Politics and technology: capturing the state to accelerate socio-technical transitions for sustainability

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1. Introduction

This paper explores the roles played by politics and technology (and the interplay between them) in sustainability transitions. More specifically, it discusses the essential role of politics, the state and technology in achieving transitions towards sustainable development in the area of energy, and discusses examples of emerging sustainability transitions witnessed in some developed countries over the 30 years since *Our Common Future.*

Our Common Future was essentially a programme for *political* action. It urged all nations to start on a transition towards sustainable development defined by global limits and social justice within and between generations. Key to the concept of sustainable development in *Our Common Future* was 'the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs' (WCED 1987, p. 43). Despite its importance, this critical concept was not explicitly defined or elaborated in any detail in the Report. Yet other passages make clear that the author's accepted that there were absolute environmental limits, while arguing that those limits were mediated by technology and social organization. Thus the development of technology and the adjustment of social organization were critical to managing human impacts on the biosphere.

Politics was both an element of social organization (which also included economic practices and institutions, social structures and norms, and so on) and a critical mechanism by which societies could consciously adjust social organization and orient technological development down certain desired pathways. Sustainable development was characterized as a transformational process: '[d]evelopment involves a progressive transformation of economy and society' (WECD 1987, p. 43). For energy, it was argued, 'the period ahead must be regarded as transitional from an era in which energy has been used in an unsustainable manner', thus requiring 'profound structural changes in socio-economic and institutional arrangements' in order to 'transition to a safer, more sustainable energy era' (WECD 1987:

201). In the words of the Commission, renewable energy ‘should form the foundation of the global energy structure during the 21st century’ (WECD 1987, p. 195).

Even today everyone does not share this vision. A ‘low carbon transition’, for some, will allow room for fossil fuels in the future energy mix through an application of carbon capture and storage (CCS) (e.g., Bataille, Sawyer, and Melton 2015). Others emphasize the importance of nuclear energy (e.g., UK Government 2017; Trottier Energy Futures Project 2016). While many believe a low carbon transition equals a future energy mix that is almost exclusively renewable (e.g., Jacobson et al. 2017). There are champions of centralized and decentralized models of energy provision, and the relative significance of demand management and energy efficiency are also contested (Lilliestam and Hanger 2016). This is to say nothing of the alternative understandings of the impacts the various spheres of social life -- transport, the built environment, agriculture, domestic consumption, etc. These conflicting views on technologies and the visions they entail are present in many countries, and they can be seen as reflections of different actors’ underlying interests as well as ideas about what a low carbon transition implies, how it should be achieved and indeed what it is possible to achieve (Rosenbloom 2017). Yet they all share a belief in technological development and importance of technological choices (Rosenbloom, Haley, and Meadowcroft 2018; Foxon et al. 2013).

What then, determines what is done in order to ‘develop the potential for renewable energy’ (WECD 1987, p. 195)? This paper explores three hypotheses in order to answer the question. The first is that *both* politics and technology are crucial for a transition to a sustainable development trajectory. While this statement appears relatively bland, it can be understood as a rebuke to those who see solutions just from technology and markets, as well as to those who seek answers only in politics and social adjustment. The second is *that politics significantly influences technology choices.* As John Dryzek, puts it: ‘most of the important things that happen to [the environment] are the subject of politics, and the target of public policy’ (2013, p. 6). The third is that the most promising emerging sustainability transitions witnessed in the energy field since *Our Common Future* are *technological* and are to a large extent driven by *politics* and *states*. That is, political action and the use of the state apparatus has played a pivotal role in developing niches and scaling up emergent technologies (Raven et al. 2016).

The paper is somewhat optimistic, arguing that it is actually possible to decarbonise the global economy. How fast this can be done is another question (Sovacool 2016; Smil 2016). But making progress requires capturing the state (at various levels) through politics and the use of the state apparatus to enhance technological development and deployment. A number of forces can bring pressure to re-align state policies, including social movements, inputs from science and the scientific community, international agreements and the action of other states, the state bureaucracy and economic interest linked to emerging technological configurations. *But political parties and party coalitions play the key role in the capture of the state*. *And politics is what determines policy*. Many – if not most – states are currently captured by (or at least form high level politico-economic alliances with) incumbent industries like the fossil fuel industries and lobbies (Geels 2014; Rosenbloom and Meadowcroft 2014). For decarbonisation to succeed, this alliance has to be broken, and this can only be done by politics and technology. The argument is not that this will automatically solve all sustainable development issues (like social justice, poverty eradication, health care for all, or slowing biodiversity loss) but that it may help mitigate the specific issue of climate change.

