MOREMix - Power sector optimization for Morocco

Jürgen Kern, Tobias Fichter, Massimo Moser, Franz Trieb, Frank Seidel, Klas Heising, and Philippe Lempp

Citation: AIP Conference Proceedings **1734**, 080004 (2016); doi: 10.1063/1.4949184
View online: http://dx.doi.org/10.1063/1.4949184
View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/1734?ver=pdfcov
Published by the AIP Publishing

MOREMix - Power Sector Optimization for Morocco

Jürgen Kern[1], Tobias Fichter[1], Massimo Moser[2], Franz Trieb[3]
Frank Seidel[4], Klas Heising[4], Philippe Lempp[5]

[1] *Dipl.-Ing., German Aerospace Center (DLR), Institute of Engineering Thermodynamics, Wankelstraße 5, 70563 Stuttgart, Germany, Tel. +49 711 6862-8119; Fax +49 711 6862-8100; E-mail: juergen.kern@dlr.de*
[2] *Dr.-Ing.,* [3] *Dr.rer.nat., DLR, Institute of Engineering Thermodynamics, Stuttgart, Germany*
[4] *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 65726 Eschborn, Germany*
[5] *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 10000 Rabat, Morocco*

Abstract. DLR developed the optimization model REMix-CEM (Renewable Energy Mix - Capacity Expansion Model). REMix CEM to generate a cost-effective expansion planning of thermal and renewable assets with respect to a use optimization (dispatch) of various types of power plants for the energy system. Working closely with the Moroccan Ministry of Energy energy scenarios are created to support Morocco in the medium to long-term energy planning to develop cost-effective, and technically feasible expansion plans for renewable energy and better coordinate the interaction between different forms of electricity generation.

INTRODUCTION

Over the last 20 years, Morocco has undergone a large-scale electrification program, raising the share of the population with access to electricity from 22% in 1996 to 99% in 2014. According to the government's Prospective Study of Energy Demand Towards 2030, electricity demand in the country rose annually in the range of 6.7% and 7.3% from 2000 to 2012 and is expected to rise within the range of 5.4% and 9.2% by 2020. The constant rise in demand and the scarcity of domestically available fossil resources have increased the country's dependence on energy imports. [1]

In order to reduce the economic impact of fossil fuel imports and ensure energy supply, the National Energy Strategy was launched in 2009 with 5 main pillars: (i) optimization of the energy mix, (ii) accelerating the development of renewable energy, (iii) setting energy efficiency as a national priority, (iv) promoting foreign investment in oil and gas development and (v) fostering greater regional integration. With regard to power supply, the National Strategy targets an overall increase of the domestic supply by adding 2 GW of coal-fired generation capacity and further capacity of 6 GW from renewable generation, with 2 GW from wind, solar and hydroelectric power respectively by 2020. In order to reach its goal of a 42% share of renewable energy generation capacity, Morocco will make use of its diversified geography and abundantly available renewable energy resources. However, due to an increased energy demand the domestic power sector is at stress which requires forthcoming energy planning activities to be based upon fundamental and evidence-based research and analysis. In addition to this, water availability for hydroelectric power generation and for cooling purposes constitutes a further fundamental issue.

Given the issues mentioned above, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) has offered to support the Kingdom of Morocco in achieving its renewable energy targets. Therefore, the relevant Moroccan ministries and utilities shall be supported by applying energy planning models - developed by the German Aerospace Center (DLR) - that are suitable to the country's specific situation. Furthermore, the proposed energy planning shall incorporate water-energy nexus related issues given the increasing water scarcity in the country. Hence, the proposed modelling activity is envisaged to offer (i) an in-depth analysis of the Moroccan electricity system and the development of an adequate and cost-efficient capacity expansion plan, and (ii) insights on the optimal water resource management with regard to the power sector.

