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SCS-478; No. of Pages 11

ARTICLE IN PRESS

Sustainable Cities and Society xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Sustainable Cities and Society

journal homepage: www.elsevier.com/locate/scs

Stakeholder-oriented energy planning support in cities

Najd Ouhajjou[a,*], Wolfgang Loibl[a], Stefan Fenz[b], A. Min Tjoa[b]

[a] AIT—Austrian Institute of Technology, Vienna, Austria
[b] Vienna University of Technology, Vienna, Austria

ARTICLE INFO

Article history:
Received 31 October 2015
Received in revised form 23 April 2016
Accepted 3 August 2016
Available online xxx

Keywords:
Urban energy planning
Planning support
Ontologies

ABSTRACT

The successful implementation of urban energy planning strategies (applied as a set of measures to improve energy efficiency and enhance renewable energy generation to reduce CO_2 emissions) depends on the satisfaction of the stakeholders, involved in future implementation processes. This article presents a stakeholder-oriented approach, implemented in a planning support system, to provide stakeholders with specific information from their points-of-view, regarding the impact of energy strategies on their interests in the built environment. The approach is based on semantic web technologies, where an ontology has been developed to provide targeted information for different stakeholders while developing urban energy strategies. Measures to be implemented are defined. Stakeholders are identified and questions they raise for their decision making are listed, as competency questions of the ontology. Computation models to answer these questions are identified or developed, based on the data availability in the city. The semantics used in these models are then captured and classified within the ontology. Then the decision making knowledge of the stakeholders is integrated within the ontology, as inference rules. Finally, the ontology is used through a web-map-based interface. The proposed solution anticipates the potential decisions of the different stakeholders, easing the progress of the energy planning process, typically happening in workshops or forums in collaboration with different stakeholders.

1. Introduction

In order to cope with CO_2 emissions increasing worldwide, it is important to develop integrated strategies that include appropriate CO_2-reduction measures (e.g. equipping buildings with solar photovoltaics installation and thermally insulating them). These energy related strategies are the result of energy planning processes, which involve various actors and stakeholders e.g. city administration, buildings owners, urban planners, etc. Thus, such processes require support in terms of providing a quantitative assessment of the impact of different energy strategies.

This article addresses the problem of providing quantitative assessment of energy strategies, from the different perspectives of the stakeholders they involve, at the city level. The motivation of this work refers to the following facts: (i) Most CO_2 emissions are emitted in cities. Therefore, energy strategies (sets of measures) are required at the level of cities, tackling the problem in an integrated way. (ii) A quantitative assessment of the impact of these energy strategies is essential, making sure that they contribute in reaching desirable objectives, without negative side-effects. (iii) The impact assessment of such city-level strategies requires modeling –relevant parts of- the city, which is challenging due to its size, dynamics, and the diversity of domains that are involved, requiring IT-based support tools. (iv) The ultimate successful implementation of energy strategies relies on the approval of the involved stakeholders. Thus, stakeholders need specific information to their view-points during the energy planning process.

There exist numerous definitions of "urban energy planning" processes. However, the focus of this paper addresses urban energy planning processes that rely on supporting (software) tools, combine sets of measures and have a long term planning horizon (Mirakyan, Lelait, Khomenko, & Kaikov, 2009). Sub-section 1.1 addresses the definition of urban energy planning processes that are within the scope of this paper. In sub-section 1.2, we give a brief overview of existing supporting tools for the urban energy planning processes. In sub-section 1.3, the objectives and the adopted design concepts are described.

1.1. Urban energy planning support processes

Williams (Williams, 2002) summarizes the primary goal of urban energy planning processes as embedding the decision mak-

* Corresponding author.
E-mail address: najd.ouhajjou@gmail.com (N. Ouhajjou).

http://dx.doi.org/10.1016/j.scs.2016.08.006
2210-6707/

ing process in a conceptual framework, thus, defining some structure concerning what is needed to be accomplished. Accordingly, more emphasis is put rather on the implementation process and actors than on the implementation content. A more generic definition of urban energy planning processes, within the scope of this article, has been given by Mingers and Brocklesby (Mingers & Brocklesby, 1997), defining this process as a set of guidelines and/or activities to support a target group of people in performing their tasks. More specific, but aligned with the previous definitions, Mirakyan and De Guio (Mirakyan & De Guio, 2013) define urban energy planning as the process of finding solutions to the best mix of energy demand and supply in a given area. The solution shall support a sustainable development of the area in a long-term run, and at the same time shall be socially acceptable and institutionally sound.

Regarding the nature of the process, this definition (Mirakyan & De Guio, 2013) emphasizes urban energy planning to be a participatory transparent process. It offers the opportunity to the planners to simplify and present complex issues in a structured way, taking account the system as a whole. Therefore, decision makers have a better understanding of the issues and are supported regarding their planning decisions. The process is structured into four phases (i) Preparation & orientation, (ii) Detailed analysis, (iii) Priorization & Decision, and finally (iv) Implementation & Monitoring.