The remainder of the paper is organized as follows. The first part of the paper gives a brief overview of the current energy situation and the challenges facing the energy transition. The second part outlines the framework for the analysis, a modified version of the multilevel perspective (MLP) with a distinct political landscape and the state as an important *political* actor. The third part then goes on to examine some of the emerging transitions witnessed over the last 30 years, focusing on some rapid transitions discussed by Sovacool (2016): the coal phase-out in Ontario, and the move towards electric vehicles (EVs) in Norway. These are discussed from the perspective of politics, the state, different actors' interests and ideas, the institutional embedding of various technologies and the different policies driving these low carbon technological transition strategies. The last section reflects on the role of politics and technology in sustainability transitions in energy.

2. Accelerating a sustainable energy transition

The renewable energy sources growing fastest today (wind and solar) were still a dream in the early 1970s. The following from *Only One Earth* (1972) by Barbara Ward and René Dubos reflects the status of renewable energy sources back then:

> … the sun itself, safely shielded from us by banks of oxygen and ozone, streams down day after day its inconceivable energies upon our planet. Is there no more direct way of plugging ourselves into these daily supplies of which we use only one-third of 1 percent? If any such technological breakthrough proved possible, we could then look back upon man's rapid exhaustion of fossil fuels as simply the 'self-starter' for his vast energy system which, invented by the technologies which fossil fuel made possible, plugs the planet into cosmic supplies and carries it along at acceptable levels of self-renewing and inexhaustible energy (Ward and Dubos 1972, p. 128).

From almost nothing in the 1970s, solar and wind has grown rapidly, especially the last decade. Newly installed renewable power capacity set new records in 2016, increasing the global total by almost 9% relative to 2015. Solar PV accounted for about 47 percent of the total additions, followed by wind power at 34 percent and hydropower at 15.5 percent. And even more important, for the fifth consecutive year:

> … investment in new renewable power capacity (including all hydropower) was roughly double the investment in fossil fuel generating capacity, reaching USD 249.8 billion. The world now adds more renewable power capacity annually than it adds in net new capacity from all fossil fuels combined (REN21, 2017, p. 7).

Still, wind, solar, biomass and geothermal power only made up 1.6 percent of the global total final energy consumption in 2015. All renewables together (including traditional biomass, hydropower, geothermal, solar, solar heat, and biofuels for transport) constituted 19.3 percent of the global total final energy consumption in 2015 (REN21, 2017, p. 30). Thus, the world is still overwhelmingly a fossil-fueled world (Smil, 2016). A primary reason for the low number is the overall growth in energy demand, which 'counteracts the strong forward momentum for modern renewable energy technologies' (REN21, 2017, p. 30). So – in parallel – the world has witnessed continually increasing consumption of fossil fuels. Fossil fuels constitute almost 80 percent of total global energy consumption, making the transition away from fossil fuels a formidable task. Scale actually matters. Hence, Smil (2016, p. 196) argues that 'the existing global energy system based on fossil fuels comprises the largest, and the most expensive anthropogenic infrastructure that cannot be either written-off or displaced rapidly'.

Historically, all global energy transitions have also been gradual, prolonged affairs. Smil (2016) observes that after coal reached 5 percent of the global primary energy supply (around 1840) it took another 35 years to rise to 25 percent and 60 years to reach 50 percent supply. It took 40 years for crude oil to go from 5 to 25 percent of the global primary energy supply (1915–1955) and it took 60 years for natural gas. And since supply has become more diversified, Smil (2016, p. 195) argues that 'no primary source will again provide most of the total supply as did traditional biofuels or coal', effectively ruling out a complete transition to renewables as envisioned, for example, in GreenPeace's Energy Revolutions Scenario (Krewitt et al. 2009) or the Solutions Project (Jacobson et al. 2017).

