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# Critical choices and the politics of decarbonization pathways: Exploring branching points surrounding low-carbon transitions in Canadian electricity systems

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ABSTRACT

Transition pathways have attracted increasing interest as a useful analytical lens through which to capture the interlocking processes, patterns, and directions that might constitute substantial movement toward sustainability. While recent research has elaborated the political character of pathways, there is still room to further scrutinize the role of *critical choices* and *branching points* in defining diverging pathways. Contributing to the growing body of research on pathways, this study develops an approach that: (1) elaborates the dynamics that open branching points and (2) illustrates how critical choices help define the direction taken at these openings, giving rise to diverging decarbonization pathways. As part of this, the contested nature of critical choices is examined, revealing how actors struggle to shape possible trajectories. This approach is demonstrated by exploring unfolding low-carbon pathways in Canadian electricity systems, drawing lessons for the practice and theory of pathways. In particular, findings indicate that attending to branching points more explicitly exposes the implications and trade-offs embodied within choices by linking near-term decisions to long-run low-carbon configurations.

## 1. Introduction

Mitigating the most serious impacts of climate change implies a radical transition from high-carbon energy configurations to low-carbon arrangements by mid-century. Over the past decade, transition perspectives have emerged as an increasingly important research paradigm for contemplating this societal challenge [1]. *Transition pathways*, in particular, have attracted rising interest as a useful analytical lens through which to capture the interlocking social and technical processes, patterns, and directions that might constitute substantial movement toward sustainability [2,3]. Moving beyond traditional forward-looking techniques, transition pathways draw lessons from historical episodes of change in order to embrace complexity and the plurality of possible co-evolutionary changes in practices, rules, actor networks, technology, and culture that are likely to shape future low-carbon transitions [4]. While some analysts have focused on emerging innovations and the protected niches within which they develop as key transition pathways [5], others have developed typologies that offer a more differentiated understanding of the potential origins, influences, and directions of change [6,7]. Extending this work, more recent studies highlight how pathways are shaped by struggles among interests [8], continual agent-structure interactions [9], and sequences of decisions at branching points [10]. These contributions suggest that pathways not only relate to broad patterns and directions of change but also concern sequences of "decision making at critical points" [10]:156 and "rounds of moves and counter-moves" by contending actors [9]:898, particularly around key sites of contestation (e.g., infrastructure investment). Similarly, research bridging transition and discursive perspectives indicates that continual processes of contestation over energy choices and low-carbon pathways often take the form of framing struggles among competing actors [11]. Indeed, contending material interests, frames of reference, and visions for the future are at least as important for critical choices around energy as institutional and infrastructure rigidities [12]. Yet, while these contributions point to the inherent political character of transition pathways, there is still room to further scrutinize the role of *critical choices* and *branching points* in defining diverging pathways as well as the way in which these sites of contestation are negotiated over time.

Contributing to the growing body of work on transition pathways, this study develops an approach that: (1) elaborates the dynamics that open branching points and (2) illustrates how critical choices help define the direction taken at these openings, giving rise to diverging

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decarbonization pathways. In doing so, we explore socio-technical patterns and pressures in electricity systems (illustrated by regional systems in Ontario and Quebec, Canada) and identify a series of critical choices (out to 2035) that have implications for the direction of long-term low-carbon pathways for electricity configurations (out to 2050 and beyond). Given the centrality of electricity systems for long-term societal decarbonization, we focus on electricity configurations and their linkages to emissions reductions in broader energy systems (e.g., transport and heating). Indeed, research on decarbonization pathways [13] suggests that electricity systems will need to meet vastly growing demand (due to the electrification of other energy end-uses, for instance) while simultaneously enabling rapid low-carbon system change.

This study proceeds in the following fashion. The paper begins by discussing the analytical approach, which draws together different perspectives on transition pathways. This approach is then applied to examine the socio-technical patterns, emerging pressures, critical choices, and branching points surrounding decarbonization pathways for electricity systems in Ontario and Quebec. The paper concludes by contrasting potential low-carbon pathways for the selected jurisdictions, drawing lessons for both future research and governance.

## 2. Critical choices, branching points, and pathways

This study draws upon diverse insights on transition pathways in order to explicate the role of critical choices and branching points. Transitions can be understood as long-term co-evolutionary processes involving the reorientation of one or more socio-technical systems such as energy or transportation [1]. These processes are often conceptualized in terms of interactions among three dimensions: the regime, niche, and landscape. The regime represents the dominant social (e.g., institutions) and material (e.g., infrastructure) configuration through which a societal function is met. The regime displays path dependent characteristics as deeply embedded social and material structures, resources, and power relations constrain current choices in a fashion which tends to reproduce existing patterns. Niches, on the other hand, embody emerging innovations along with their supporting actor networks, which are often envisioned as the loci of more radical change. The landscape represents broad developments such as shifting cultural, political, and economic conditions. Historical analysis has suggested socio-technical transitions come about when landscape developments and internal issues put pressure on the regime, resulting in windows of opportunity through which niche innovations can emerge and modify system configurations [14]. Other work, however, also points to the importance of niche-regime symbioses and even regimes themselves in driving transformations [6,7], prompting a more differentiated understanding of the ways in which transitions may unfold.

