Least Cost Energy Supply Model for a Multiple Scenario Analysis of Northern Africa

Long Abstract

Presenting Author: Oliver Broad (KTH Royal Institute of Technology, division of Energy Systems Analysis, SE 11400 Stockholm, Sweden – broad@kth.se)

Co-Authors: Nawfal Saadi[1], Mark Howells[2], Asami Miketa[1], Constantinos Taliotis[2] and Manuel Welsch[2]

1. International Renewable Energy Agency, IRENA.
2. KTH Royal Institute of Technology, division of Energy Systems Analysis, SE 11400 Stockholm, Sweden

Abstract

Energy is, and has always been, at the heart of the development of human societies: it provides everyday services that we take for granted from lighting and cooking through to transportation, or water and food supply. Appearing increasingly as part of high priority agendas in governments and international organisations, universal access to modern, clean and sustainable energy services by 2030 was woven into the central objectives of the United Nation's Sustainable Energy for All programme (SE4All, 2014)

In contrast and according to the World Bank, the African Continent is home to over 1/3rd of the people worldwide living without electric lighting totalling 589 million: just over half of the total African population (1.05 billion in 2011 projected to double by 2050)(UNDESA, 2011). Further, 62% of African population rely on traditional biomass for daily tasks, specifically cooking, and are subject to its health and environmental hazards (UNDESA, 2011). Per capita energy use on the continent is one of the lowest worldwide. Electricity consumption for Sub Saharan countries averages at 534.9 kWh/capita in 2011 as compared to 5465.2 kWh/capita for Europe & Central Asia in the same year (WB, 2014) meaning that a continent currently representing 15% of world population only answers for 5% of total primary energy use (UNDESA, 2011).

When considering Northern African – i.e. Algeria, Egypt, Libya, Mauritania, Morocco and Tunisia – the picture changes showing an average energy use of 1776.7 kWh/capita ranging from Libya 3926.4 to Morocco 826.4 kWh/capita (WB, 2014). With a global electrification rate close to 97% and standards of living much closer to other Mediterranean and European countries, this region has different issues to resolve. With a total installed capacity just shy of 168 GW in 2014 (U.D.I, Platts) in the region dedicated to electricity generation, current ratios show the region's high dependence on fossil reserves with values as high as 99% for Algeria or 87% for Morocco (REEEP, 2012). National energy systems being, to a great extent, installed and operational, the question becomes less how to increase generation capacity and more to assess the strengths, weaknesses and efficiencies of the system while investigating the relative interest of switching supply away from controversial fossil reserves.

The present model was developed using the modelling platform called Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE), which is a dynamic, bottom-up, multi-year energy system model applying linear and mixed-integer optimisation techniques. The modelling platform was originally developed at the International Institute of Applied System Analysis

(IIASA), but more recently has been further enhanced by the International Atomic Energy Agency (IAEA). The modelling platform is a flexible framework within which the actual model is developed. It is also a cost based optimisation framework the results of which will therefore combine optimal power plant dispatch to meet demand subject to all system constraints while minimising the total discounted system cost that are incurred in each year of the simulation.

Focusing on the study of the Northern Africa with the suggested set of scenarios for its future development, this work represents each country within the modelling framework as an independent node, all nodes being interlinked by existing and planned transmission lines. With a primary on electric power supply this work looks at three demand categories defined for each country and including (1) heavy industry (2) urban residential, commercial and small industries and (3) rural residential and commercial. This specific breakdown to allows for a better representation of decentralized power supply and improves the representation of demand load curves while differentiating transmission and distribution infrastructure needs and transmission losses for each different sector.

The scenarios developed in this paper compare alternative transition paths to future national power systems with varying degrees of regional integration over the period 2010 to 2050. These transition paths were developed to compare a so called base case to alternate futures where decreased levels of subsidy for regional natural gas use and lower investment costs in renewable power infrastructure gradually push the regional energy mix to include higher penetrations of clean energy. To achieve this result, the model was populated with both public and private sector data including, inter alia, the retirement and online dates of current and new power infrastructure, the geographical distribution and level of renewable resources, the capacity of existing and planned transmission and distribution infrastructure as well as diversified technology options with their corresponding techno-economic data. In total, this work includes as much as 19 technology options for each country covering all standard thermal options, hydro and non-hydro renewable options. Further, these technologies are split between centralised and de-centralised categories to allow for a more diverse solution.

Drawing on this database of power systems and this range of future technology options, the results from these scenario runs offer some insight into potential power system configurations as well as the economic implications of such systems, in terms of investment needs, fuel savings, energy security, emission levels etc. Currently, North Africa is heavily dependent on fossil fuels and gas in particular. In parallel, it is also an important exporter of gas to Europe – included in this modelling work as a simple trade option for selected countries. It appears however that, by using its gas locally - rather than exporting it – the region foregoes potential revenue. Further, at present North Africa attracts low carbon projects: Egypt, Morocco, Tunisia, Libya and Algeria actively register Clean Development Mechanism (CDM) projects (Gelil, 2014).

The initial results presented in this paper suggest that, supported by reducing investment costs of renewable energy technologies and accompanied by a gradual increase in natural gas pricing to reach current market price levels even on domestic supply, the development of such projects could increase even further. Indeed, from a base situation – where natural gas is the key element to almost all countries in the region – a progressive energy and technology (PET) scenario where the cost of natural gas reflects the ‘net-back’ profits that countries would make by exporting to Europe at current and anticipated prices shows an increased penetration of windpower towards the end of the modelling period. Un-intuitively however, this important change in the energy mix for the region does not have to come at a significantly higher cost to the consumer in each country. Although reliant on a definite

level of international cooperation, the initial conclusions of this work show that it is possible to achieve lower emission levels using stable energy systems relying on higher penetrations of renewable power without penalising the overall system and its individual actors.

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