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Promoting low-carbon transitions from a two-world regime: Hydro and wind in Québec, Canada

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HIGHLIGHTS

- A socio-technical exploration of wind and hydro synergies.
- Discusses technological complementarity in sustainability transition frameworks.
- History of Quebec hydro and wind energy development.
- Details transition pathways and niche shielding, nurturing, and empowering dynamics.
- Explores potential futures of wind-hydro development block.

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ABSTRACT

Technical synergies exist between wind energy and hydroelectricity because conventional hydro plants can effectively store wind in their reservoirs. However, the presence of low-cost, lowcarbon hydro resources could also inhibit wind energy development. This paper examines the tension between wind-hydro complementarity and competition through a case study of Québec, Canada. The case highlights that debate over the societal conception of the hydroelectric system, or "regime", and its potential to enable wind, creates different innovation pathways. The paper calls attention to the value of shielding and nurturing renewable energy niches to create transformative pressures that activate the complementary potential of existing technologies. To maintain momentum a wind-hydro development block will need to expand towards incorporating new technologies and geographies.

1. Introduction

Preventing dangerous climate change requires transitioning from conventional fossil fuel to low-carbon technologies. New renewable energy sources can significantly reduce greenhouse gas emissions (GHG) (IPCC, 2011). However, the variable output of sources such as wind is often presented as a barrier to large-scale diffusion (IEA, 2011; Sovacool, 2009). Places like Canada and Norway are already endowed with electricity systems based on waterpower. In addition to generating renewable, low-carbon electricity, traditional hydro resources could complement newer renewable energies by balancing their resource variability. As stated in an International Energy Agency report, "the inherent flexibility of [hydro] generators and the potential for energy storage in their reservoirs make them well suited to integrate wind into the power system. As wind penetration increases, the agile hydro generation can address wind integration impacts and this service represents an economic opportunity for many hydro generators" (Acker, 2011, xv). Due to these distinctive technical features, hydroelectricity could play a role in promoting global low-carbon *transitions* by generating synergies with variables renewables such as wind.

Even though there are potential technical wind-hydro complements, actors within hydro-rich jurisdictions will need to adapt network operations, find political and social support for this technological configuration, and change institutional structures where necessary. It might be difficult to build sufficient societal momentum. For instance, Gullberg's (2013) study on the political feasibility of Norway's hydro resources acting as a "green battery" found insufficient actor support, in the short-term.

In Canada, weak inter-industry linkages from natural resource industries, such as hydroelectricity, is a traditional problem (Watkins, 2007). Hydroelectricity has been successful in complementing the development of consulting engineering (Niosi and Faucher, 1987) and attracting downstream industries like aluminum (Dales, 1957; Carpentier, 2006). However, hopes that hydro would enable secondary manufacturing expansion have gone unrealized (Froschauer, 1999). With climate change, natural resource linkages that support low-carbon technologies should be explored (Haley,

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2011). To date, no study in the Canadian context has investigated the prospect of complementary linkages between hydroelectricity and other renewable generation technologies from a socio-technical perspective.

This paper will use a case study of the Canadian province of Québec to consider how and why complementarity is achieved between wind and hydro technologies and to explore the factors that induce or block wind development within a hydro-intensive system. It will outline the treatment of technological complements in transition theory and provide a research approach to explore the characteristics of Québec's hydroelectric system and the history of wind energy development, thus far. It will discuss Québec's transition pathways and the factors that enabled wind energy, and then consider theoretical and policy implications. The paper finds that wind-hydro technological complements are possible, but are activated through tension filled technical, social, and political processes.

2. Transitions, niches, and technological complementarity

Low-carbon transition studies are interested in processes of change. In place of economic approaches emphasizing equilibrium, transition scholars look to evolutionary economic concepts (van den Bergh et al., 2007). Evolutionary frameworks examine actor searches for new technologies and organizational routines. Technological and organizational choices then face selection pressure from existing policies, markets, and other characteristics of the structural context, or selection environment (Nelson and Winter, 1982). Moreover, socio-technical theorists emphasize that elements such as cultural symbols, regulations, and user practices influence transitions alongside technical changes (Bijker, 1995). The *direction* of change is shaped by multiple interactions between actors following existing routines and undertaking new searches, using the social and technological elements available to them. Rip and Kemp (1998) outline how different socio-technical *configurations* result in pathways or trajectories towards sustainable or unsustainable futures. Policy analysis from an evolutionary perspective considers the consequences of different pathways, and the potential to change pathways by creating new system configurations (see Lehtonen and Kern, 2009).