SolarPACES 2015
AIP Conf. Proc. 1734, 080004-1–080004-6; doi: 10.1063/1.4949184
Published by AIP Publishing. 978-0-7354-1386-3/$30.00

IMPACT OF VARIABLE RENEWABLE ENERGIES

Integration of variable renewable energies (VRE, wind power and photovoltaics) has a significant impact on the performance of conventional thermal power plants (e.g. number of start-ups, part-load operation, etc.) and the need for different kind of adequacy and system operation reserve capacities in the electric system which should be considered already within capacity expansion planning. Typically, capacity expansion models using load duration curves (LDC) for capacity expansion of hydro-thermal dominated power systems. This approach has the advantage of low computational effort and was highly suitable in times where VRE technologies have been no economical feasible investment options or no climate mitigation strategies were of interest. Using s LDCs for capacity expansion planning leads to the loss of load chronology and information about the availability of renewable energy resources over time whereby the impact of VRE on the power system cannot be considered within capacity expansion planning. Utilizing LDCs for capacity expansion optimization has two major drawbacks:

Firstly, a simultaneous capacity expansion of conventional generators and power generation technologies based on intermittent primary energy resources is not possible since no information exists if power generation from VRE matches with chronological load. Therefore, within capacity expansion models based on LDCs the expansion of VRE is set model exogenously and the model is used to optimize expansion of the residual hydro-thermal system. Secondly, inter-temporal technical constraints of thermal generators (including Concentrating Solar Power (CSP)), i.e. minimum on/-offline times, minimum generation level, start-up times and costs, part-load efficiency or maximum ramp rates, cannot be considered directly within capacity expansion optimization even so the importance of these constraints increases with deployment of VRE. Such constraints of thermal generators and the impact of VRE on the power system are typically addressed within short term unit commitment or economic dispatch optimization models. However, neglecting these issues within long term expansion planning can lead to an unreliable system design and suboptimal least-cost expansion plans [2]. This is especially the case for power systems of the Sunbelt countries with strongly growing electricity demand, which have, compared to most developed OECD energy sectors (compared to the gross national product), a significant higher investment demand in new generator and transmission capacities [3]. Accordingly, from a system perspective, real costs of integrating VRE in the power system may be underestimated if capacity panning of conventional and renewable power generation technologies is based on optimization models which apply LDCs.[1]

CAPACITY EXPANSION MODELS FOR THE INTEGRATION OF RENEWABLE ENERGY WITH REMix-CEM

To overcome the limitations of conventional capacity expansion models based on LDCs, the Department of Systems Analysis and Technology Assessment of the Institute of Engineering Thermodynamics has developed the REMix-Capacity Expansion Model [4]. The capacity expansion model is based on energy system modelling platform REMix which is developed by DLR since 2007 [5]. REMix-CEM, which stands for Renewable Energy Mix – Capacity Expansion Model, was developed to support energy planning authorities especially of the sunbelt countries in the process of integrating renewable energy technologies efficiently in the short-term and transforming their strongly growing fossil fuels dominated power systems of today towards higher shares of renewable energies.

REMix-CEM is a power sector specific, deterministic mixed integer linear programming (MILP) optimization model. The bottom-up model optimizes capacity expansion of conventional and renewable energy technologies on a single unit level for a given power system by minimizing the net present value of total systems costs over the entire planning horizon from a central planning perspective. Contrary to traditional expansion models, capacity expansion optimization within REMix-CEM is based on chronological load time-series with high temporal resolution (typically hourly) in order to take into account the impact of VRE on the power system directly within capacity expansion optimization. Due modelling with high temporal resolution, inter-temporal constraints of thermal generators and system operating reserve requirements which are typically addressed within short term unit commitment optimization models can be considered directly in the long term expansion planning process (see Fig 1).

Capacity expansion optimization with perfect foresight allows path-optimization over the entire planning horizon to find optimal short- and long-term investment strategies under defined boundary conditions (scenarios). The model

[1] Nevertheless, it needs to be mentioned that there are, besides the system perspective, several other factors that need to be considered while assessing the real value of vRE in a power system, such as: foreign exchange rate, financing conditions, yield predictions, load and generation profiles, electricity market design.

can be used to test innovative, explorative, or normative scenarios, in order to investigate the impact of innovative technologies in future power plant portfolios (i.e. the role of CSP or utility-scale PV), to identify optimal strategies to achieve targets (i.e. GHG reduction), or to analyze the consequence of policy targets (i.e. quotas for RE) respectively. Formulated as multi-node model, REMix-CEM provides not only optimal investment strategies for new generator capacity but can also give first indications for required transmission grid reinforcements and expansion associated with the respective generator capacity expansion.

Since REMix-CEM was developed especially for energy planning authorities of the sunbelt countries, special focus is set on the detailed representation of Concentrating Solar Power (CSP) within the power system. Technical and economic performance of dry- and wet-cooled CSP power plants are modeled in detail within capacity expansion optimization and plant configurations (size of solar field, thermal energy storage and back-up boiler system) of the candidate CSP units can be optimized model endogenously [6] [7]. With information derived from the model, energy authorities, such as ministries or regulators, gain the opportunity to correctly assess their sector and hence design their regulations accordingly.