And yet, despite this, energy systems in various part of the world have been undergoing a transition since the end of the last century. There are now clear signs of rapid developments in terms of renewable energy deployment, most notably in Germany, Denmark, Sweden, China and parts of the US to mention but a few. This for a number of reasons. Concern with climate change and mitigating GHG emissions, local air pollution, high fossil fuel prices (before the collapse in the oil price in 2014), the rapidly falling costs of renewable energy, local value and jobs, energy security, the 'transformative potential of new technologies', such as decentralised electricity generation and the use of information and communication technologies (ICT) in the energy sector, are all drivers of renewable energy deployment (Schreuer, Rohracher and Späth, 2010, p. 649; REN21, 2017, p. 9).

There is general agreement however that the speed of the energy transitions is too slow to reach the Paris Agreement targets. Hence, the question of how fast the transition can go, and how it can be accelerated. In what has been described as a 'thought-provoking' (Kern and Rogge, 2016, p. 13) and 'speculative and slightly provocative' paper (Sovacool and Geels, 2016, p. 236), Sovacool (2106) argues that transitions may actually go much faster than the mainstream literature on historic transition suggests.

In a reply to Smil (2016), Sovacool and Geels (2017, p. 234) accept the general point that energy transitions measured at the global scale and covering entire economies 'are necessarily slow and gradual'. But they also argue that 'taking scalar thinking seriously', 'global "grand" transitions unfold country by country and sector by sector, which involves concrete actors and institutions', and here changes can be more rapid. Hence, even for 'global transitions, it thus remains important to analyse rapid country-level transitions, because these first movers contribute to learning processes, scale economies, articulation of positive discourses, and changes in businesses strategies' (Sovacool and Geels, 2017, p. 234). In order to explore emerging transitions, therefore, one has to look at the specifics -- where and under which conditions they actually occur.

3. Understanding energy transitions

The Multi-Level Perspective (MLP) is probably the most used framework for exploring sustainability transitions (Markard, Raven, and Truffer 2012). It sees socio-technical transitions as an interplay of forces active on three analytical levels: 'niches (the locus of radical innovations), sociotechnical regimes (the locus of established practices and associated rules that enable and constrain incumbent actors in relation to existing systems), and an exogenous socio-technical landscape' (Geels, 2014, p. 3). These are described by Avelino and Wittmayer (2016, p. 631) as 'three levels of functional aggregation', where the landscape includes exogenous macro-trends, regimes represent the dominant institutions and practices, and niches are the places of innovative practices. The key point of the MLP perspective is that 'system innovations come about through the interplay between processes at different levels and in different phases', it includes internal niche dynamics, external regime and landscape development and there is 'no simple "cause" or driver in transitions.' A transition requires that dynamics at all three levels come together, align and re-inforce each other (Geels and Kemp, 2007, p. 443-444).

While specific definitions of the socio-technical regime have varied according to Avelino and Wittmayer (2016, p. 631), 'an essential characterization lies in its dominant position and its reproduction of dominant structures in the societal system under study.' Regimes reflects the existing set of rules, routines and practices that different actors and institutions use which (re)create and sustain a specific technological system (Foxon, Hammond and Pearson, 2010, p. 1204). Regimes account for the stability of the socio-technical system (Geels and Kemp, 2007, p. 443), reproducing 'longstanding development trajectories' (Rosenbloom et al., 2016, p. 1276). As such, 'the regime is—by definition—associated with "power", "dominance" and "vested interests"' (Avelino and Wittmayer, 2016, p. 631).

