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Exploring sustainability transitions in the electricity sector with socio-technical pathways

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ABSTRACT

This paper analyses sustainability transitions in the electricity system, using recent theories on socio-technical pathways. The paper describes three possible transition pathways and indicates the implications for (grid) infrastructures. The 'transformation pathway' is characterised by a further hybridization of the infrastructure; in the 'reconfiguration pathway', internationalisation and scale increase in renewable generation lead to the emergence of a 'Supergrid'. The 'de-alignment and re-alignment pathway' is dominated by distributed generation and a focus on more local infrastructures. We suggest that this pathway, which involves a major restructuring of the electricity system, is less likely than the other two. The de-alignment and re-alignment pathway is therefore more dependent on external developments and/or strong policy interventions. All pathways, however, require major investments in infrastructure and innovative technologies.

1. Introduction

The energy sector faces serious problems, e.g. oil dependency, reliability and climate change. Large jumps in environmental efficiency may be possible with sustainability transitions, i.e. shifts to new energy systems. Hence, policy makers and NGOs show increasing interest in energy transitions. The Dutch government, for instance, gave transitions a central place in its fourth National Environmental Policy Plan, as did the Ministry of Economic Affairs in its recent Energy Report [1,2].

Transitions do not come about easily, because existing systems are characterised by stability and lock-in. This applies in particular to infrastructural systems like the electricity system. The sunk investments in technologies (power plants, cables and lines, transformer stations etc.), skills, social networks and belief systems complicate a swift shift to completely new systems. However, a major transition has occurred in the electricity sector in the EU during the last two decades: changes in the institutional framework have resulted in a shift from a system dominated by engineers to a market-based system, ruled by managers. But despite an increasing interest in renewable energy technologies, the recent transition has not (yet) contributed substantially to the 'greening' of electricity systems [3].

Several visions have articulated what a sustainable electricity system could look like in the future. Most popular are visions or scenarios with a central role for small scale or Distributed Generation (DG) like PV systems, urban wind turbines or small biomass plants. A couple of articles in *The Economist* can serve as an illustration. In August 2000 this magazine published an article on: 'The dawn of Micro Power', promising a more sustainable, cheaper and more reliable system [4]. A couple of years later *The Economist* wrote: "More and bigger blackouts lie ahead, unless today's dumb electricity grid can be transformed into a smart, responsive and self-healing digital network—in short, an energy internet" [5]. However, in another provocative article published in 2007 a grandiose plan was presented to link electricity grids all over Europe. The proposed Supergrid would enable wind energy to become one of the major suppliers of electricity, or the 'Star of the show', as they put it [6]. The Global Energy Network Institute

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goes even one step further by trying to combine both visions: "Research shows that the premier global strategy is the interconnection of electric power networks between regions and continents into a global energy grid, with an emphasis on tapping abundant renewable energy resources—a world wide web of electricity"[7].

It is difficult to assess the quality and value of such visions and scenarios [8]. In our view, most of them suffer from one or more problems: a) they tend to be more about 'end states' than about dynamic pathways towards end states, b) they focus too much on technological fixes and pay too little attention to social dynamics and contexts, c) dealing with discontinuities and transitions remains difficult in the scenarios literature [9] partly because it lacks a good understanding of socio-technical transitions, d) if there is attention for dynamics of change, the scenario conceptualization tends to be either exogenous, which is related to the typical 'scenario axes technique' that varies two macro-variables in a 2×2 matrix [10] or mechanistic, due to exclusive emphasis on economic mechanisms (prices, investments, supply, and demand); while external contexts and economic mechanisms *are* important, most scenarios pay insufficient attention to *endogenous* dynamics, which relate to beliefs, decisions, struggles and interactions between various actors and social groups, e) most scenarios focus on particular aspects of transitions, often technological change (which tends to be conceptualized via learning curves and/or R&D investments), rather than on changes in broad socio-technical systems, which not only include technology and markets, but also infrastructure, cultural aspects, regulatory paradigms and consumer behaviour [11].

Because of these problems, we use a different approach to explore future transitions in electricity systems. We are inspired by and build on the socio-technical scenario approach [12,13], which uses the multi-level perspective (see below), as scientific theory to conceptualize transition dynamics, focuses on socio-technical systems, pays attention to co-evolution and the role of actors. Our contribution to this approach is the introduction of new theoretical ideas about transition pathways [14], which provides a stronger theoretical logic for our scenarios. A similar approach has been adopted by Foxon et al. for developing transition pathways for the UK [15]. With our contribution, we aim to address the following research questions: (1) how can we analyse sustainability transitions for the electricity sector, with a particular focus on electricity generation and infrastructure and (2) who are the main actors in different transition pathways? To answer these questions, we will not present full scenarios, but only give brief indications of the main characteristics of these scenarios, the pathways leading to these scenarios and some implications for infrastructure development and policy.

2. Multi-level perspective and transitions

Academics show increasing interest in the dynamics of transitions and system innovations [16,17] and governance aspects [18]. An important theory in this respect is the multi-level perspective [19], which understands transitions as the outcome of multi-dimensional interactions between radical niche-innovations, an incumbent regime, and an external landscape.

Transitions are about changes at the meso-level of *socio-technical regime*, which consists of three dimensions: a) material and technical elements; in the case of electricity systems, these include resources, grid infrastructure, generation plants, etc., b) network of actors and social groups; in the electricity regime important actors are utilities, the Ministry of Economic Affairs, large industrial users, and households; c) formal, normative and cognitive rules that guide the activities of actors (e.g. regulations, belief systems, guiding principles, search heuristics, behavioural norms). Existing socio-technical regimes are characterised by path dependence and lock-in, resulting from stabilising mechanisms, e.g. vested interests, 'organizational capital', sunk investments, stable beliefs [19].

Niches form the micro-level, the locus where novelties emerge. Small market niches or technological niches act as 'incubation rooms', shielding new technologies from mainstream market selection. Such protection is needed because new technologies initially have low price/performance ratio. Protection comes from small networks of actors who are willing to invest in the development of new technologies. The macro-level is the *socio-technical landscape*, which forms an exogenous environment that usually changes slowly and influences niches and regime dynamics. The relationship between the three levels is a nested hierarchy (Fig. 1). Pioneers

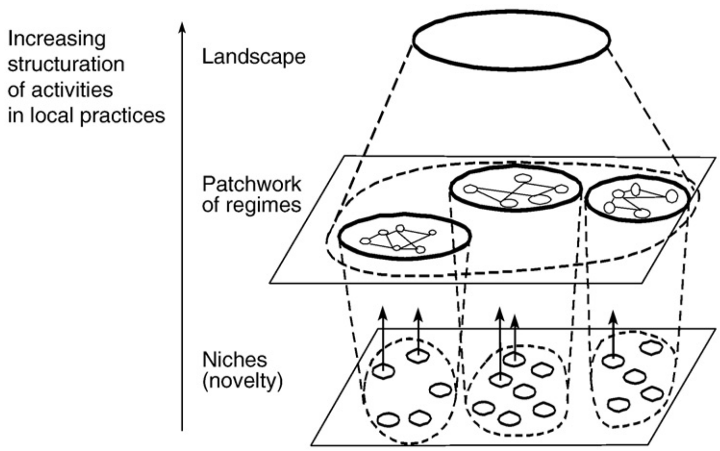

Fig. 1. Multiple levels as a nested hierarchy [18].