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ANALYSIS

Access to electricity in the World Energy Council's global energy scenarios: An outlook for developing regions until 2030

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ABSTRACT

Approximately 2 out of 10 people in the world still live without access to electricity. The UN "Sustainable Energy to All – SE4All" initiative aims at eradicating this electricity access deficit by 2030. To estimate the financial effort required to achieve this target we analyse two long-term scenarios developed by the Paul Scherrer Institute and the World Energy Council, which describe two alternative economic and energy system developments. We focus on developing Asia, Latin America and Sub-Saharan Africa, which currently have the largest percentage of population without access to electricity. We couple a long-term energy system model with regional econometric models that forecast population electrification rates. We find that establishing universal electricity access by 2030 requires significant, but attainable investments in power generation infrastructure, and results in low impacts on primary energy demand and CO_2 emissions.

1. Introduction

Access to electricity is essential to overcome poverty, promote economic growth and employment opportunities and support the provision of social services such as education and healthcare that lead to sustainable human development [1]. The International Energy Agency (IEA) defines electricity access as a first supply connection to a household and then an increasing level of electricity consumption to reach the regional average. This approach reflects the fact that the eradication of energy poverty is a long-term endeavour [2]. Following the IEA definition 1267 million people worldwide did not have access to electricity in 2010 [3]. This figure increased to 1285 million in 2012 [4], implying that population growth outpaced the number of new electricity connections. More than 95% of the population without access to electricity lives in developing Sub-Saharan Africa, Asia and Latin America (Fig. 1).

In September 2011, UN Secretary-General Ban Ki-Moon launched the initiative "Sustainable Energy for All – SE4All" to mobilise action from all sectors of society to promote universal electricity access by 2030 [5]. The initiative has generated significant momentum and more than 100 countries are already participating in it. As global development agendas are increasingly recognising energy access and energy poverty as essential issues for society, it is important to address them in the context of two other significant socio-ecological issues of our time: energy security and environmental sustainability [6]. This triple challenge is referred by the World Energy Council (WEC) as the "energy trilemma" [7].

The Paul Scherrer Institute (PSI) together with WEC developed two energy scenarios to 2050 assessing the energy trilemma at global and regional scales [8]. The two scenarios incorporate a coherent set of key economic, social and political drivers that are quantified and implemented with a detailed energy system model. The WEC/PSI scenarios are exploratory in their nature in the sense that no specific targets were set along the axes of the energy trilemma. The first scenario ("Jazz") is market-facilitated with a focus on achieving economic growth through competitive and low-cost energy. The second scenario ("Symphony") considers stronger policy regulations with priority given to environmental sustainability and energy security. Both scenarios include climate policies and recent technological advances.

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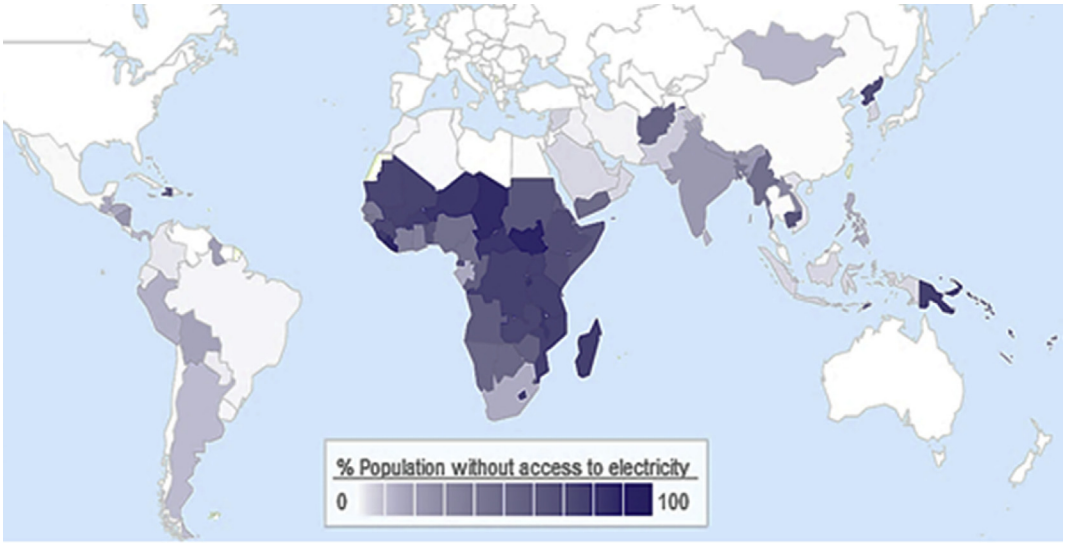

Fig. 1. Population without access to electricity as % of country's population, 2010 (source: own illustration using data from Ref. [3]).