Like regimes, niches also consist of rules, technologies, and actor groups, but are far less stable and include fewer actors. Niches are described as 'the locus of radical innovations around which new systems may develop', as '"incubation rooms" for radical novelties' (Geels and Schot, 2007, p. 443), and as 'protective spaces' that shield novel innovations from adverse market selection and other selection pressures (Smith and Raven, 2012, p. 1025). Innovation efforts within these spaces interact with established regimes within a macro-landscape. As noted by Rosenbloom et al. (2016, p. 1276), early strands of transition research viewed niches 'as the principal seeds of change' (Geels, 2002; Kemp et al., 1998; Rotmans et al., 2001), while more recent interpretations have suggested that 'niche-regime symbioses and even regime actors themselves may play important roles in driving transformations' (Rosenbloom et al., 2016, p. 1276; Geels and Schot, 2007; Verbong and Geels, 2010).

The socio-technical landscape refers to 'aspects of the exogenous environment that is beyond the direct influence of actors' (Geels and Kemp, 2007, p. 443). The landscape includes things such as the physical climate, rapid external shocks, such as wars or oil price fluctuations, and long-term changes in a certain direction (trend-like patterns), such as demographical changes (Geels, 2011). Geels and Kemp (2007: 443) operate with a heterogeneous socio-technical landscape and differentiate further between a material landscape and a *political* landscape, where the political landscape is said to be 'more dynamic: we may witness revolutions, new coalitions and new ideas, creating room for novelty and system change'. Geels and Schot (2010, p. 25) also argue that landscape pressure does not mechanically influence existing regimes, but is 'mediated by actors' perceptions, negotiations and agenda setting.' Hence, policy makers, whether they are elected officials, ministers, members of parliament or un-elected policy makers/civil servants working in the ministries etc., are part of the political landscape (and who have themselves to operate within the broader context of the broader landscape level).

As Kuzemko et al. (2016: 96) argue, it is the political institutions that 'mediate … between forces for sustainable change and forces of continuity'. As Meadowcroft (2011) and Langhelle et al. (2018) argue, politics and political institutions plays a potentially powerful role in defining the landscape, propping up or destabilizing regimes, protecting or exposing niches. Arguably, therefore, the political institutions (Parliaments and other political institutions at different levels) at the political landscape are not fully detached from the other levels. It is possible to influence and also exploit the political landscape to some extent and vis a versa. And it is the political contestation and struggle that takes place in political institutions that determine the policies that can either challenge or support various niches and regimes through policy changes. So, ultimately, politics determines policy.

The political institutions (Governments, Parliaments) also to a large extent control the state and the state apparatus. Through its different policies, the state is enmeshed with all three levels. The state can come under pressure from changes to the political landscape (from the political institutions and political parties, but also from citizens, public opinion, interest organizations, social movements and actors and intentional agents working for both change and continuity at the political landscape), from the socio-technical regimes (which some state institutions may be seen as closely allied to or even integrated with), and from niches. Bringing the state to center stage is important for several reasons. First, states:

> ‘structure political, economic, and social interactions, maintain legal frameworks (including systems of property rights) backed by coercive power, and deploy significant economic and administrative resources through taxation/expenditure and their bureaucratic apparatus’ (Duit et al. 2015, p. 3).

Hence, the state can be seen as the ‘most powerful human mechanism for collective action that can compel obedience and redistribute resources’ and ‘embody legitimate authority’ in most cases (Duit et al. 2015, p. 3).

Second, the state with its authoritative character and institutionalized mechanisms for collective decision making, ‘can respond to the “public good” and “free-rider” dimensions of environmental problems, as well as to the distributional conflicts they typically embody’ (Duit et al. 2015, p. 4). Lastly, the state connects ‘environmental politics and policy and more general patterns of political continuity and change’ (Duit et al. 2015, p. 4). The state is therefore the object of political struggle and pressure and continuously contested both internally and externally, reflecting its ‘fragmented, self-contradictory, and only partly coherent’ nature (Duit et al. 2015, p. 4).

From this analytical framework we now turn to some emerging energy transitions that have occurred (or may be occurring). Drawing on a selection of energy transition studies from the literature, we explore the assumption in the introduction by enquiring: What has been the role of politics in technological choices? What has been the role of politics and the state apparatus? To what extent do politics and technology explain transitions?

4. Energy technology transitions

4.1 The speed of technological transitions

Sovacool's (2106) argument that transitions may actually go much faster than the mainstream literature on historic transition suggests, is based on ten empirical examples of actual rapid historic transitions. Table 1 below lists the ten examples:

Overview of rapid energy transitions.

