should be developed, offering bigger capacities, to enable both increasing domestic demand and RES generation. AC technology will remain the main choice to develop the grid further, while HVDC technology may offer opportunities for long-distance, underground or subsea transmission.

Smart solutions like dynamic line rating, FACTs devices, high temperature low sag conductors etc. leverage system flexibility and can help defer or avoid building new transmission corridors.

At distribution level, decentralized RES generation, where it exceeds demand, will create reverse power flows to upstream voltage levels. These flows are often coupled with voltage rises. Integrating distributed RES generation leads to a review of the distribution grid architecture[5].

Before developing transmission and distribution grids with capital-intensive projects, the system operations must evolve to maximize the use of the existing infrastructure.

When active network management is implemented, controllable distributed RES generation can help relieve congestion in the grid, potentially deferring or cancelling costly grid reinforcements. Distributed generation should also support voltage control, by the provision of on-demand reactive power and active power curtailment when needed. Developing more accurate RES generation forecasts contributes as well to use the infrastructure more closely to its limit. In these applications, the observability and controllability of distributed RES generation, e.g. via a RES control center, is key to operating the power system in a secure and economical way.

High RES integration leads to less conventional power plants operating in the system, whereas these guarantee today the stability of the system. Both bulk and distributed RES generation can play a role in system stability if an appropriate technical regulation (i.e. grid codes) is developed and applied when RES generators are connected.

At a later stage, once the local grid has been optimized and developed to cope with demand increase and RES generation, the grid architecture can be extended to enable cross-border interconnections. On the one hand, once the local country has been served, the RES surplus can be traded abroad and create value for the local economy. On the other hand, these cross-border links enable import energy to cover demand in case of emergency.

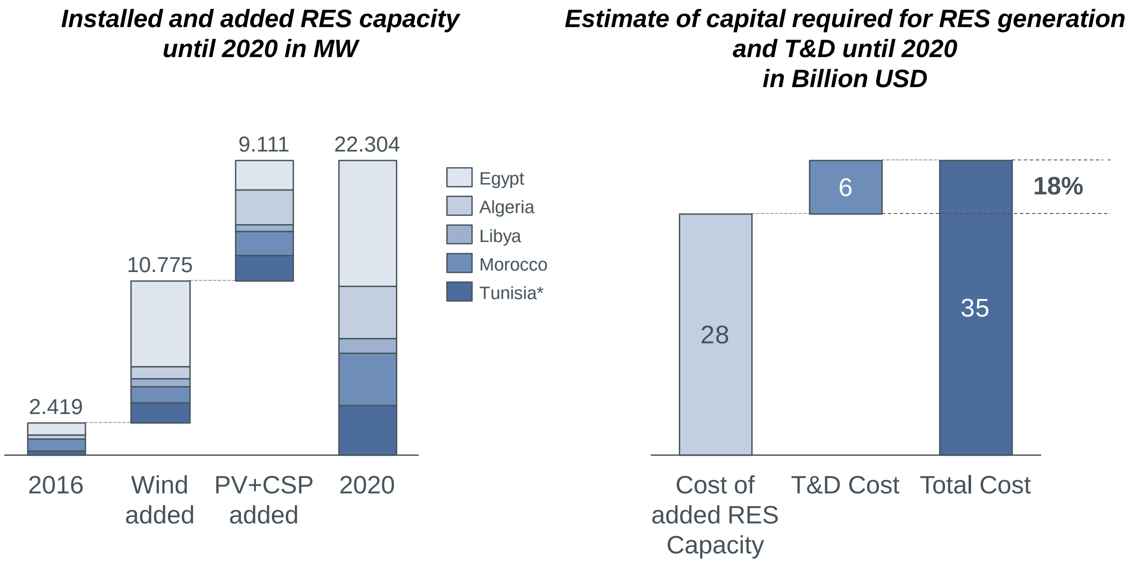
The most promising strategy consists of interconnecting North Africa to Europe with subsea HVDC links, enabling RES surplus to be traded beneficially, and helping Europe reach its RES targets.

[4] Fraunhofer ISE (2016): Supergrid study. Approach for the integration of renewable energy in Europe and North Africa. Fraunhofer Institute for Solar and Energy Systems ISE, Freiburg; Scenario 1
[5] Appen, Jan von et al. (2013): Time in the sun – The challenge of high PV penetration in the German Electrical Grid. IEEE power and energy magazine.

c. Electricity sector framework needs to adjust to attract capital required

Another challenge to overcome by North African countries will be the funding of the massive capital investments required to build up the needed infrastructure, both in generation and transmission and distribution (T&D). For the 2020 objectives targeted in North Africa, EGI estimates that an investment program of US$ 35 billion by 2020 in generation, transmission and distribution will be required to integrate RES.