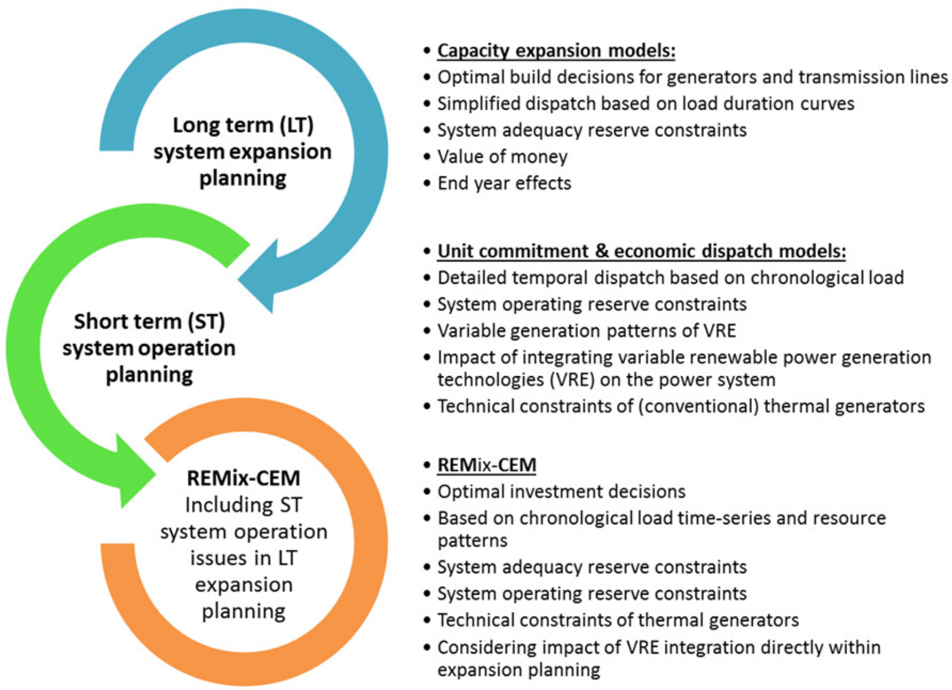

FIGURE 1: REMix-CEM – including short term system operation issues in long term expansion planning

THE MOREMix PROJECT

The objectives of this project are to provide the Moroccan Ministry of Energy, Mines, Water and Environment (MEMEE) and other involved actors, such as the national utility Office National de Electricité et de l'Eau Potable (ONEE), with an in-depth analysis of the local energy system, in view of enabling and equipping them to develop adequate long-term energy roadmaps based upon an evidence-based energy model, such as REMix-CEM, to provide fundamental research on cost-efficient and appropriate capacity expansion planning for the Kingdom of Morocco until 2050, and to shed light on aspects of optimal water resource management with regard to the water use of the power.

A multi-node expansion model based on the existing transmission grid infrastructure is developed taking into account electricity demand and primary resource patterns of reneweable energy technologies of different regions of Morocco (see Fig. 2 and Fig. 3). Taking into account the existing generator fleet and transmission grid, least-cost and reliable expansion plans to satisfy the strongly increasing electricity demand of the Kingdom until 2050 will be optimized for different sets of scenario assumptions. Besides the least-cost expansion plans, model results will provide information of the role of each generation technology, the utilization over time, short term generation costs, unit commitment and dispatch patterns.

