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# Multi-criteria analysis of electricity generation mix scenarios in Tunisia

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ABSTRACT

The diversification of the national electricity generation mix has risen to the top of Tunisia's energy planning agenda. Presently, natural gas provides 96% of the primary energy for electric power generation, but declining domestic gas reserves and a soaring electricity demand are urgently calling for alternative fuel strategies. Currently discussed diversification options include the introduction of coal and nuclear power plants and/or an increased use of renewable energies. This article presents a methodology to assess different electricity system transformation strategies. By combining an electricity market model with a subsequent multi-criteria decision analysis (MCDA), we evaluate five power mix scenarios regarding power generation costs as well as non-economic dimensions such as energy security, environmental impact and social welfare effects. Based on criteria valuations obtained during consultations with Tunisian stakeholders, a final, best-ranking electricity scenario was selected, consisting of 15% wind, 15% solar and 70% natural gas-generated electricity in the national power mix by 2030.



**Contents**



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## 1. Introduction

The Tunisian electricity sector is faced with a multitude of challenges, pressing for decisions about a new national power supply strategy. As for many other North African countries, one particular concern is the ever-growing electricity demand, which, despite successful efforts to reduce energy intensity in the past,[1] is still on a constant surge in Tunisia. Between 1990 and 2010, domestic power consumption almost tripled, from 4.9 TWh to 14 TWh; for the next two decades, the demand is expected to further grow, reaching 25–33 TWh by 2030 [1]. The challenge to cope with this soaring demand is joined by another issue: Tunisia's unbalanced primary energy supply of power generation. Currently, the national electricity system is almost entirely fueled by natural gas, making up around 96% of the generation mix. This dependency will become particularly problematic in light of an imminent natural gas deficit that is forecasted for 2018 or 2020 [2], putting Tunisia's electricity supply security at risk. So far, the following options to render the Tunisian electricity mix more diverse have been proposed:

(1) *Coal Power*. The use of imported hard-coal for power generation is already extensively practiced in another North African country, Morocco, and decision makers frequently discuss whether Tunisia should likewise adopt this model. A study by the national electricity and gas utility STEG [1] evaluated the option to install up to three coal-fired steam power plants in the country, each with a capacity of 600 MW.
(2) *Nuclear Power*. This option is also discussed in Tunisia, since in 2006, the former government signed a bilateral agreement with France on the civilian use of nuclear power [3]. Under exploration is the installation of one pressurized water reactor with a tentative capacity of 900–1000 MW, slated to become operational by 2027 [1].
(3) *Renewable Energies*. Tunisia is endowed with excellent renewable resources. The country's wind potential is valued at 8 GW, with three main regions being particularly suitable for large wind farm projects: the North-East, the Central-West and the South-West of Tunisia [4]. Solar radiation conditions are the best in Southern Tunisia, but generally very favorable across the entire territory. Gross estimations for Tunisia's solar potential reach 844 GW for PV and 65 GW for CSP technology [4] although these values must be assessed with care, as they usually do not include considerations about the actual availability of the land for solar power projects. The "Tunisian Solar Plan", a renewable energy roadmap drafted by the Tunisian energy conservation agency ANME, acknowledges the high renewable potential and points particularly to wind, photovoltaic and concentrated solar power (CSP) as diversification options to replace natural gas in the electricity mix [5].

The extent to which these three diversification options – or a combination of them – can become part of a Tunisian electricity strategy is a matter of ongoing deliberations. The political context in which these discussions are taking place is marked by the Tunisian revolution of January 2011, which brought a new way of political decision making to the country along with considerable consequences for the culture of energy system planning. In the past, Tunisia's electricity strategies were discussed in closed circles accessed only by a small group of public decision makers, many of them with strong links to the national gas and electricity sector. The decision process itself was biased by the view of the incumbent national gas and electricity utility STEG, whose maxim for power system optimization was a least-cost planning approach, mostly disregarding social and environmental aspects. Nowadays, after the upheavals in early 2011, the interests of the civil society and other stakeholder groups can no longer be ignored. One aspect frequently raised in the discussions about power system choices are socio-economic benefits, most prominently the aspect of domestic added value, local manufacturing opportunities for the Tunisian industry, and its potential effects on job and income creation. Tunisia is suffering from a lack of jobs; the country's youth is plagued by a high unemployment rate, which, according to a study of the World Economic Forum [6], is currently around 30%. Aspirations for job creation and concerns of the local population (social acceptance) need to be given much more attention in the new democratic context. Also environmental aspects and the question of ecological sustainability of the national energy supply are increasingly discussed topics in the Tunisian society. Moreover, as a signatory of the Kyoto protocol, Tunisia has taken international responsibility to combat climate change by reducing its carbon emissions. A survey carried out in 2012 at a multi-stakeholder workshop within the framework of a joint project of the Tunisian energy conservation agency ANME and the German development agency GIZ [7] revealed following four major groups of criteria that are pertinent to electricity strategy development in Tunisia:

- economic costs;
- security of supply;
- ecological sustainability; and
- socio-economic benefits.

It is obvious that the above-listed goals are partially conflicting. Therefore, any decision on future electricity system transformation pathways can only be a compromise, which, at best, maximizes the satisfaction of the majority of the stakeholders, taking into account their varied preferences and objectives.

An analysis framework that includes these objectives must consider other criteria than just the economic costs of electricity generation. One possible approach would be to use external costs as guidance for decision-making on electricity strategy options [8]. The valuation of externalities, however, is a difficult undertaking as it requires attributing quantified "market" prices to the different societal and environmental impacts of electricity production. Although there have been attempts to quantify such externalities, for instance for public health and environmental impacts in Europe [9], estimations are generally associated with high uncertainties. Moreover, it is not clear whether the externality values obtained from a European project can properly reflect the North African conditions: for the Tunisian context, for instance, no valid quantifications of the external costs (or benefits) of social acceptance, job creation and energy security are available at the moment.

An alternative – and for our purpose a more suitable approach – is multi-criteria decision analysis (MCDA). Dealing likewise with strategy optimization problems, MCDA has been widely applied to social, economic, agricultural, industrial, ecological and biological systems, and likewise to energy supply systems [10]. In the present study, we use MCDA in conjunction with an electricity generation system model to calculate and evaluate different Tunisian power system scenarios. This combined approach is presented in Section 2, where the basic features of the model as well as the MCDA method are described. Section 3 proceeds with an outline of the simulated scenarios and gives details about the assumptions and parameters used in the study. Section 4 presents the results, followed by a concluding discussion in Section 5.

[1] Tunisia was one of the first North African countries to subscribe to a national energy efficiency strategy, which it has pursued since the 1980s.