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Transmission transitions: Barriers, drivers, and institutional governance implications of Nordic transmission grid development

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ABSTRACT

Transmission grid development is key for the decarbonization of our energy systems, but has not been much addressed within the social sciences of energy studies. This paper addresses this gap and examines institutional barriers for developing the grid towards a decarbonized Nordic power system by 2050. The analysis focuses on current grid development practices from an institutional perspective to understand barriers and drivers to grid development for the case of Sweden. The results show that the transmission grid development regime is generally capable of implementing the grid investments needed to support a decarbonized Nordic power system, but that there are a few key barriers that need to be addressed. From this analysis we deduce possible governance options that could alleviate the barriers, enabling the development of the transmission grid that is needed for the Nordic power grid to become decarbonized by 2050.

1. Introduction

In the transition to a low carbon energy system, electricity plays an important role as a carrier of low-carbon energy [39,59]. This, in turn, implies a need for a well-developed grid infrastructure that can accommodate the successful integration of renewable power (such as biomass, on and off-shore wind power and solar power) in the electricity supply [26,57]. In the European Union, at least 20% of the energy used should come from renewables by 2020 [21]. This translates into a renewable share of 30–35% of all electricity production [19]. In the longer term, EU climate and energy policies aim to reduce CO_2 emissions by 80% before 2050 [20,22], and to achieve this the electricity sector will need to be 95–100% decarbonized [15]. In other words, Europe's contribution to tackling the climate change challenge implies a close to total penetration of low carbon electricity in the power system [35]. One of the frontrunners where such a goal is clearly in sight is the Nordic region [33]. The region also has a potential to play an important role in supporting decarbonization of the continental European power system, through export of low carbon electricity and balancing power [59,68].

From a Nordic perspective, the implications of the decarbonization goal can result in several different future grid developments. In Graabak and Warland [33], alternative strategies are described which we have used as a background to our analysis on how the Nordic power grid can be decarbonized by 2050. The strategies are built based on two uncertainties, first, the level of renewable electricity expansion (and – relatedly – whether nuclear power is maintained or expanded) and second, the degree of integration with continental Europe. Graabak and Warland model different scenarios to explore what these two uncertainties would imply in terms of transmission capacities in the Nordic power system and its integration with the European grid.

The first scenario describes a future where the Nordic power system works as one market, and load balancing mainly takes place between bidding areas in the Nordic countries. Increased power production using renewables is provided mainly by new windpower plants, particularly in the north of Norway and Sweden. The second is characterized by an increased integration of the Nordic and European power system. Load balancing takes place at a Northern European level through the focus on expansion and on interconnectors. This is supported by an increase in external transmission capacity of the Nordic region, which, in order to avoid bottlenecks, needs to be accompanied by an increase in transmission capacity also within the Nordic countries, especially in the north-south axis of Sweden.

In addition to these developments, a third and potentially more disruptive scenario has gained increasing interest recently. This is focusing on significant scaling, and ultimately dominance, of

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decentralized renewable electricity generation taking over more and more of the total installed capacity. Such a development is currently playing out in Germany through its *Energiewende* [31] and has already proven to pose serious challenges to grid operations as well as the utility sector [55]. If such a development came to dominate, it would change the power system in a more fundamental way than the other scenarios, moving away from the current highly centralized grid development and management to a transmission and distribution system with load balancing at a local scale [56]. However, transmission grid developments will still be necessary.

Significant political and analytical work has gone into understanding governance of the development of renewable supply technologies, i.e. how renewable electricity production can be scaled up and promoted as well as balanced in the grid (see [20,40,42,43,45,66]. Also the demand side is well studied, including technical solutions related to distribution (see [16,34,38,41,70,91]. However, far less has been written in the literature on the implications of decarbonization for developing and governing transmission grids (but see [32,68,76]. Still, it is widely recognized as a crucial concern: grid investments have not taken place at the required pace and they need to intensify if Europe is to meet its targets [11].

Research on grid development is dominated by the disciplines of energy economics and engineering [75], which tend to view grid development as an issue predominantly to do with regulations, market potential and investment [10,46]. In the social sciences, a body of research on local public resistance to grid development has emerged (e.g [4,9,17,44,49,50,68], whereas research into grid politics, planning, and governance at national and international level has been scarce (but see [8,13,64]. This paper aims to contribute to the latter body of work and also to the research agenda suggested by Sovacool [74] and Puka and Szulecki [64] on the underlying social explanations behind the too-slow development of the transmission grid in many places, despite the widely agreed benefits of it.