Country	Technology/fuel	Market or sector	Period of transition	Number of years from 1 to 25% market share	Approximate size (population affected in millions of people)
Sweden	Energy-efficient ballasts	Commercial buildings	1991–2000	7	2.3
China	Improved cookstoves	Rural households	1983–1998	8	592
Indonesia	Liquefied petroleum gas stoves	Urban and rural households	2007–2010	3	216
Brazil	Flex-fuel vehicles	New automobile sales	2004–2009	1	2
United States	Air conditioning	Urban and rural households	1947–1970	16	52.8
Kuwait	Crude oil and electricity	National energy supply	1946–1955	2	0.28
Netherlands	Natural gas	National energy supply	1959–1971	10	11.5
France	Nuclear electricity	Electricity	1974–1982	11	72.8
Denmark	Combined heat and power	Electricity and heating	1976–1981	3	5.1
Canada (Ontario)[a]	Coal	Electricity	2003–2014	11	13

[a] The Ontario case study is the inverse, showing how quickly a province went from 25% coal supply to zero.

These ten transitions occurred very rapidly in a time span of between 1-16 years. The first five examples (Sweden with energy efficient ballasts, China with improved cookstoves, Indonesia with liquefied petroleum gas stoves, Brazil with flex-fuel vehicles, and United States with air conditioners) are transitions in prime movers (end-use devices). The five other examples (Kuwait with crude oil and electricity, the Netherlands with natural gas, France with nuclear electricity, Denmark with combined heat and power and Canada (Ontario) with coal) are transitions in energy supply.

Although Sovacool (2016) received criticism for using 25 percent market share as the measure for transition; for ignoring the formative phases, which are usually long (what happens before 2,5 percent of end users have adopted the technology, which takes on average 22 years); for mixing up stocks and flows; for ignoring diffusion issues; and for using examples that do not relate to more complex technological systems -- there are other striking features with the ten empirical examples other than speed. With the exception of the US case (air conditioners), *all of the other technological transitions are connected to politics and state interventions*. As is evident from Sovacool's case descriptions:

Sweden: ‘Swedish Energy Authorities arranged …’, ‘… the Government directly purchased almost 30,000 units’, China: ‘The Chinese Ministry of Agriculture sponsored …’, Indonesia: ‘… ran a large household energy program’, Brazil: ‘… created its Proàcool program’, ‘The Brazilian Government started incentivizing …’, Kuwait: ‘Kuwait Oil Company’ (electricity), ‘Kuwait National Petroleum Company’ (oil), The Netherlands: ‘the Government decided … to abandon all coal mining …’, France: ‘Prime Minister Pierre Messmer announced a large nuclear program …’, Denmark: ‘The Danish Energy Policy of 1976’, ‘the 1979 Heat Supply Act’, ‘Danish Parliament passed the “coal stop”’, Ontario, Canada: ‘… the Government of Ontario committed to retiring …’ (Sovacool, 2016, pp. 5-10).

Hence, 9 out of 10 of these rapid technological transitions where arguably driven by politics and the use of the state apparatus.

