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Identification of objectives for national energy planning in developing countries

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ABSTRACT

Defining objectives is an essential part of planning processes, useful to induce creative alternatives and to derive the attributes (criteria) on which the alternatives will be assessed. This article identifies a set of energy planning (EP) objectives and measurable attributes specifically tailored for promoting sustainability in developing countries. A literature review was conducted as part of a problem structuring activity to identify applicable EP objectives. The Economic Community of West African States (ECOWAS), with an emphasis on Ghana, was used as a representative area of study. Two EP objectives specific to the context of the ECOWAS were identified, namely, ensuring maintainability of the final energy supply system and access to final energy services. These were included within a set of EP objectives which consisted of the additional of increasing primary energy security and reliability of the final energy system, and decreasing costs (investment, operation & maintenance), influence of the energy system on the global climate, impact of the energy system on the local environment. These EP objectives were made operational through the identification of a set of corresponding measurable attributes. This EP objective set, used within a structured EP methodology, may support the implementation and sustainability of national EP activities in the countries of the region.

1. Introduction

Developing countries are facing formidable challenges to economic and human development for which energy plays an essential role [1]. Energy planning (EP) is an essential activity in the establishment of an energy trajectory which meets society's demands for final energy (FE) services and supports the achievement of national development objectives.

The EP practices of the countries of Sub-Saharan Africa (SSA) remain relatively nascent in comparison to those of more developed countries and frequently lack the frameworks necessary to support energy policy development [2]. The EP practices of the Economic Community of West African States (ECOWAS), in particular, have been hindered by largely non-existent or weakly implemented institutional structures and frameworks [3]. The absence of adequate EP frameworks can lead to deficient, ad-hoc, and short-term decision making in the place of coherent medium to long-term EP [2]. The lack of adequate EP activities also adversely affects the successful development of energy strategies and the implementation of the resulting energy projects [3].

Innovative EP and policy development frameworks are required in order to set and achieve medium to long-term EP objectives. These must establish coherent policies with precise targets and be based on clearly detailed EP strategies [4]. One component of these frameworks is the identification and use of a set of EP objectives that are specific to the context of application. A review of EP activities of members of the ECOWAS by Lee and Leal [5] found that EP activities of countries in the region employed EP objectives which resembled those common to EP activities of developed countries. It was, however, unclear if this convergence of objectives represented a fundamental nature or if it represented the appropriation of objectives without the comprehensive bottom-up activity of identifying the fundamental objectives applicable to each EP activity. The EP objectives of developed countries fall into the “three E” themes of energy security, economic development, and environmental protection [6]. A recent work from Haydt et al. [7] on

Abbreviations: DMs, decision makers; Dev-C, developed country; ECOWAS, Economic Community of West African States; EP, energy planning; ESA, energy security attribute; FE, final energy; GHG, greenhouse gas; IPCC, Intergovernmental Panel on Climate Change; PE, primary energy; PSMs, problem structuring methods; SNEP, Strategic National Energy Plan; SSA, Sub-Saharan Afric; CoreUrban, urban core population; PeriUrban, urban periphery population; US $, United States dollars

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energy efficiency planning in Portugal identified a set of six objectives comprising (1) impact on global climate, (2) investment risks, (3) energy security, (4) risk of plan failure, (5) time until the effect of the plan, and (6) investment costs.

The purpose of the current work was to identify a set of EP objectives and quantifiable attributes which were specific to the context of application and influential for the implementation and sustainability of energy sector plans and to employ these in a case study evaluation. The ECOWAS, with an emphasis on Ghana, was used as a representative sample of developing countries in SSA. Currently, a bottom-up process to identify context specific objectives and corresponding quantifiable attributes that enables the assessment and choice of attractive national EP alternatives (policy options) appears to be absent in the current EP practices of the region [8]. This work proposes an extended methodology to identify objectives, operationalize these objectives with quantifiable attributes, and compute these attributes with existing data sources. This methodology may be beneficial in EP activities of countries in the region and possibly for those of other developing countries.

Defining objectives is an essential part of planning processes, useful for inducing creative alternatives and deriving the attributes (criteria) on which the alternatives will be assessed. This often includes several possibly conflicting economic, environmental, and practical (e.g., technology availability) objectives [9]. Problem structuring methods (PSMs), also referred to as *soft* operational research methods were developed from efforts to ensure that a holistic approach was used to account for the widening boundaries of problems as well as the multiple actors – often excluded from purely quantitative operational research methods. PSMs aid in managing rather than reducing complex issues and are helpful in reaching a comprehensive understanding of situations and reaching a common definition of problem [10,11]. Literature on the use of PSMs in real-world EP activities is rapidly growing. The use of PSMs in EP is often a multi-methodology approach for structuring in support of decision problems. Neves et al. [12] employed PSMs for identifying the key issues, objective hierarchy, and means-ends network for structuring objectives and attributes in the development of a generic multi-criteria decision analysis (MCDA) model for use in evaluation of energy efficiency initiatives. Neves et al. [13] developed a cognitive and causal map in addition to an objectives hierarchy to support an evaluation of alternatives with a MCDA model. Haydt et al. [7] used the Delphi method to identify relevant EP objectives as well as the value-focused thinking approach from Keeney [14] to structure the objectives and quantifiable attributes for energy efficiency planning. Recently, Antunes et al. [15] employed the value-focused thinking approach to frame the problem of evaluating technological innovations and incentive policies in the electricity sector.