Thus, the aim of the paper is to contribute to filling the gap in social science research related to grids by analysing the institutional barriers to developing the transmission grid. It examines barriers and drivers within the institutional system around grid planning and development and it also suggests governance measures that could help overcome key barriers.

1.1. Delimitations

Our empirical study focuses on the case of Sweden, where, regardless of choice of strategy, grid development is needed. Sweden's power system is almost fossil-free due to its hydropower and nuclear power, but because Sweden's power system is part of an integrated Nordic power market, Sweden needs to look at development paths that will strengthen the capacity for renewables also in neighbouring countries. The Swedish transmission grid's capacity to integrate with the Nordic market is therefore important in order to decarbonize the Nordic power system by 2050.

The paper addresses development of the transmission grid, which is defined as the large "back-bone" network of lines and stations used to transmit electricity from power plants to substations. The power distribution system comprises two additional levels: the regional and local distribution grids. From the substations, the distribution grid distributes the electricity to the end-users (i.e. the transmission grid never reaches the end users) [77]. Developing the transmission grid is central to achieving decarbonization targets in the power system, both in order to enable the connection of new renewable energy generation sites, and to provide system stability and security of supply in view of variable renewable energy production (see [10,16,64]). However, this study does not go into connections to new production sites, distribution grids or decentralized smart grids with advanced demand management, new storage and generation (e.g. [24,60,71]).

2. Theory and analytical framework

We draw on institutional theory to elaborate on drivers and barriers to developing the transmission grid so that it can accommodate the projected increases in renewables and European integration (see e.g. [25,57,67]). We also use concepts from the multilevel perspective (MLP) on socio-technical systems change [29,30] to classify drivers and barriers for the transmission grid regime. MLP conceptualizes the dynamics of socio-technical transitions, which emerge from the interaction between three societal levels: *niches* – the micro level of innovations and deviations, *sociotechnical regimes* – the structures that provide stability to the system, and *landscape* – the macro level trends, i.e. the external environment [29].

Niches are spaces where radical novelties grow that deviate from the logic of the regime. These novelties can be behavioral, technology driven or take the form of new business models. The niches are initially unstable and vulnerable and require protection and nurturing [29,47].

Regimes are the interrelated set of a) *tangible* (material) *elements* of the system that provides societal functions such as mobility, heating, sustenance/food and light/power. This may include production facilities, supply chains and infrastructure; b) *actors and social groups*, who reproduce and maintain the system elements, e.g. firms, universities, consumers/users, policymakers, wider publics/stakeholders, NGOs; c) the set of *rules and institutions,* which shapes the beliefs and mind-sets as well as planning and decision making practices, habits, behaviours, interpretations, of different actors (in the literature, sometimes the "regime" identity is delimited to c) [29].

Landscape factors are drivers of change external to the regime and therefore beyond the direct influence of the regime. They include higher level and macro-political frameworks e.g. at the EU level or the global climate change agenda, but also market and cultural patterns. Changes in landscape can be in the form of sudden external shocks (war, crisis) but also as more gradual changes (oil prices, regulatory change) [29]. Landscape factors are not always macro-level. Also public opinion, at different levels, should be considered landscape factors as they are external to the actors in the regime. This means that local resistance to development, a common feature in power infrastructure processes, is a landscape signal and cannot be overcome through governance measures by the actors within the regime.

The regime is stable but constantly pressured by a blend of new landscape signals. These include shifting global priorities and EU level policy paradigms, as well as political and non-political leadership on decarbonization at the national level. Analytically, it can be difficult to distinguish between landscape signals and regime drivers and barriers. Landscape signals gradually influence the regime and translate into drivers (or barriers) of change.

MLP studies have traditionally tended to focus on niches and niche penetration as drivers of change [28,65], yet there is also a small but growing body of research on how transitions can be driven from *within* a regime (see [27,25,65,68]). This approach fits well with the analysis of transmission grids which feature long-lived infrastructure and technologies as well as a stable configuration of actors and rule systems. The transmission grid system in developed countries are mature systems with a long history of gradual institutionalization of mutually reinforcing actor configurations, rule systems and technologies [37,90]. In this study, we focus on transmission grid development through a Nordic strategy or a strategy focusing on deeper integration with Europe, these sce-