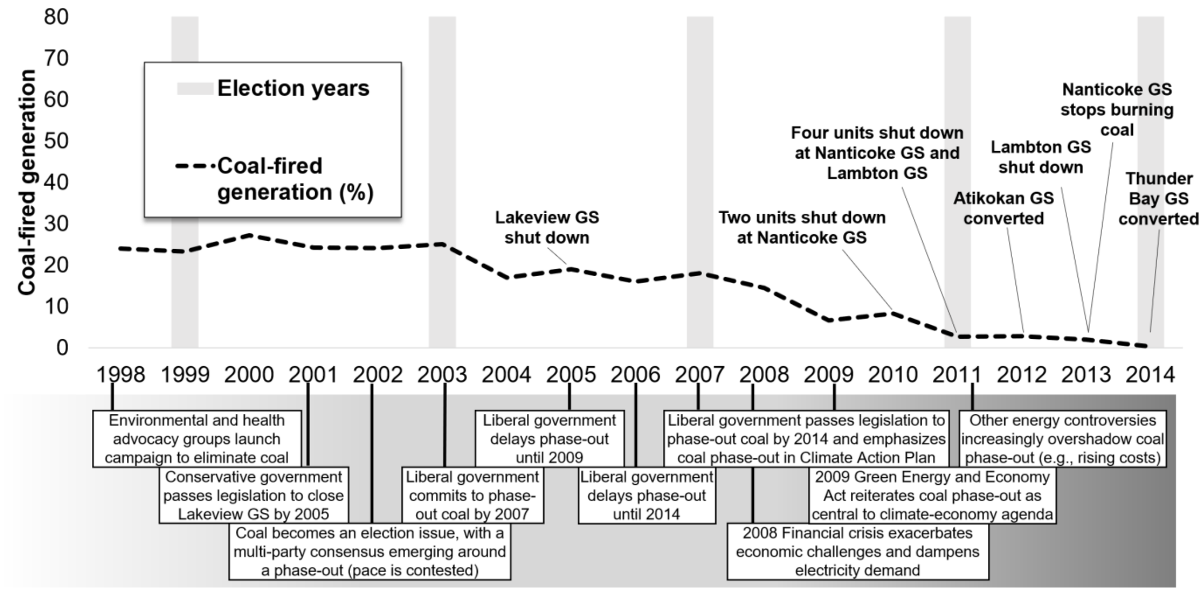
Seen from the modified MLP perspective, the general feature of these rapid transitions are the occurrence of changes in the socio-technical landscape that are *further elaborated, mediated, defined and socially constructed politically* (at the political landscape). What does the oil shock (in 1973) imply for Denmark as a nation? What shall we do with coal in light of climate change (Ontario)? What should be the national emission targets? This is questions that to a large extent is debated, negotiated, contested and determined in Parliaments (by politics), not at the regime or niche level, although it can be (heavily) influenced also by regime and niche advocates (see for instance Geels (2014)). And it plays out between policymakers who are part of – or allies of the regime (sustaining it) and policymakers who want to change the regime in question, working together with or being influenced by social movements and various interest groups.

It is when the state is 'captured' through the political institutions that the apparatus of the state can be put in motion to challenge regimes, support niches and new technologies. This is when transitions can and do speed up. As Sovacool and Geels (2016, p. 234) argue, ‘[p]olitical intervention and support policies … led to rapid diffusion of renewable electricity in Germany (from 5.2 in 1999 to 30.1 percent of German electricity production in 2015) and the UK (from 2.5 in 2001 to 24.7 percent in 2015).’ Two other cases can illustrate the importance of politics and technology for energy transitions.

4.2 The Coal phase-out in Ontario

Politics played an integral role in driving the coal phase-out in Ontario. Indeed, the adoption and implementation of this regulatory measure involved the interplay of central political players: political parties, environment-health advocacy groups, core electricity institutions, unions, and municipal officials. Broader publics concerned about the health and environment impacts of coal also had an important place in the decline of coal. This experience saw the relatively rapid shut down of coal-fired generating stations (GS), with coal output falling from roughly 25% in 1998 to less than 1% in 2014 (see Figure 1). The phase-out can be explained by a number of prominent factors: (1) the vigorous and persistent mobilization of environment and health advocacy groups; (2) a concerned public activated by successful communication campaigns; (3) the emergence of a multi-party political consensus (though this consensus eroded somewhat over time); and (4) the continual renewal of phase-out commitments by the Liberal government over the course of its implementation (Rosenbloom 2017). Five enabling factors also merit mention, including: (1) the restructuring of the electricity sector in the late 1990s and early 2000s, which limited the ability of key actors to fend off political interventions; (2) the fact that legacy coal plants were aging and publicly owned; (3) the absence of coal production in Ontario (fewer employment losses); (4) relatively stagnant electricity demand growth; and (5) the growing abundance and affordability of natural gas (Rosenbloom and Meadowcroft 2014). Together, these factors (some intentional and others unintentional) helped realize the coal phase-out. The following discussion will trace the coal phase-out experience, revealing the central role of politics and the state in driving this episode of change.

