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Research Paper

Spatial transition analysis: Spatially explicit and evidence-based targets for sustainable energy transition at the local and regional scale

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A R T I C L E I N F O

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A B S T R A C T

Climate change, depletion of fossil fuels, and economic concerns are among the main drivers of sustainable energy transition. Over the past decade, several regions with low population density have successfully transited towards renewable energy (for example Siena, Italy). In the Netherlands and other countries, more densely populated regions have drawn up ambitious targets for energy transition. Most of these transition targets lack empirical evidence with regard to spatio-technological feasibility. This lack of evidence may compromise energy transition if constraints are discovered *posteriori* and short-term milestones missed. To address this shortcoming, we propose an integrated approach. *Spatial Transition Analysis (STA)* can assist in defining spatially explicit and evidence-based targets for energy transition. *STA* combines quantitative modelling of energy potentials, qualitative spatial considerations for the siting of renewable energy technologies and comparative scenario development. The application of STA in a case-study (Parkstad Limburg, the Netherlands) revealed that the region has the potential to become energy neutral between 2035 and 2045. Examining and illustrating the different types of constraints as well as the possible choices between renewable energy technologies enabled stakeholders to start planning for energy transition and implementing first interventions. This shows that *STA* provides a solid framework to foster sustainable energy transition initiated by regional stakeholders and informed by local preferences.

1. Introduction

Climate change, depletion of fossil fuels and concerns about local economies are among the main drivers of sustainable energy transition (Bridge, Bouzarovski, Bradshaw, & Eyre, 2013). This transition is not limited to the transformation of energy infrastructure, but involves transformations of "the broader social and economic assemblages that are built around energy production and consumption" (Miller, Iles, & Jones, 2013, p. 135) and is being increasingly studied by social scientists, geographers, spatial planners, landscape architects and other environmental designers (see e.g. Stremke & van den Dobbelsteen, 2013; Sijmons, Hugtenburg, Feddes, & Van Hoorn, 2014). The part of the physical environment affected by energy transition is commonly referred to as 'energy landscape' (see e.g. Pasqualetti, 2013; Selman, 2010; Van der Horst & Vermeylen, 2011). In line with the European Landscape Convention, landscape refers to 'an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors' (Council of Europe, 2000).

In Europe, several regions have successfully transitioned towards renewable energy, for example Siena, Italy (Casprini, 2013) and Samsø, Denmark (De Waal & Stremke, 2014) − all of which have a low population density. In the Netherlands and other countries, more densely populated regions have defined ambitious targets for energy transition, within a relatively short period of time. Examples in the Netherlands are Stedendriehoek (Pijlman & Bosman, 2014) and the cities Utrecht (Gemeente Utrecht, 2011) and Groningen (Gemeente Groningen, 2008) aiming to achieve 100% energy or carbon neutrality by 2030 or even 2025. Energy neutrality refers to "the extent to which a district […] can supply itself with sustainable energy generated within the boundaries of that district" (Jablonska, Ruijg, Opstelten, & Willems, 2010, p. 1). Regions are often unaware whether spatial characteristics of the region are suitable to achieve energy neutrality (see e.g. "Energietransitienota Duurzame Energie Achterhoek", 2015; Pijlman & Bosman, 2014). Next, transition targets are often based on little evidence regarding technological feasibility. Furthermore, many targets are conceived without involving stakeholders. Considerations of stakeholders with regard to the way the energy transition should take place are not taken into account. Such bold and superimposed transition targets may compromise energy transition if constraints are discovered *posteriori* and short-term milestones are missed. To illustrate, the target of the municipality

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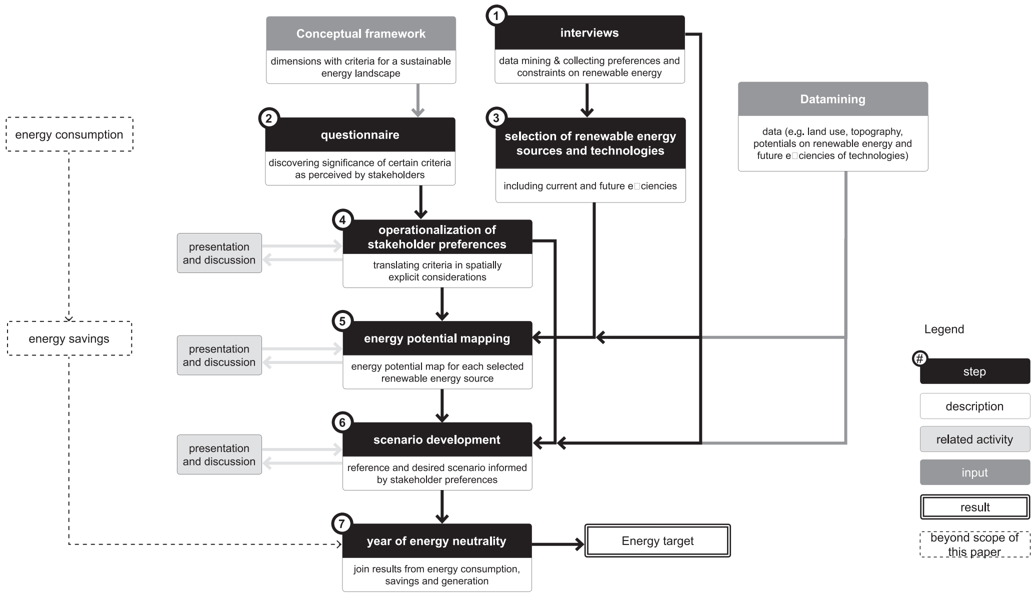

