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Scaling up sustainable energy innovations

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ABSTRACT

Current electricity grids do not fit the needs and challenges of the 21st century, such as the need to transition to renewable energy sources and the variability in power supply concomitant with such energy sources. In this context, smart electricity grids have been proposed as a solution. A large number of pilots and experiments have been set up, but a key challenge remains how to upscale them. Upscaling is critically important to enable a wide-scale integration of renewable energy sources. This paper mobilises literature on the strategic management of experimental niches to explore the upscaling of smart grids in the Netherlands. On the basis of existing literature, a typology of four different patterns of upscaling is proposed: growing, replication, accumulation, and transformation. The relevance of this typology to understanding upscaling of smart grids is explored in a comparative qualitative case study design. On this basis we argue that the building of broad and deep social networks is important for growing and replication; articulating and sharing expectations is important for replication; and broad and reflexive learning processes are critical to transformation and replication. The paper concludes by arguing that these findings can provide important guidelines for future energy innovation policies.

1. Introduction

The idea of the traditional power grid is to deliver electricity from a few central generators to a large number of consumers (Fang et al., 2012). However, these hierarchically and centrally controlled power grids do not fit the needs and challenges of the 21st century (Güngör et al., 2011). Especially the large-scale introduction of renewable energy sources (e.g. wind and solar) into the grid, leading to fluctuating production, the increase of local energy production resulting in multi-directional flows of electricity, and new increased loads (e.g. from electric vehicles and heat pumps) are great challenges for the current electricity grid (Verbong et al., 2013). A new concept of next generation electric power system has emerged, namely the so-called ‘smart grid’, which can be defined as “*a system that includes a variety of operational and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficiency resources*” (Federal Energy Regulatory Commision, 2008, p. 17). In such an integrated system, information and communication technologies (ICTs) provide communication capabilities absent in traditional power grids. Smart grids are believed to increase the electric power quality and reliability, reduce greenhouse gas emissions, facilitate the expanded deployment of renewable energy, and provide cost reductions for all users along the energy value chain (Fang et al., 2012; Güngör et al., 2011; Schwister and Fiedler, 2015; Verbong et al., 2013).

Smart grids are a central element in European energy policies. For instance, in 2009 the European Commission established a Smart Grid Task Force to help shape EU smart grid policies and smart grids have received substantial support in European funding programs (Mosannenzadeh et al., 2017). As one of the EU member states, the Netherlands early on acknowledged that smart grids are to play a crucial role in energy transitions (CE Delft and KEMA, 2012; Taskforce Intelligente Netten, 2010), and initiated several programmes to experiment with smart girds. One of these programmes is the Innovation Programme Smart Grids (IPIN), which was established in 2009 by the Netherlands Enterprise Agency (RVO) and commissioned by the Ministry of Economic Affairs. The aim of the programme is to accelerate the diffusion of smart grids in the Netherlands (RVO, 2015a; Taskforce Intelligente Netten, 2010). Sixteen million euro was made available for this programme and since 2012, a total of 12 smart grid pilot projects have become part of this programme (RVO, 2011a). In September 2015 the IPIN finished. Most pilot projects had demonstrated positive techno-economic evaluations. For example, a pilot project in the island of Texel showed that households saved on average 5.1% on electricity and 10.3% on gas during the trial period (Hobbel and Rienks, 2016; RVO,

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2015b). Another project, the 'Powermatching City' pilot, showed that the benefits of smart grids for the Dutch consumer market could amount to as much as € 3.5 billion (DNV GL, 2015; RVO, 2015c).

However, despite such promising techno-economic performances of smart grids, a widespread transition to smart grids has not yet happened in the Netherlands. Innovation studies literature has indeed long recognised that techno-economic performances are important but not sufficient for successful diffusion or upscaling. For this reason, this paper is concerned with understanding the socio-institutional challenges of the transition towards smart grids. In doing so, this paper develops and tests an analytical typology of upscaling on the basis of socio-technical transition theory, and in particular strategic niche management (Kemp et al., 1998; Van der Laak et al., 2007). Hence, the contribution of this paper is not only empirical and policy-relevant, but also conceptual in developing a framework that can be useful for future research on upscaling of sustainable innovations. Despite a few notable exceptions (e.g. Jolly et al., 2012; Seyfang and Longhurst, 2015), little is known about how experiments scale up and which processes are important for the upscaling of experiments. The research question of this paper is: *How and why have smart grid experiments of the Innovation Programme Smart Grids scaled up in different ways?*

The remaining part of this paper is structured as follows. Section 2 reviews relevant literature and develops a theoretical framework for analysis. Section 3 discusses the methodology. Section 4 presents results and Section 5 compares across cases. Section 6 concludes and provides suggestions for further work along the lines of the analytical framework provided in this paper.

