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Emissions reduction and economic implications of renewable energy market penetration of power generation for residential consumption in the MENA region

M. El Fadel*, G. Rachid, R. El-Samra, G. Bou Boutros, J. Hashisho

Faculty of Engineering and Architecture, American University of Beirut, Bliss str., PO Box 11-0236 Beirut, Lebanon

HIGHLIGHTS

- ► Heterogeneity in GHG emissions in MENA region with Turkey contributing the most.
- ► Average regional GHG tCO_2e/capita of 0.42 decreases to 0.17 with RE penetration.
- ► GHG emissions regional reduction reaches 8–36% depending on RE target penetration.
- ► Return on investment in RE promises up to 54% savings excluding positive externalities.
- ► Carbon credits offer economic incentives rendering RE investment more attractive.

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ABSTRACT

This paper examines the implications of renewable energy (RE) deployment in power generation for residential consumption in the Middle East and North Africa (MENA) region under various RE penetration targets. A comparative assessment revealed a great heterogeneity among countries with Turkey dominating as the highest emitter. At the sub-regional level, the Middle East sub-region contributes more than double the GHG emissions estimated for the Gulf and North Africa sub-regions with all sub-regions achieving reductions in the range of 6–38% depending on the RE target penetration and promising up to 54% savings on investment excluding positive externalities associated with the offset of greenhouse gas (GHG) emissions savings.

1. Introduction

Historically, the use of fossil fuels has dominated the energy supply to meet the continuously increasing energy demand for economic and human development worldwide. Provision of energy services including power generation, however, has greatly contributed to the increase in anthropogenic greenhouse gas (GHG) emissions and concentrations in the atmosphere, resulting in global warming and climate change (IPCC, 2007). World statistics show that in four years (2004–2008), while the world population increased by 5%, the gross energy production and annual CO_2 emissions increased by 10%, reaching 12 billion tons of oil equivalent of total primary world energy supply and 29.4 billion tons of CO_2 emissions in 2008 (IEA, 2010). By the end of 2010, ambient CO_2 concentrations have reached ~390 ppm (39% above pre-industrial levels) and continue to rise (IPCC, 2011; NOAA, 2010). With lower carbon intensity in emissions per energy output, renewable energy (RE) sources are promoted worldwide as measures to mitigate climate change (IPCC, 2011). Beyond emissions' reductions, investment in RE is highly driven by efforts for social and economic development due to associated benefits including environmental protection, diversification, and economic gains. It is estimated that various RE sources accounts for 14% of worldwide total primary energy supply, with a potential to reach ~50% of the global energy demand by 2050 (Bilen et al., 2008).

Research on the development, application and implications of RE systems is continuously growing (Lin et al., 2010; Akella et al., 2009; Manish et al., 2006; Tsioliaridou et al., 2006). A plethora of studies have also investigated the benefits of RE use on energy production and GHG emissions reduction, mainly, through simulating scenarios of RE penetration (Foyn et al., 2011; Blumsack and Xu, 2011; Chiu and Chang, 2009; Tsoutsos et al., 2008; Cai et al., 2007; Chedid et al., 2001). Common tools and models of energy input and output analysis used for RE penetration simulations include Energy PLAN and LEAP (Connolly et al., 2010; Lund and Mathiesen, 2009; Giatrakos et al., 2009). Simulation studies

* Corresponding author. Fax: +961 1 744 462.
E-mail address: mfadel@aub.edu.lb (M. El Fadel).

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reported potential GHG emission reductions worldwide ranging from as low as 4.8% by 2020 in South Korea (Jun et al., 2010) to as high as 40–45% in China (Shan et al., 2012; Liu et al., 2011) under different economic growth and RE supply scenarios. A 32% reduction in emissions was estimated for Mexico by 2025 (Manzini et al., 2001) while an 11.2–35% emission reduction from the electricity generation only was foreseen for Lebanon under different RE use scenarios (Dagher and Ruble, 2011; El-Fadel et al., 2003). Similar results were reported for various developing and developed countries i.e. Sri Lanka, Thailand, Cyprus, Greece, Denmark, Norway and G7 countries (Gebremedhin and Granheim, 2012; Tsilingiridis et al., 2011; Wijayatunga and Prasad, 2009; Sadorsky, 2009; Tanatvanit et al., 2003; Tsoutsos et al., 2008; Lund and Mathiesen, 2009) as well as for the global energy system (Foyn et al., 2011; Krewitt et al., 2009). In parallel, high initial RE investment needs were invariably highlighted, with a potential to delay and discourage wide RE deployment (Shan et al., 2012; Liu et al., 2011; Jun et al., 2010; Wijayatunga and Prasad, 2009; Cai et al., 2007).