North Africa's RES agenda will require attracting substantial capital investments



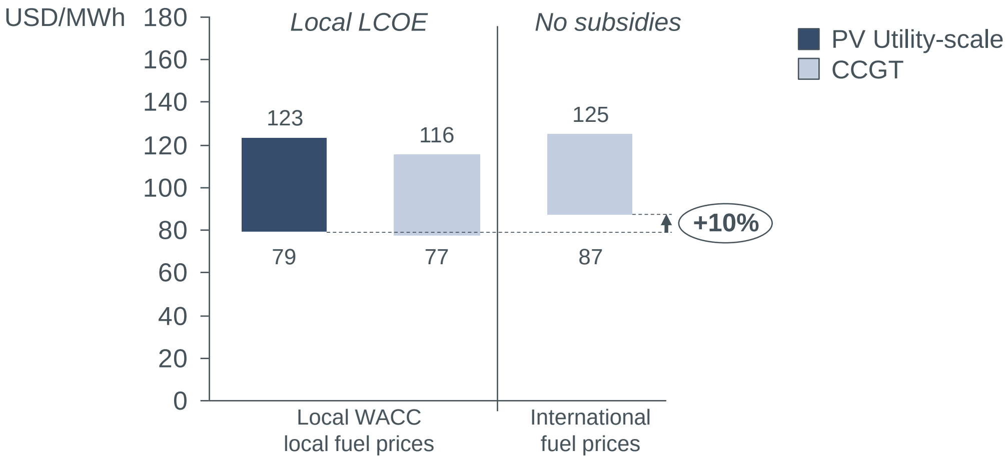
Source: EGI Analysis, Agora Energiewende (2015): The Integration Cost of Wind and Solar Power. An Overview of the Debate on the Effects of Adding Wind and Solar Photovoltaic into Power Systems, Berlin and EGI Analysis; *Grid cost and cost to offset differences between forecasts and actual production

Chart 7: North Africa's capital requirements to integrate RES (generation capacity and T&D)

One alternative is to promote an electricity sector reform and implement a comprehensive framework conducive of investments. Some countries are already experimenting with mechanisms such as opening generation through Independent Power Producers (IPP) and power purchase agreements (PPA) and feed-in tariff schemes. There are problems however: in Egypt for example only 400 MW of solar capacity got awarded in 2016 compared with 2.6 GW target for 2017. An explanation to that may lie on the subsidies for fossil fuels which in turn limits the competitiveness of renewables.

Lower fuel subsidies make Solar PV competitive against fossil fuel generation

LCOE comparison utility-scale PV and CCGT with and without fuel subsidies in Egypt



Source: Fraunhofer ISE (2016): Electricity Cost from Renewable Energy Technologies in Egypt. Fraunhofer Institute for Solar Energy Systems ISE, Freiburg. CCGT fuel prices: 10-27 USD/MWh (Egypt 2016) and IFP of 24 USD/MWh

Chart 8: LCOE comparison of utility-scale PV and CCGT, with and without subsidies

Roadmap of possible adjustment for the sector framework

The electricity sector must evolve in order to fully benefit RES integration at an affordable cost. The transformation must touch several fields of action and a complementary approach is required to make it happen successfully.

The electricity landscape restructuring and pursuing energy-related strategic targets will be largely driven by a sector framework. Typically, such a framework would aim to put in place an economically rational design in an effort to promote the uptake of renewable energy while achieving a number of other objectives, including energy independence, diversification, competitiveness, security of supply as well as the development of a local industry and job creation.

EGI identifies three main components for paving the way toward making systemic design decisions capturing exhaustively the components of the electricity system and shaping long-term targets.

The electricity sector must evolve to fully benefit of the RES integration at an affordable cost