The findings of this article are based on the generic urban energy planning process described above (Mirakyan & De Guio, 2013), and are related to the Sustainable Energy Action Plan (SEAP) (Covenant of Mayors, 2013; Bertoldi, Cayuela, Monni, & de Raveschoot, 2010). The SEAP process has been chosen due to its wide use in Europe, with more than 6500 users (cities or municipalities) that committed to meet the European Union targets of CO_2 emission reduction.

1.2. Urban energy planning support tools

There exist a wide range of energy planning tools that can be used for decision support in energy planning, in the building sector. The following section lists examples of such tools, including their main characteristics:

SUNtool (Robinson et al., 2007) and its later successor CitySim (Robinson & Haldi, 2009) attempt to model and simulate energy flows of buildings. EnerGis (Girardin, Marechal, Dubuis, Calame-Darbellay, & EnerGis, 2010) calculates the minimum annual heat demands of buildings and displays the results in a georeferenced context. SynCity (Keirstead, Samsatli, & Shah, 2010) is a scenario development, simulation, and optimization tool that is used at a city scale. It focuses on urban energy systems aiming to achieve large reductions concerning the energy intensity of cities. UrbanSim (Waddell, 2002; Patterson & Bierlaire, 2010) is a scenario development and simulation open source tool that is used at a city scale to generate urban development scenarios based on market assumptions. CommunityViz (Kwartler & Bernard, 2001), a scenario development and GIS based decision support tool for land-use planning, is an extensions of the GIS software ArcGIS. SEMERGY (Mahdavi et al., 2012; Fenz et al., 2016) is a decision support tool that is specialized in building refurbishment decision making, at a building-level. It supports decision makers to define strategies concerning the optimization of the configuration of building components by finding an optimal trade-off between energy efficiency and cost. More comprehensive reviews of energy planning related tools are found in Connolly, Lund, Mathiesen, and Leahy (2010) and Loibl et al. (2015).

The tools addressed above provide a certain set of functions that respond to the specific requirements of their different users. Some of them, such as SEMERGY, can also be used in combination with the proposed solution in this paper. However, these tools do not fulfill at once all the main characteristics of urban energy planning support systems, which have been defined in a previous related work (Ouhajjou et al., 2013): (i) Supporting the perspectives of different involved stakeholders. (ii) Quantifying the impact of developed strategies and simplified presentation of impact (so that it is understood by all the stakeholders). (iii) Integration of the measures that compose the strategy, also in terms of stakeholders' implication. (iv) Ensuring the re-usability of the system in different cities that have different data availabilities or stakeholders.

The addressed topic in this article is not discussed from a multiple-criteria decision analysis (MCDA) point-of-view. While MCDA focuses on supporting the decision making process at the level of the decision itself, the proposed work focuses on presenting enough data to help the decision makers to discuss (in workshops) the potential decisions to be made. Hence, the proposed solution gives more attention to how to adapt the system to changing requirements, data availability, combining heterogeneous datasets and computation models. The decision support that is presented in this paper is based on modeling potential decisions of stakeholders. The logics for potential decisions (what makes a location good for a given measure) are obtained from the specific stakeholders that would use the system, then integrated within the rest of data before it is used. These logics are easily modifiable to cope with changing preferences and the diversity of stakeholders.

1.3. Objective & design concepts

The objective of this article is to show how to support a stakeholder-oriented approach in urban energy planning. This is achieved through the description of a stakeholder-oriented process that is implemented in a software tool. The development methodology of this supporting tool is described as well as its usage workflow. Later on, a more specific focus is given to how the process addresses the concerns of stakeholders (or representatives of stakeholders), that are typically using the developed tool in workshops in order to reach a common agreement on what measures to implement in which locations.

The design principles that have been taken into consideration are as the following, as discussed in a previous related work (Ouhajjou, Loibl, Anjomshoaa, Fenz, & Tjoa, 2014):

- Keeping the development of the system permanently open to change: given the data uncertainty, un-availability in different cities, this design principle allows to extend the system to cope with data availability problems, when it is to be used in a different city.
- Linking the domain concepts to the initial requirements: as the system is meant to be permanently extendible, this design principle allows the traceability of how the system fulfills the initial requirements.
- Including the notion of level-of-detail (LOD) of data: this design principle allows the integration of data that have different LODs. This is motivated by the data availability problems at the level of cities.
- Integrating different computation models: this allows the integration of existing computation models and the re-use of existing data sets, in order to save development efforts.
- Tracking the interactions between different objects and data properties: This concept is necessary to enable consistent operations among the different computation models that are used. This design principle allows the formalization of interactions and it is used by computation models to understand their mutual-interactions.
- Decoupling the interface of the system from the actual computation models that prepare all the data beforehand: this principle allows designing different interfaces that present the data according to the need of the users. Furthermore, given the large amount