With a relative lack of studies on the implications of RE use in the Middle East North Africa (MENA) region, this paper focuses on the potential benefits of RE deployment in the power generation (electricity) sector in this region. It explores the potential of renewable resources to meet the latent and growing residential demand for energy while providing socio-economic benefits to individual countries and the region. It examines environmental and economic implications of RE deployment by relying on long term simulations of GHG emissions under several scenarios on a country by country and sub-region basis.

2. Materials and methods

2.1. Region characterization

The MENA region, consisting in this study of a total of 20 countries (Algeria, Bahrain, Egypt, Jordan, Iran, Iraq, Israel, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Kingdom of Saudi Arabia (KSA), Syria, Tunisia, Turkey, United Arab Emirates (UAE), and Yemen), is responsible for ~4.5% of the global GHG emissions (1 Gt of CO_2), but has the fastest growth rate in emissions and a relatively high volume of emissions per unit of GDP and (World Bank, 2010). A region of about 8.7 Mkm^2 spans over a diverse geopolitical area hosting about 355 million people (~6% of the world total) living in high-, middle-, and low-income countries (Fig. 1) (World Bank, 2011).

The region has diverse microclimates predominantly arid and semi-arid, and is disproportionally endowed with natural and renewable resources. As in most other non-OCED countries, energy consumption in the MENA region is based on conventional, non-renewable resources originating from its 60% of the world's proven oil reserves and 45% of natural gas resources (Al Mulali, 2011; UNEP, 2007). Fossil fuel extraction has shaped the economy in many MENA countries where two-thirds of these countries are members of the Organization of Petroleum Exporting Countries (OPEC). For the purpose of this study, the region is divided into its sub-regions to reflect relatively homogenous geographical clusters: North Africa (Egypt, Libya, Tunisia, Algeria, Morocco), Middle East (Lebanon, Israel, Palestine, Jordan, Syria, Turkey, Iran, and Iraq) and the Gulf (UAE, KSA, Bahrain, Yemen, Oman, Qatar, Kuwait) where the discussion is based on individual countries, sub-regions, and the region as a whole.

2.2. Data collection

Data were collected through secondary sources of accessible country profiles, communication reports, assessment studies, databases, publications as well as governmental electronic databases and RE related international and regional organizations. Data sought was categorized into:

– *General data*: population, households, urbanization and growth rates
– *Energy data*: electricity production, capacities, demand, imports and exports, processes and efficiencies;
– *Resource data*: types, sources, reserves, yields, imports and exports;
– *Cost data*: production, operation, unmet demand, and output prices.

The data were compiled and synthesized towards building scenarios for potential RE production and tested using the Long Range Energy Alternatives Planning (LEAP) software.

2.3. Model description and simulation Scenarios

LEAP was used to simulate scenarios of RE shares in energy production for quantifying benefits of RE penetration in terms of GHG emissions reductions and cost savings for individual countries. LEAP allows data structuring, developing energy balances, projecting demand and supply scenarios, estimating associated emissions and evaluating policies (SEI, 2011; Huang and Lee, 2009). It also allows for long term scenarios over large scale areas catering for projections on population, economic development and technology (Lin et al., 2010). For the purpose of this study, two mitigation scenarios per country were forecasted in addition to the Current Accounts (or baseline) and Reference scenarios, based on LEAP input requirements (Table 1). While the assessment of the implications of RE penetration for the generation of the total power demand is important, however, the lack of

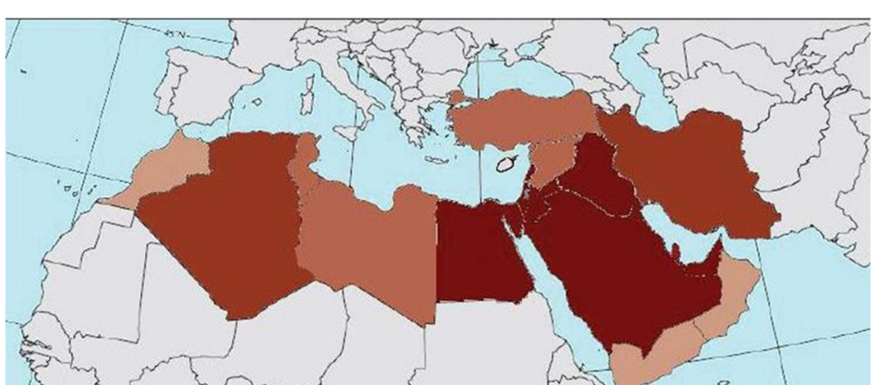

Fig. 1. Geographical Distribution of MENA countries (adapted from Tolba and Saab, 2008).