Framework encompassing electricity system paradigm

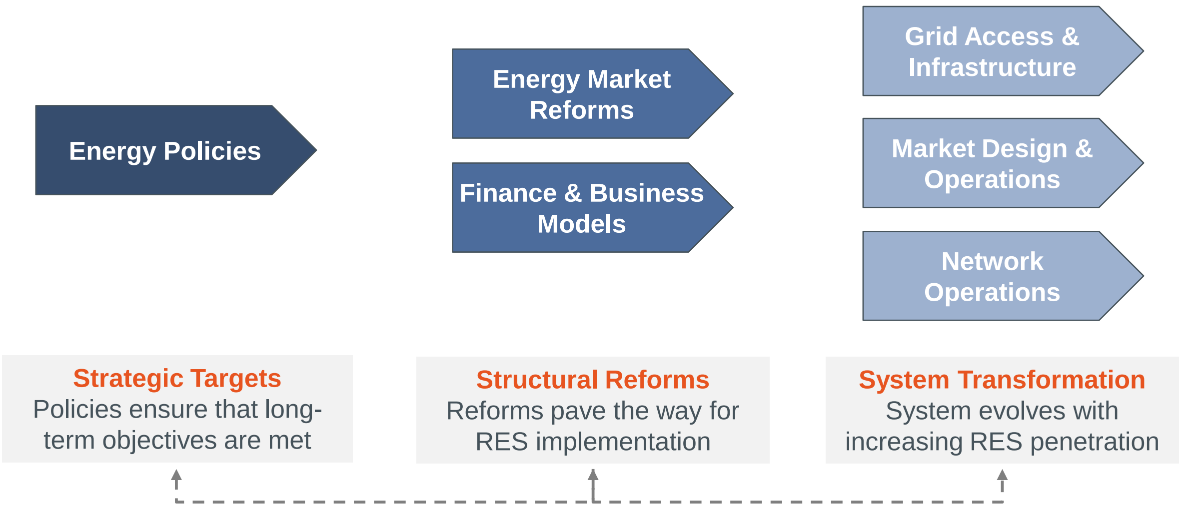


Chart 9: Framework for Electricity System Paradigm

STRATEGIC TARGETS – POLICIES TO ENSURE THAT LONG-TERM OBJECTIVES ARE MET

- Defining a clear vision with (binding) RES penetration targets.
- Tailored renewable energy support policies (feed-in tariffs, auctions, premiums, tax rebates etc.). The support regimes should be reviewed periodically to be kept cost-efficient and cost-reflective.
- As a prerequisite, the policies should be designed with a view on the development of the local economy (business opportunities for new generation, cheaper energy etc.). Once the local economy has fully benefited from RES integration, a clear vision on the development of cross-border interconnectors can be set up in order to trade energy abroad.
- In addition to bulk RES generation, fostering distributed generation sources (including RES, CHP) penetration to leverage distributed investment in generation, network efficiency, reliability and sustainability.
- Reduction and eventual elimination of subsidies for fossil fuels.
- Selection of best locations for bulk RES generation, in terms of wind/sun conditions, spatial planning and existing grid capacity. Definition of incentives (e.g. locational tariffs) to orientate RES generation in these locations.
- Streamlined permitting, authorizations and granting procedures to facilitate the development of investment opportunities.

STRUCTURAL REFORMS – REFORMS PAVE THE WAY FOR RES IMPLEMENTATION

Market reforms

- Opening the generation market for IPPs with regulated power purchase agreements (PPAs), the incumbent utility acting as a single buyer. In a second step, contracts should eventually be transferred to generators and consumers to allow multilateral trade.
- Open access to the market (for bulk RES, aggregators, distributed generation sources) to foster retail competition and improve consumer engagement.
- Implement unbundling of generation, transmission, distribution and retail activities.

- Develop a Wholesale Power Market (WPM) and allow customers to direct contract energy from generators.
- Gradually migrate long terms fixed contracts to flexible contracts negotiated via the WPM directly between generators and power consumers.
- Creation of independent regulatory authorities to ensure fair competition in the electricity sector and to protect the consumers.

Finance and Business models

- Reduction of the perceived renewable energy investment risk and leveraging financing costs.
- Funds for early-stage development.
- Green bonds issued by commercial banks, industrials or utilities.
- Institutional investment to address long term capital and liquidity constraints.
- Leasing models to increase affordability and securing capitals.
- Energy services companies as investors in households.

SYSTEM TRANSFORMATION – SYSTEM EVOLVES WITH INCREASING RES PENETRATION

Grid Access and infrastructure

- Open, guaranteed and priority access to the grid for all generators and self-generating consumers.
- Supportive grid connection regimes (e.g. shallow or deep charging) and supportive rules for connection cost recovery.
- Delivery of the necessary transmission and distribution infrastructure to integrate RES in a secure and cost-effective way.
- Network Codes to enable state of the art technological capabilities and leverage higher RES penetration

MARKET DESIGN AND FLEXIBILITY

Market design

- Smart and sustainable market design to adequately remunerate needed investment and setting of an economically rational standard for reliability (flaws of missing money and CRM claims) by enabling system flexibility through demand side management, storage and cross-border capacity exchanges.
- RES sources to fully participate in the adequately designed WPM crosslinked to other energy sectors (transport, desalination, heating…).
- Integrate storage, (aggregated) distributed generation sources and demand side management as a market and operations facilitator with a high RES integration.

Flexibility markets

- Market price signal as the key to incentivizing the required flexibility and investments in power markets.
- Enhanced DSO-TSO collaboration to best manage distributed RES generation.
- Close-to-real time operation to cover forecasting deviation and mitigate unbalances.
- Demand-side management to best synchronize demand and RES generation.
- Relieving barriers preventing small actors in distributed RES generation (e.g. residential and commercial) from accessing the market by the development of prosumers and aggregator, adapted minimum-bid size and increments for smaller distributed generation, etc.

Networks operations

- Enhanced methods for RES generation forecasts.

- RES to develop advanced controllability and observability means with the aim to support system stability and increase system resilience.
- RES to be operated via dedicated Renewable Control Centers acting as a coordinator between RES productions and the relevant system operators (DSOs, TSO).
- Full steering of conventional plants and RES in emergency and reconstruction scenarios
- Dynamic security assessment as the system is operated more closer to its limits with potential low inertia, low short circuit levels and voltage stability challenges.
- Cost-efficient network reliability under operational incertitude and volatility of production.

EGI fashions and contributes to the implementation of tailor-made roadmaps which best fit its clients' needs to integrate RES in a consistent, reliable, sustainable and value-creating way.

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