Fig. 1. Methodological framework for Spatial Transition Analysis (STA), revealing the sequence of and links between the seven steps needed to define energy transition targets.

Groningen (the Netherlands) has already been adjusted from 2025 to 2035 (Gemeente Groningen, 2011).

The urgent need to define realistic long-term transition targets and to take action was stressed again by the 2015 Paris Climate Agreement. In the Netherlands, the Dutch NGO *Urgenda*, together with 900 citizens, successfully filed the so-called Climate Case against the Dutch government (Urgenda, 2015). Energy transition has become a key challenge and (inter)national agreements need to be turned into regional and local targets.

To the best knowledge of the authors of this paper, no methodological framework exists that can help define energy transition targets that are spatially explicit, evidence-based, and informed by qualitative stakeholder considerations. The objective of this paper is, therefore, to close this knowledge gap, to present and discuss an integrated approach – *Spatial Transition Analysis (STA)* – that can be used to define targets for regional and local energy transition. To address the shortcomings of current practice, *STA* ought to be spatially explicit, evidence-based with regard to renewable energy technologies (RET), and inclusive of stakeholder values and preferences.

Several concepts, methods and approaches have provided building blocks for the research presented in this paper. Departing from the concept of 'energy landscape', Stremke (2015) introduced a conceptual framework for the planning and design of *sustainable* energy transition. He stresses that four dimensions (or types) of criteria should be addressed in the planning and design of sustainable energy landscapes, namely environmental, socio-cultural, economic and technical criteria. This typology will be revisited later in the paper.

Energy Potential Mapping (EPM) offers another building block for energy landscape research. This method is used to map and quantify technical energy potentials (Van den Dobbelsteen, Broersma, & Stremke, 2011). Wang, Mwirigi M'Ikiugu, and Kinoshita (2014) include biophysical and technical constraints that adversely affect renewable energy potentials. Stakeholder preference with regard to renewable energy technologies – another key constraint – is missing however.

Strategic planning and design provided the theoretical foundations of the research presented in this paper (see for example Albrechts, 2004). The *Five Step Approach* is a methodological framework for strategic design that has been applied to envision regional energy landscapes (Stremke, Neven, Boekel, & Koh, 2012). For this, three modes of change, namely current projected trends, critical uncertainties and intended change are integrated in a design process that explores alternative pathways for the realization of transition targets (Stremke, Kann, & Koh, 2012). In this paper the focus is on *how* such targets can be determined.

Advanced methods such as *trade-off analysis* (for example Burgess et al., 2012; Howard et al., 2013) and *multi-criteria decision analysis* (for example Grêt-Regamey & Wissen-Hayek, 2013) are complex and require vast amounts of data and resources. They can play an important role after transition targets have been defined and alternative interventions explored.

For the research presented here, literature studies and a case study (Yin, 2009) have been conducted. Insights from other closely related projects in the Netherlands, Germany, Austria and Denmark have been incorporated (for example, De Waal & Stremke, 2014). A case study was carried out in the Parkstad Limburg region (The Netherlands). The area selected consists of an agglomeration of three mid-sized cities and five rural municipalities. The research process was iterative in character and conducted in close collaboration with the regional and local initiators of energy transition as well as other stakeholders.

The second section of this paper delineates the methodological framework that can be employed to define energy targets. The third section illustrates these steps making use of materials and results from the *Parkstad Limburg Energy Transition (PALET)* project. Finally, the approach and the results are discussed in section four and conclusions drawn in section five.

2. Methodological framework for spatial transition analysis (STA)

This section gives a brief description of the methods and techniques needed to define energy targets at the regional or local level. The overall methodological framework and the links between the different steps are illustrated in Fig. 1. The aim, execution, input and output of each of the seven STA steps are addressed in the following sub-sections.