In this paper, we present a detailed analysis of the two WEC/PSI scenarios regarding electricity access in developing and emerging regions. We focus on regions in which a significant share of the population lacks access to electricity: Sub-Saharan Africa, developing Latin America, India, Central Asia, developing Pacific Asia, Middle East and North Africa.[3] For each region, we present the outlook of electricity access in WEC/PSI scenarios until 2030, we discuss the key socio-economic drivers affecting it and we evaluate the additional investment effort in power generation infrastructure required to achieve universal electricity access by 2030. In our assessment, we use an analytical approach, in which we couple a large scale bottom-up energy system model that identifies long term cost-optimal configurations of the energy system with regional reduced-form econometric models[4] that forecast the population with access to electricity.

1.1. Literature review

In general, the majority of research on improving electrification in developing countries, analysing its impacts on energy supply and emissions and identifying drivers and policies with significant contribution to the electricity access, can be divided into four main categories. The first category includes studies that describe current situations of energy demand or consumption and evaluate the outcomes of policy and programs in developing countries. This includes assessments of funding needs and financing mechanisms (e.g. Ref. [9]), evaluations of electrification programmes (e.g. Ref. [10]), policies and reforms required (e.g. Ref. [11]), and case studies at national and regional levels (e.g. Refs. [12–23]). The studies belonging in this category of research include legal, social and fiscal aspects of the policies and programs. However, they are usually highly case-oriented and it is difficult to obtain ideas applicable to other areas.

The second type of research category focuses on the potential of various electricity supply technologies to increase electricity access such as solar photovoltaic systems (e.g. Refs. [24,25]), decentralised generation and micro-grids (e.g. Refs. [26–30]), nuclear power [31], biomass [32], etc. This type of studies often contains highly disaggregated or highly precise data, but policy implications to promote these technologies are usually not sufficiently discussed.

The third category includes studies investigating relationships between electrification, poverty and economic development on national and regional scales. These studies can be qualitative, based on empirical results from past experiences (e.g. Refs. [33–35]), or quantitative, based on econometric analysis (e.g. Refs. [36–43]). The majority of these studies identify poverty, income, foreign direct investments (FDI), urbanisation, country policy and institutional development, electricity prices, subsidies and average electricity consumption per capita as key factors of electricity access.

Finally the fourth type of research, to which the present study belongs, involves the combined application of top-down and/or bottom-up economic and energy system models with specific micro-economic consumer choice models or econometric models. These studies forecast the population with electricity access by taking into account economic developments, technological parameters and governmental policies. At the same time, they evaluate the broader impacts of increased energy access on energy supply and demand fuel mix, investment requirements and greenhouse gases emissions. Bottom-up modelling frameworks, such as TIMES [44], have been employed in projecting rural electrification (e.g. for Africa in Refs. [45,46], and for other developing regions in Ref. [47]). Top-down approaches have been used for electricity access scenarios for Sub-Saharan Africa [48] and for assessing the impacts of increased energy access on greenhouse gases emissions and global warming [49]. In Ref. [50], a consumer choice model based on micro-economic foundations is implemented within the cost optimisation energy system model MESSAGE [51]. The model analyses the determinants of fuel consumption choices of heterogeneous household groups by taking into account effects of income distribution, consumer preferences and discount rates. It has been applied to explore response strategies for energy poverty eradication in India [50] and in South Asia [52], and to evaluate pathways to achieve universal electricity access by 2030 [53–55].

The International Energy Agency applies an econometric model to generate projections of electrification rates by developing region. It is based on panel estimation of historical electrification rates of different countries over income, urbanisation, fuel prices and subsidies, electricity consumption, electrification programmes and other variables [56]. The model is interfaced with IEA's World Energy Model (WEM) in the World Energy Outlook series (e.g. Refs. [2–4]).

[3] We exclude Brazil and China, since they already display high electrification rates and they are expected to achieve universal electricity access before 2030 ([3], [8]).

[4] An econometric model is in a reduced-form when it has been rearranged algebraically such that each endogenous variable is on the left side of the equation, and only predetermined variables (exogenous variables and lagged endogenous variables) are on the right side.