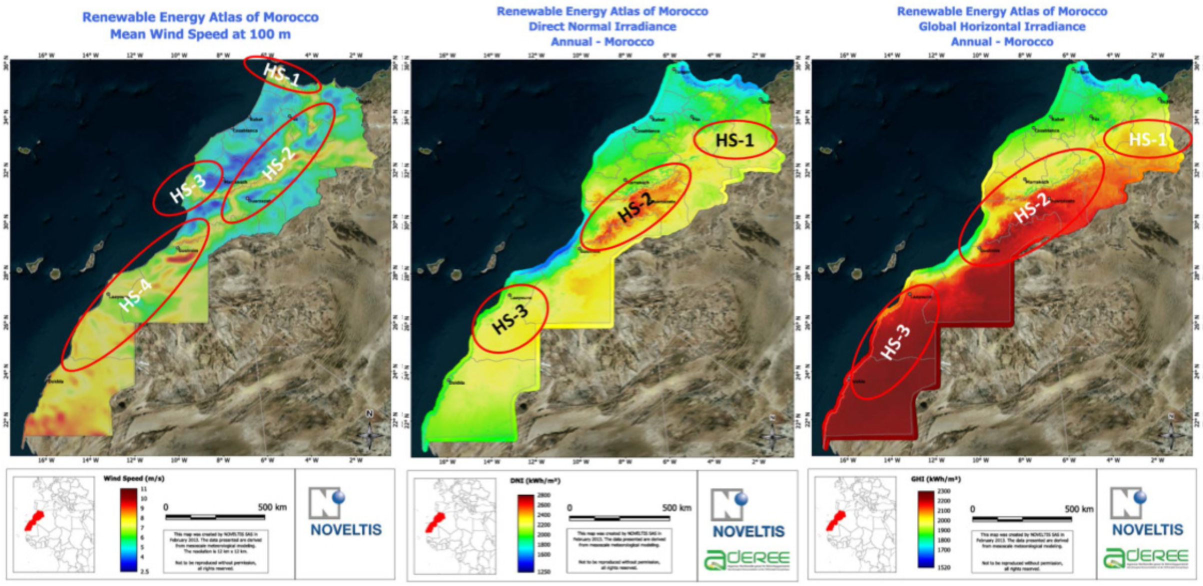

FIGURE 2: Utility-scale solar and wind power resources. [8]

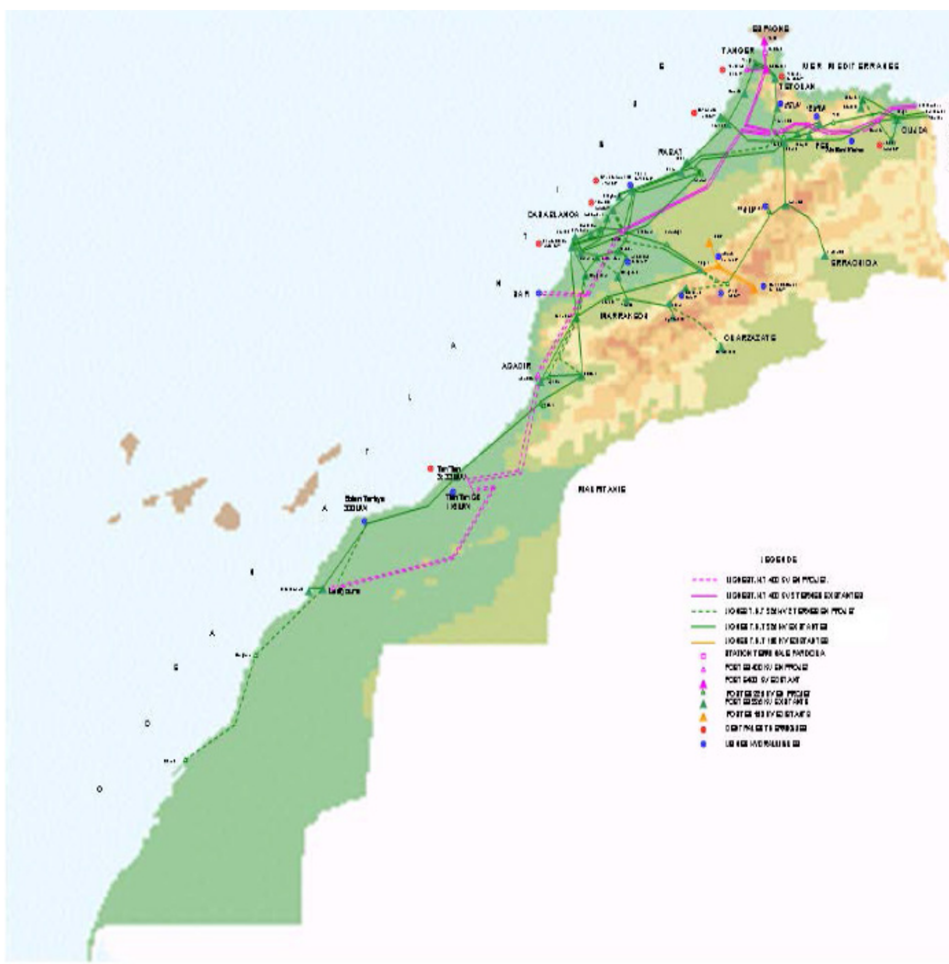

FIGURE 3: Power transmission system of Morocco. [9]

A comprehensive set of scenarios and sensitivities (Tab. 1) was defined and is now to be calculated with specific high performance computers of the DLR's department of systems analysis and technology assessment to provide energy planning authorities of Morocco with a broad view of possible expansion strategies under a large variety of different boundary condition and the impact on certain parameters on the least-cost solution.

