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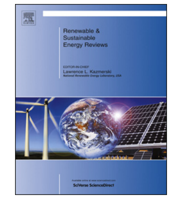

Modelling and uncertainties in integrated energy planning

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ABSTRACT

Significant progress has been done in the last decades to characterise and define uncertainty in model based planning and decision making in general and in areas like integrated assessment or water resource management. However, existing uncertainty typologies are only partially shared. In city or territory integrated energy planning literature less attention has been paid to uncertainty aspect. Integrated energy planning and model building process have been defined on the base of literature review and the need for consideration of uncertainty is highlighted at the beginning of this work. Using this planning and modelling framework, a conceptual basis of uncertainty showing the allocation of different types of uncertainty according to each planning and modelling stage is provided. Uncertainty concepts proposed in existing typologies of uncertainty from different domains are harmonised into a framework and adapted to the special energy modelling and planning conditions, in a holistic way. Based on this framework, a review of practices in energy planning and modelling shows the gap between needs and practices and raises the question of methodological supports for fulfilling it. The suggested framework can be used to identify and classify different types of uncertainty in context of sustainable model based integrated energy planning in cities or territories, or develop methods to address them.

Contents

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1. Introduction

1.1. Integrated energy planning and modelling in cities and territories

Integrated energy planning in cities and territories (IEPCT) is defined in [1] as "Regional (sub-national) integrated energy planning is an approach to find environmentally friendly, institutionally sound, social acceptable and cost-effective solutions of the best mix of energy supply and demand options for a defined area to support long-term regional sustainable development. It is a transparent and participatory planning process, an opportunity for planners to present complex, uncertain issues in structured, holistic and transparent way, for interested parties to review, understand and support the planning decisions".

An integrated energy system in cities or territories incorporates energy supply and demand systems with many subsystems having different energy up- and downstream flows, services from primary energy to final energy supply to the customer. The intermittent nature of renewable energy resources, energy market deregulation, and different interests and behaviour of different actors (supplier or energy consumer) make planning and modelling of such complex integrated systems a very challenging task having different uncertainties.

1.2. Motivations to make uncertainty explicit in integrated energy planning

Uncertainty analysis received less attention in energy planning and modelling by politicians and scientists in the regulated energy market era. In the last decades and in a competitive energy market, the need for uncertainty analysis becomes important for different reasons.

Firstly: The investment in energy infrastructure is not always guaranteed by states or by strong market power of the energy supply company. In free market conditions with unexpected energy price changes, energy carrier substitution or energy demand change etc., uncertainty increases. Investments in public sector are in a dynamic and constantly changing environment with much uncertainty. Bock [2] argues that sensitivity and uncertainty analysis should be part of a comprehensive management procedure in public sector investment projects.

The practical case Flavin [3] shows the consequences of not addressing uncertainty explicitly and being focused only on average value or central tendency. The projections of peak electricity demand in this study have been used by utility planners throughout the US and Canada. The consequence using this projections is analysed by Flavin [3] and commented on by Cooke [4]: "The difference between the summer peak demand in 1983 and that projected for 1983 a decade earlier was equivalent to the output of 300 large nuclear plants, representing an investment of about $750 billion at 1984 prices". Similar results were found by Laurent et al. [5] in a retrospective study. In most studies, projection differs strongly from real observations.

Secondly: Different natural, technological, social and institutional processes and their interactions have to be considered in planning for the long term, which makes planning and modelling very complex and their output uncertain. For example, considering the diffusion or appearance of new technologies in the energy market is a hard to predict and complex phenomenon.

Thirdly: Scarcity of fossil energy resources, climate change, increasing environmental restrictions and the resulting high share of intermittent energy resources, such as wind or solar energy in energy system, make the need for uncertainty analysis necessary.

Fourthly: Interactive planning involves different planning participants with different worldview, interests and uncertainty perception. There is a need to discuss uncertainty from the participants or investors' perspectives that takes into account their uncertainty perception.

Klauer [6] indicates the importance of implementing uncertainty analysis in the whole decision making process. "General approach to uncertainty should include the analysis of the entire decision-making process from problem recognition, over the development of alternative actions and the evaluation of these alternatives to the implementation of the chosen alternative." The study [7] states "[…] uncertainty affects the competitiveness of energy sector options in ways that are not easily predictable without an explicit, rigorous treatment of uncertainty." The need for uncertainty analysis is also indicated by Hodge et al. [8]: "Ideally the energy system must be modelled in a way that allows the investigation of multiple future scenarios, in order to account for this uncertainty and accurately gauge the benefits and costs of any energy policy." Uncertainty is stated to be a critical element in integrated resources planning [9].

1.3. Purpose and remaining structure of the paper

Previous motivations provide the feeling that there are different types of uncertainty behind them. Following the example of integrated assessment and environmental research [10], we assume that uncertainty in IEPCT is a polymorphous concept varying with the different planning and modelling activities. As a consequence, uncertainty analysis and management in IEPCT are also multiform and depend on these activities. The purpose of this paper is twofold:

- to propose conceptual basis of uncertainty for model based IEPCT,
- to provide a link between model based IEPCT activities and uncertainty types,
- to highlight the gap between reported studies and required practices of uncertainty analysis in IEPCT and provide orientations for further research works thanks to the defined conceptual basis for uncertainty.

In order to provide these results the remaining part of the paper is organised the following: First, Section 2 presents an overview of uncertainty types, which are reported in environmental planning and modelling like integrated assessment and water resource management. On the base of this review and our experiences, a conceptual basis of uncertainty for model based IEPCT is proposed. Second, Section 3 provides the link between IEPCT activities, proposed modelling steps and uncertainty types provided in Section 2.2. This framework is then used to review actual practices in IEPCT and highlight the gap between needs and practices in Section 3.3. The implementation of proposed concept of uncertainty typology is illustrated using Singapore case study in Section 4. The main findings, their significance and limitation are discussed in the last section.