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Scarcity in abundance: The challenges of promoting energy access in the Southern African region

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ABSTRACT

The paper deals with the challenges of energy access, efficiency and security as essential conditions to improve people's living in the Southern African region. It supports energy policies by providing material for an integrated assessment of alternative energy systems at national level. Taking the example of Namibia, the paper applies the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) approach to assess the energy systems and scenarios. Using historical data from 2000 through 2013, the authors initially characterize energy supply and demand conditions of Namibia. Subsequently they conducted simulation analyses to find out a desirable energy policy to promote energy access in Namibia through 2030 under various environmental and societal constraints. The simulation results reveal that sustainable energy access in remote areas can be better achieved by small-scale distributed renewable energy systems rather than by large-scale energy technologies. Moreover, the study shows that energy policies should adopt a broader perspective to face the challenges of sustainable energy access in countries of the Southern African region by designing alternative development pathways rather than focusing on implementing new energy technologies.

1. Introduction: the challenges of energy access

The objective of this paper is to contribute to existing methodologies used to promote energy access in the Southern African region. In particular, it seeks to provide evidence of the importance of dealing with the issue of scales and dimensions in assessments. Lack of energy access affects most developing economies but mainly concerns countries of the Southern African region (Hailu, 2012). Many studies have explained the socio-economic factors that act as obstacles to improve electricity access in energy deprived countries (for a review, see (Magnani and Vaona, 2016)). These factors include the remoteness of communities, the low consumption level in remote areas due to low income and high costs of distribution, and the lack of availability of human capital and financial capital. However, most of the literature concern case studies for which there is no agreement on the method to use to assess energy access scenarios (Hailu, 2012). Moreover, it has been observed that many of the policy recommendations made these studies generally fail to address the urban-rural energy divide, which in some cases can lead to counter-productive recommendations (Khennas, 2012). This can be explained by the difficulty to describe the complex patterns of demand and supply of energy in societies.

Moreover, socio-economic factors alone cannot explain the systemic lack of energy access. To improve the understanding, these factors must be mapped against problems of availability and access to natural resources. Energy access is neither only a socio-economic problem, nor only a resources problem. It is both. Socio-economic factors prevent these countries from being able to improve the performance of their energy supply sector. Conversely, the difficulty in exploiting both renewable and non-renewable energy resources and even in securing energy imports prevent the same countries from improving the consumption of energy demand that would support economic development. Energy access is one further example of the complex relations between production and consumption of energy organizing human societies. This complexity calls for adopting a specific set of rules for the quantitative assessment of energy access scenarios.

Policy-relevant and technically-robust assessment from a complex systems approach cannot rely on the use of simple models, given that precise quantification cannot be achieved in the context of uncertainty

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(Saltelli and Funtowicz, 2014). However, it is possible to characterize patterns by combining approximate assessments of the structural and functional characteristics of the metabolic system[*1] with benchmarks[*] used to define the system's behaviour—*e.g.*, the amount of energy consumed per unit of land use[*]. In so doing, it is then possible to represent general trends and highlight the existence of incompatibilities with external constraints[*] and/or the emergence of internal constraints[*]. As complexity cannot be addressed by simply adding further quantification, a sound approach to energy access needs to embrace complexity to better deal with uncertainty.

Other applications of the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) approach have been conducted to address issues of energy access in urban setting, specifically in informal settlements (Kovacic and Giampietro, 2017; Kovacic et al., 2016). But there lacks an application that deals with both urban and rural settings at local levels and that can map these patterns to an assessment of energy access scenarios at national level.

The paper is structured as follows: Section 2 introduces the approach of multi-scale integrated analysis used to assess energy access at national level. Section 3 provides background information and details on the data used for the selected case study of Namibia. Section 4 presents and discusses the results of the application of the integrated approach to the scenario assessment in Namibia as well as its limitations. The concluding Section 5 points at the policy implications over energy access in countries of the Southern African region, of performing an integrated assessment of their energy systems.

2. Method

2.1. Standard definition of the MuSIASEM approach

MuSIASEM is an accounting approach for the assessment of sustainability (Giampietro et al., 2014). In the standard definition of MuSIASEM, a society can be described by a hierarchical structure of functional compartments (see Fig. 1). The five lower-level functional compartments are:

- *Households*, which ensures the reproduction and maintenance of the population (sleeping, eating, chores, children and elderlies, leisure, etc.);
- *Services and Government*, which ensures the reproduction and maintenance of institutions (education, health, military, government, etc.);
- *Building and Manufacturing*, which ensures the reproduction and maintenance of the infrastructures;
- *Agriculture and Fisheries*, which ensures the reproduction and maintenance of the flows of food;
- *Energy and Mining*, which ensures the reproduction and maintenance of the flows of energy.