Figure 1: The pathway to eliminate coal-fired power in Ontario



Source: Adapted from Rosenbloom (2017)

At the very outset of the coal phase-out debate in the late 1990s, electricity generation in the province of Ontario was principally based on nuclear (~40%), hydroelectric (~25%), and coal-fired (~25%) sources. This was a time of unprecedented turbulence for the electricity regime (Rosenbloom and Meadowcroft 2014). The nearly century old public utility was facing financial difficulties due to overexpansion and challenges related to the management of nuclear facilities – some reactors were shuttered due to safety concerns (Ontario Hydro 1997). Not only did this encourage a greater reliance on coal assets but it also created a window of opportunity for the Conservative government to break up the public utility.

The growing reliance on coal power became increasingly contentious as environmental and health concerns mounted among the public (Rowlands 2007; Winfield 2012). Environmental and health advocacy groups helped activate these concerns and direct them at coal-fired sources, launching a series of effective campaigns. In 1998, the Ontario Medical Association released an influential report that received considerable attention in the media. It crystallized the links between coal, environmental issues (air quality), and public health (premature deaths). Along with the prevalence of smog days, this report provided a credible evidence base from which advocates placed pressure on the regime and lobbied for government intervention to eliminate coal-fired power. In 2001, the emerging environment-health coalition won two initial victories (Harris, Beck, and Gerasimchuk 2015). The Conservative government appointed an all-party Select Committee on Alternative Fuel Sources to investigate more sustainable energy options in response to public outcry (Legislative

Assembly of Ontario 2002) and passed legislation to close the Lakeview coal-fired station near Toronto by 2005 (Ontario Ministry of Energy 2015).

The coal problem intensified during the 2003 election as advocates successfully framed coal as a public health crisis (Rosenbloom 2017). While there was still much disagreement about the details, an all-party consensus emerged around a coal phase-out. The Conservatives targeted 2015, whereas the Liberals and New Democrats proposed 2007. This signalled to industry, the public, and others that efforts would be made to eliminate coal no matter which party came to power (Harris, Beck, and Gerasimchuk 2015).

The Liberals formed a majority government following the 2003 election, with a mandate to begin to implement the phase-out. They moved to procure alternative electricity sources (natural gas but also emerging renewables), bring laid up nuclear reactors back online, and promote conservation. The phase-out would entail billions of dollars in infrastructure spending to displace the publicly-owned coal units (Ontario Ministry of Energy 2015).

As implementation advanced, resistance from rivals began to intensify (Rosenbloom 2017). Many of these actors were core to the regime. Labor unions (e.g., the Power Workers' Union) and industry associations (e.g., Association of Major Power Consumers of Ontario) were particularly vociferous opponents. The Ontario Power Generation, the public entity that now owned and operated the coal plants, also made efforts to reassert the importance of coal-fired power but could not challenge the agenda of its primary shareholder. The political allies of the regime also attempted to mount resistance (e.g., officials from the municipalities where coal plants were sited such as Haldimand County). Actors aligned with the regime (e.g., think tanks such as Fraser Institute and Energy Probe) also challenged the phase-out on reliability and cost grounds.

In the face of this resistance, the Liberal government began to express doubts about the 2007 timeline for the phase-out (Rosenbloom 2017, 201). In the summer of 2005 and then again in the fall of 2006, they extended the target to 2009 and then 2014, citing reliability and capacity issues (Cundiff 2015). Health and environment advocates responded to delays by stressing the importance of the phase-out and calling for an accelerated timeline.

The above battles continued to unfold during the 2007 provincial election. While the Liberal government capitalized on the popularity of the phase-out by enshrining the 2014 deadline in legislation (Ontario Ministry of Energy 2015) and making it a key part of Ontario's first climate action plan (Ministry of the Environment and Climate Change 2007), the Conservatives began to back away from their commitment (McCarthy 2007). Throughout this period, environment and health advocates continued to mobilize and place pressure on the government through media campaigns (Rosenbloom 2017).