2. Upscaling smart grid experiments: a typology

Smart grid experimentation occurs in the context of wider sustainability transitions in the energy system. A transition can be defined as *"a society-wide change that involves fundamental and interrelated changes in technology, organisation, institutions and culture"* (Van den Bergh and Kemp, 2006, p. 1). Hence, transitions do not only require new technologies, but changes also occur in elements such as regulations, user practices, infrastructure, and symbolic meaning (Geels, 2002). To get a better understanding of the complex dynamics of transitions the Multi-Level Perspective (MLP) has been developed (Geels, 2002). The MLP framework builds upon evolutionary and social constructivist approaches to innovation and distinguishes three levels: niche, regime and landscape. There is a nested hierarchy between these layers, which means that regimes are embedded within landscapes and niches within regimes.

The MLP has been elaborated in more detail elsewhere (Rip and Kemp, 1998). The focal level of the MLP is the socio-technical *regime*, which refers to the incumbent socio-technical configurations and dominant way of realising a societal function (Smith et al., 2010). Regimes usually change incrementally, but more radical innovations can take place at the *niche* level. Niches are protective spaces that shield radical innovations from too harsh selection pressures in the regime, such as fierce price competition (Geels and Schot, 2007; Smith and Raven, 2012). Niche innovations are initially unstable socio-technical configurations with lower performance and are more expensive. In this way niches provide space for learning processes and building support for the innovation. Finally, the *landscape* level refers to the exogenous context of a socio-technical system. Landscape changes usually take place slowly and may end up taking decades, and are behind the direct influence of niche and regime actors (Geels, 2004).

The Strategic Niche Management (SNM) approach has been developed to further understand and govern processes of niche creation (Schot and Geels, 2008). SNM is not a simple technology push approach – which would argue that a focus on technical designs suffices. Sustainable development requires interrelated social and technical change. Thus, in niches not only the technological design, but also (new) institutions can be tested and developed. SNM distinguishes three critical processes that are important for successful development of a niche: *social network building, articulation of visions and expectations, and learning processes*. A key aspect of strategically managed niches is to design socio-technical *experiments* in such a way that they contribute positively to these three processes. Experiments can be defined as: *"inclusive, practice-based and challenge-led initiatives designed to promote system innovation through social learning under conditions of uncertainty and ambiguity"* (Sengers et al., 2016).

In the early phases of an innovation, the network of actors involved with the innovation in question is often fragile. Actors' commitments to the niche are at this point limited, because actors do not yet have vested interest and withdrawal does not result in large losses. Experimentation in projects brings new actors together and new social networks emerge (Raven, 2005). A social network is important to create support for the technology, facilitate interactions between stakeholders and provide necessary resources. Social network building contributes to niche development when, first of all, the network is *broad,* meaning that multiple actor types (firms, users, policy makers, academics, entrepreneurs, scientists, etc.) are included. The inclusive character of social networks is important, as multiple kinds of stakeholders facilitate the articulation of multiple, potentially conflicting views. Second, a network contributes to niche development when the network is *deep*, which means that actors should be able to mobilise commitments and resources within the networks (Schot and Geels, 2008). Large firms that support the incumbent technology often have enough resources to support the niche. However, these firms may slow down the development, because of vested interests in the incumbent technology.

Actors participate in experiments on the basis of visions and expectations, which provide legitimacy to invest time and money in a technology that does not yet have market value. Particularly when the technology is still in its early developments, *expectation articulation* is important to attract attention, resources and new actors (Schot and Geels, 2008). Furthermore, expectations provide direction to learning processes and contribute to successful development of the innovation when they are *robust*, which means that they are shared by many actors – the power of expectations increases when they are shared between people (Van Lente, 1993). Expectations also contribute to niche development when they are substantiated by tangible results from experiments. When more experiments, research reports, experts, and specialists support the actors' expectations, the *quality* of the expectation increases (Hoogma et al., 2002).

Learning processes are crucial because they enable adjustment of the technology and societal embedding to facilitate diffusion. A good learning process is *broad*, which means that it is not only directed to the accumulation of data and facts, but also focuses on the alignment between the technical (e.g. technology, infrastructure, and industrial development), and the social (e.g. user context, regulation, societal impact) (Van der Laak et al., 2007). Furthermore, a good learning process is *reflexive* (second-order learning) which means that there is willingness to change direction if the technology does not match the underlying assumptions. This means that learning is not just about instrumental learning about technological solutions, but also concerns learning about underlying assumptions and values; it is about changing the frame of reference and ways of looking at problems or solutions (Byrne, 2009).

These SNM processes are not isolated, but they interact with and influence each other (Geels and Raven, 2006; Raven and Geels, 2010). Nevertheless, niche innovations are rarely able to transform an established regime without broader forces and processes. Transitions come about through interactions between the three levels of the MLP: niches build up internal momentum, landscape changes put pressure on the regime and the regime gets destabilised and *windows of opportunity* are created for the niche innovations (Schot and Geels, 2008). When the key internal niche-development processes are present in the niches and when niches experience favourable external conditions in the regimes and landscapes, niche innovations can diffuse more widely into society