TABLE 1: Exemplary scenarios and sensitivity analysis for specific strategies.

Free Development Strategies — Business as Usual with sensitivities

- **Change in Fossil Fuel Prices for Oil, NG, LNG and Coal**
- **CO2 prices**
- **Financial Boundary Condiationy (Equity/Dept Shares and Conditions)**
- **and others**

Forced Development Strategies — Business as Usual with forced implementations strategies

- **Forced Gas Entry (of LNG)**
- **Forced Distribted PV**
- **and others**

Climate Policy — Specific Climate Policy with sensitivities

- **Fluctuating Renewables (PV and Wind) versus Capacity Solar Power (CSP)**
- **Advanced Battery Storage with ambitious reduction of Li-Ion Battery Storage Prices**
- **Reduced demand due to energy efficiciency gains**
- **Modification of the natioanal and regional load curces due to production and comsumptions changes**
- **Evalation of specific storage technologies (Pumped Storage, Batteries)**
- **National Energy Independency**

CONCLUSIONS

The MOREMix project is still under progress. Results will be provided to the Moroccan partners end of 2015.

The optimization of the integration of renewable energy technologies into an existing power plant portfolio requires a detailed modeling of all the characteristics of the different generation technologies. Due to their specific properties all types and sizes of renewable energies can play key roles for Morocco in the sustainable transformation of existing energy systems and in achieving sustainable energy security.

Combined capacity expansion of conventional and renewable power generation technologies requires high temporal resolution in order to investigate if RE generation matches with temporal load. Therefore REMix-CEM using hourly load data instead of Load Duration Curves (LDC) can give more realistic answers to the challenges of the utilities and guide ministries and decision makers in defining feasible pathways for RE and conventional expansion. VRE integration may force more frequent cycling of dispatchable generation technologies with more challenging operation and higher costs. Also REMix-CEM can apply short-term operation constraints (from the so-called unit commitment problem) for thermal generators directly in (long-term) capacity expansion optimization.

Capacity expansion based on high temporal and spatial resolution by REMix-CEM will provide MEMEE and ONEE with informations about least-cost strategies to meet the increasing power demand in the future, to reduce dependency from fossil fuel imports, to reach climate targets and to ensure a reliable and sustainable system design over time. Special focus is led to the interaction between the conventional hydro-thermal system and renewable energies including CSP, utility scale PV and wind power for a concerted and reliable expansion of conventional and renewable energies technologies. The project will help to set up targets and road-maps of renewable energy penetration in the power sector beyond 2020 for which the energy system planning authorities have defined already ambitious plans.

REFERENCES

[1] L'Office National de Electricité et de l'Eau Potable (ONEE) (2013): Prospective de la demande energetique a l'horizon 2030
[2] K. Heising, F. Seidel (2014). Towards Adequate National Renewable Energy, Planning for dynamic energy sectors BMWi POLICY: vRE Discussion Series – Paper # 01 https://energypedia.info/images/7/71/Discussion_Series_01_Policy_web.pdf
[3] B. Palmintier, and W. Webster (2012). Impact of Unit Commitment Constraints on Generation Expansion Planning with Renewables, IEEE 2012.
[4] T. Fichter (2015). The REMix-Capacity Expansion Model - Integrating short term operations issues into long term expansion planning, PhD-Thesis University of Stuttgart, ongoing.
[5] Y. Scholz (2012). Renewable energy based electricity supply at low costs - Development of the REMix model and application for Europe, PhD-Thesis University of Stuttgart
[6] T. Fichter, F Trieb, M. Moser, J. Kern (2013). Optimized Integration of Renewable Energies into Existing Power Plant Portfolios, SolarPACES2013
[7] T. Fichter , F. Trieb, M. Moser (2014). Optimized Integration of Renewable Energy Technologies into Jordan's Power Plant Portfolio, Heat Transfer Engineering, 35:3, 281-301, DOI:10.1080/01457632.2013.825183
[8] Agence Nationale pour le Développement des Energies Renouvelables et de l'Efficacité Energétique (ADEREE) : Renewable Energy Atlas of Morocco
[9] L'Office National de Electricité et de l'Eau Potable (ONEE): Electricity Grid of Morocco