The multi-level perspective (MLP) helps represent and analyze complex social and technical interactions (Geels, 2002). The MLP describes transitions with reference to three socio-organizational levels: regime, niche, and landscape. The *regime* outlines the dominant technological trajectory and accepted social practices involved in the provision of a societal function or service, such as electricity or communications. Geels (2006b) says a regime's structural elements consist of technologies, organizational actors, and rules or institutions. The *niche* is a space, protected from the selection pressure of the regime, where novel innovations can improve their performance. The *landscape* refers to macro phenomenon such as global events and cultural values, and can be treated as exogenous changes that influence the other levels. Transition patterns are explained via landscape pressures creating an opening within the regime for the adoption of niche-level innovations. Geels and Schot (2007) outline different patterns based on the timing and nature of interactions between these three levels.

Smith and Raven (2012) suggest a framework to study the development of niches within transition processes. They ask where niche protection comes from and how niches evolve out of their protected space. They outline three functional properties that niches play in transitions: shielding, nurturing, and empowering. *Shielding* is the process that protects new technologies from regime selection pressure. They discuss *passive shielding*, where protected spaces exist because of contingent reasons such as geographic separation or institutional spaces such as consumer networks or public support for research activities. In contrast, *active shielding* results from actors strategically and deliberately creating protected spaces through policy interventions and political advocacy. *Nurturing* is a process that supports the development of the innovation, so it can increase its innovation capabilities or performance. Strategic Niche Management (Schot and Geels, 2008) and Technological Innovation System approaches (Bergek et al., 2008; Hekkert et al., 2007) outline activities or processes that strengthen technological performance. For example, technical and social learning; the creation of expectations and visions, or guidance of the search; and the creation of networks to share knowledge, build up human resources, and establish political actor coalitions. Finally, *empowering* refers to interactions between the niche technology and its wider regime environment. Innovations become competitive within the established selection environment (labeled *fit and conform*) or the niche influences the regime selection environment in a way favorable to itself (labeled *stretch and transform*). Smith and Raven emphasize that these processes are shaped by power struggles, and the agency of niche advocates. Actors seek to achieve institutional reforms by creating political narratives about the character of “good” performance, by “strategically re-telling the past to make new sense of the present and envision alternative futures” (Smith and Raven, 2012), and through claims about the niche in relation to the regime.

The technological histories that informed the MLP (see Geels, 2005, 2006a, 2006b) as well as studies in development economics (Chang, 2008) highlight the role of niche protection. However, since a political process often establishes protection it can be difficult to remove protection at the appropriate time (Krugman, 1987). Smith and Raven note that transition policy should focus support on niches accumulating “innovation capabilities”, and suggest developing political institutions that can avoid capture by vested interests.[1] Moreover, empowering could maintain protections because they are institutionalized in a new regime configuration (Verhees et al., 2013). For instance, to promote a democratic, resilient, and socially acceptable energy system, a higher price paid to community energy projects might become routine and no longer be viewed as a subsidy.

The interest in niche developments stems from the understanding that the regime is not an optimal equilibrium, but rather the dominant structural configuration at a moment in time. A regime configuration could create socially undesirable trajectories, akin to problems resulting from lock-in or path dependence (Arthur, 1989; David, 1985). In the climate change era, the regime could promote carbon lock-in (Unruh, 2000). Thus green niches are frequently studied as an alternative to fossil based energy systems (Verbong and Geels, 2007; Hofman and Elzen, 2010).

While the dominant transition storyline involves niches “constructed in opposition to incumbent regimes” (Smith, 2007), transition typologies also include the potential for regimes to adopt symbiotic niches to solve particular problems (Geels and Schot, 2007). In addition, innovation scholars highlight technological complements within larger systems. Rosenberg (1982) emphasized that a technology's full contribution is often not limited to its immediate production performance, but its influence on larger systems through complements with other technologies and linkages with other industries. Sandén (2004) discusses bridging technologies capable of molding structures towards sustainability.

[1] See Jacobsson and Bergek (2011) on the need to study politics and public administration issues.