In line with this more differentiated view of transitions, a variety of studies have adopted the concept of “pathways” to engage more deeply with the plurality of low-carbon possibilities [2,3]. The growing body of work on pathways draws upon and complements scenario approaches (see [15] for an insightful discussion of low-carbon scenarios), which often serve as an input for applications of pathways [16]. Yet, studies that apply a pathways approach deviate from traditional scenarios in important ways, including their linkage to historical, prospective, and backcasting (i.e., working backward from a particular emissions target or technological configuration as a set endpoint) techniques [3]. And, from a conceptual standpoint, pathways possess distinct attributes and functions which are being leveraged by diverse research strands to call attention to different dimensions of low-carbon transitions (consider [2] for a discussion of biophysical, techno-economic, and socio-technical conceptions of pathways). Here we draw upon the *socio-technical conception of pathways* to embrace the “unfolding socio-technical patterns of change within societal systems as they move to meet human needs in a low-carbon fashion” [2]:39. In this view, the emphasis is on the way societal system configurations move from one arrangement to another over time by attending to multi-level interactions and co-evolutionary patterns.

Broadly, transition scholars have deployed socio-technical pathways to: (1) characterize patterns of historical system change ; and (2) provide insight into future sustainability transitions . With respect to the former, a prominent strand of research focuses on developing pathway typologies to elaborate the different multi-level patterns that may characterize transitions [6,7,9,17]. From this body of work, several important insights are central to our discussion. First, pathways are not comprised of one dominant pattern (e.g., niche-driven change) but rather involve a plurality of possibilities that can manifest in vastly different directions of change. In this way, pathways are uncertain as they involve complex and cascading interactions among different potential developments and interventions across multiple levels. Second, transition pathways embody both processes of continuity and discontinuity. As they describe the movement of socio-technical configurations over time, pathways exhibit the relatively well understood characteristics of path dependence and momentum [19]. However, they also display path creation tendencies that permit for the possibility of more radical change. Geels et al. [9], for instance, suggest that pathways should not be viewed as entirely self-reinforcing but rather require continuous enactment by actors (as agent behavior is influenced by and continually reproduces and produces rule systems). In this fashion, pathways are not only shaped by entrenched structures, historical contingency, and chance exogenous developments but are also endogenously influenced by contending actors as they leverage their resources (ideational and material) to frame problems and influence solutions [20]. And, as recent work shows, these competing actors often possess fluid strategies and positions rather than rigid alignments with regime or niche [21]. Third, pathways are deeply temporal [22,23] as historical contingencies, context, and deliberate action interact to modulate the shape and pace of transitions. That is, pathways involve the interplay among past, present, and future socio-technical patterns in specific contexts as sequences of choices are layered over time, creating cascading effects that set the conditions for future rounds of action.

With respect to approaches that focus principally on future transition pathways, two central strands of research have attracted growing interest. First, *socio-technical scenarios* [24] are a foundational technique for exploring future system change. According to Hofman et al. [25], socio-technical scenarios are distinguished from traditional scenario methods in that they more explicitly engage with the co-evolution of society and technology, drawing insights from innovation studies and sociology (consider [25] for a more extensive discussion of socio-technical scenarios and how they deviate from more traditional scenario methods). Often linking to the multi-level perspective and the typologies it has inspired, socio-technical scenarios focus on exploring “the way linkages between the different levels may set in motion transition paths” [24]:655. Complementing traditional scenario approaches, the aim here is to produce plausible narratives about the future co-evolution of society and technology as low-carbon transitions unfold, extending and perhaps challenging more technically-focused diffusion trajectories [26].

Building on socio-technical scenarios, a second research strand more explicitly develops an approach to explore pathways [4]. Here, the essential analytical task is to characterize multi-level interactions and specify those that may give rise to or influence pathways. As part of this, there is an effort to focus more closely on governance, highlighting the way in which pathways are shaped by competing orientations linked to diverse societal interests [18]. Perhaps most importantly however, Foxon et al. [10] elaborate how pathways “reflect the outcomes of multitudes of decisions made by interacting actors along the way”. Invoking the concept of *branching points* [27], they demonstrate how actors can shape the orientation of pathways by influencing decisions around the renewal of institutional commitments and infrastructure at key moments in time. Acting as an important analytical complement to path-dependence, branching points represent potential openings in established trajectories where multiple alternative choices