These functional compartments are very helpful to understand how human societies have self-organized their activities over the ages leading to strong metabolic patterns (Giampietro et al., 2012). For instance, after the industrial revolution, the massive use of fossil energy (Smil, 2017) made possible for human societies to move as much as possible resources from the productive sectors – also called "hypercyclic compartments[*]" in Fig. 1 – to the non-productive sectors – "dissipative compartments[*]" in Fig. 1 – which comprise households, services and institutions. This phenomenon of a (temporary) emancipation from land (Mayumi, 1991) and from other resources – mainly labour and energy – for the productive activities explains why Western societies have been able to rapidly increase their standard of living. Quantifying the metabolic patterns of societies using these functional compartments

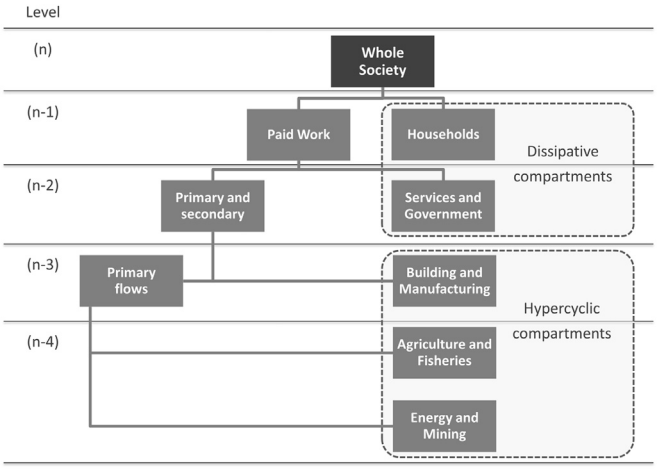

Fig. 1. The standard hierarchical structure of functional compartments of society used in MuSIASEM.
Source: own elaboration, based on (Giampietro and Bukkens, 2014b)

allows now to evaluate the possible constraints, for instance, on energy transitions and societal changes. Of particular interest for our paper, exploring the metabolic patterns of countries makes it possible to better understand the challenges of not having sufficient access to energy.

The MuSIASEM framework can be used for diagnostic as well as for simulation purposes (Giampietro and Bukkens, 2014). The application of the MuSIASEM approach consists of three steps: (1) diagnostic analysis, (2) simulation, and (3) scenario assessment. As a diagnostic tool, MuSIASEM is used to characterize existing metabolic patterns of the socio-economic systems under analysis. It provides integrated information on population, labour force, land (defined as fund elements[*]) and on food, energy, water and money (defined as flow elements[*]). The funds (*e.g.*, human activity[*], managed land[*]) provide the relevant structural elements serving as external referent to the metabolic analysis. They provide information about "what the system *is*". Conversely, flows (*e.g.*, energy, food, water, money) provide information about "what the system *does*". Relative distributional changes of funds are much slower than for flows (Diaz-Maurin, 2016). For this reason, funds are considered as more stable than flows in the time horizon of a metabolic analysis, hence can be considered as external referent. The use of external referents is essential to avoid relying only on the use of flows that cannot capture the metabolic characteristics of society. For instance, the aggregate indicator *economic energy intensity* (EEI) measuring the energy consumption per unit of gross domestic product (GDP) (a flow/flow ratio) is inadequate—even misleading—in metabolic analysis because economic and biophysical variables are often correlated and their value is determined by characteristics which can only be observed across different scales (Fiorito, 2013; Sorman and Giampietro, 2011). By combining the allocation profiles of flows and funds across the different functional compartments (*e.g.*, households, services and government, energy and mining), a series of flow/fund ratios can be obtained. The flow/fund ratios characterize the rate (per hour of human activity) and density (per hectare of managed land) of the flows across different scales, including the whole society and each one of the lower-level compartments defined in the accounting scheme, such as the various economic sectors.

In the MuSIASEM methodology, the societal compartments are linked through forced relations of congruence across scales formalized by the profiles of allocation of the flows and funds, whereas the dimensions of analysis (*e.g.*, energy, land, human activity) are linked together through the flow/fund ratios (Giampietro et al., 2014b). Allocation of flows and funds, and flow/fund ratios are presented in the form of a multi-dimensional multi-scale table (see Table 1). The use of a metabolic table illustrates the system closure at each level—the sum of

[1] A definition of each term followed by an asterisk (*) can be found in the Glossary.