The current work employs the value-focused thinking approach to identify the *fundamental* objectives, and corresponding quantifiable attributes for national EP activities in the ECOWAS. The structuring of decision problems also includes the steps of selecting appropriate structures (e.g., a decision tree structure or a multiple objective structure) and the refinement of these structures (e.g., defining *fundamental* objectives and quantifiable attributes). Problem structuring in the current work was conducted in support of a decision analysis problem and consisted of the three steps of (1) framing or identification, (2) development of a structure and (3) refinement of this structure [16].

The term EP is used to cover a number of activities in the energy sector. This work considers the EP activity in developing countries with a focus on ECOWAS member states for a medium-term planning horizon (5–20 years for example). A medium-time horizon permits time for the purchase and installation of infrastructure which potentially requires a number of years, as is the case for electrical energy systems. The medium-term horizon is evaluated here in annual time slices allowing for an understanding of the state of the energy system in each year. The current work concentrates on technical measures as opposed to policies and subsidy programs established by governments and utilities. The costs for energy use (e.g., electricity) can be divided into the actual costs for generation and delivery of energy carriers and the margin above these costs which provide profits to utilities and governments. As the profit margin is dependent on government and utility policies or subsidy programs this remained outside of the technical focus of this current work. This technical focus also applies to technical energy sector planning activities as opposed to implementation mechanisms, such as financial incentives or information programs. Although it is acknowledged that promotional mechanisms are influential in the implementation of energy plans, there are many possible implementation mechanisms and these are often context specific.

Section 2, which follows, details the framing stage where a detailed literature review was completed to identify potential implicit and explicit factors important for EP in developing countries. Section 3 describes the structuring phase, where the value focused thinking approach was beneficial in structuring the EP objectives into a hierarchy of *fundamental* objectives and a network of *means-ends* objectives. In Section 4, the refinement phase, the scope of each of the EP objectives was defined and quantifiable attributes were identified. A reference projection (business as usual), for a case study of Ghana is evaluated with this set of objectives and corresponding attributes in Section 5. A discussion of the EP objectives, corresponding attributes, and the case study is presented in Section 6.

2. Framing the problem

To identify a set of objectives specific to the context of EP in the ECOWAS, a literature review was initially completed to identify factors considered influential in the implementation and sustainability of energy sector plans and projects in developing countries. Following this literature review a consultation with stakeholders was conducted as part of the case study (Section 5) to verify the EP objectives.

The reviewed literature consisted of 18 scientific articles, 8 reports from governments, organizations and one company, and finally 5 news articles, presented in Appendix A. This literature review resulted in the identification of a preliminary set of 109 factors. A filtration process was then conducted to establish a final set of factors. A flow-chart detailing the literature review and the filtration process is presented in Fig. 1. The full set of factors and the filtration process is also detailed in Fig. A 1 of Appendix A.

The filtration process began with an initial screening of factors to eliminate redundant or duplicate factors. The factors were then evaluated in terms of their capacity to be developed into an objective rather than being characteristic of a constraint. Constraint type factors can be described as “yes/no” conditions (e.g., availability of funds, as opposed to an objective type factor such as minimizing costs). This resulted in a list of 43 factors after the removal of 66 factors. Several of the identified factors concerned implementation mechanisms, such as financial incentives or information programs, rather than technical measures, considered out of the scope of this work as described in Section 1. Focusing on factors related with technical measures resulted in a list of 11 factors. Next, factors considered circumstantial to EP efforts as opposed to fundamental factors, such as government support for actions, were filtered out. The list consisted of nine factors after removing circumstantial factors. Finally, similar factors which could be expressed within a more general single factor were combined to produce a final list of seven factors. An example of similar factors combined to form a single factor (as opposed to redundant factors described previously) consisted of “Availability of technical know-how” and “Availability of maintenance and servicing resources and facilities” which were combined to form the final factor of “Maintainability of energy systems”. The final seven factors are presented in Table 1 and are separated into factors specific to technologies or systems, economic and financial considerations, and environmental concerns. The majority of the factors corresponded to the first of these themes.