The Liberals were re-elected in 2007 with a majority government and carried on with the coal phase-out. Implementation received an unanticipated boost from the 2008 global financial crisis, which led to a decline in economic production but also electricity consumption (Winfield 2012). With annual electricity consumption dipping from roughly 150 TWh in 2007 to 139 TWh in 2008, concerns about system reliability were eased and the closure of coal units was facilitated (6 units were shut down between 2010 and 2011). The Liberal government also continued to leverage the popularity of the coal phase-out, this time to lend legitimacy to their green energy and economy agenda (Rosenbloom 2017).

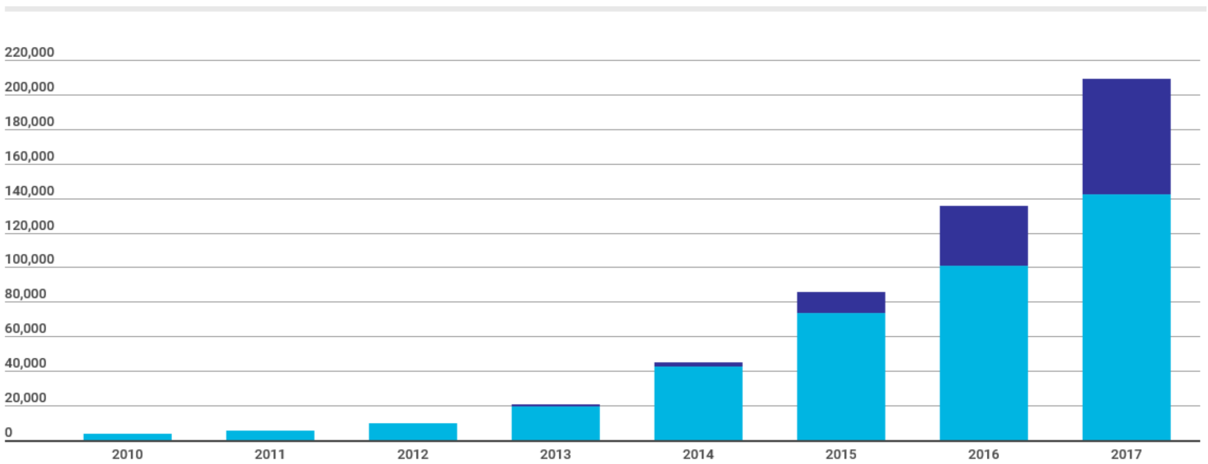
By the 2011 elections, the place of coal-fired power had declined to less than 5% of total generation. The Liberals lost their majority status during this election but carried through with their promise. Signalling the end of the coal-fired era in the province, Nanticoke GS stopped burning coal in 2013 (Ontario Ministry of Energy 2015). This was once the largest coal plant in North America and the single most important point-source of GHG emissions in Canada, accounting for 29.3 Mt of CO2eq or 4% of Canada's total GHG emissions in 2005. The remaining coal units were either shutdown or converted to burn biomass by April 2014. Conversions, despite being costly, helped allay fears of job loss in the affected communities.

4.3 Norway and the EV revolution

In the story of EV deployment in Norway, the political landscape plays an important - if not crucial - role. The proper context is climate change policies. With growing emissions domestically, an almost emission free electricity sector (hydro power) and a climate policy tailored to shield oil and gas production, there are few options left than to do something in other sectors if emissions are to be mitigated. The transport sector stands out as an obvious candidate for a transition, with an increase in GHG emissions of 24 percent between 1990 and 2016.

Figure 3 shows the growth in in sales of EVs in Norway between 2010 and 2017. About 5.1 percent of cars in Norway are now EVs. The share of hybrids was 5.3 percent, of which nearly half is plug-in hybrids. The market share of new car sales for EVs was 17.1 percent in 2015. In 2016, the share fell to 15.7 percent, but the share increased sharply in 2017, to 20.8 percent, partly due to the introduction of new models. If one adds plug-in hybrids, the market share was 39 percent in 2017. If one includes regular hybrid cars, the market share in 2017 was 52.2 percent. And many are still waiting for their Opel Ampera-e, Tesla model 3, the new Nissan Leaf and new models of Renault Zoe and VW e-Golf and also for new models expected in 2019.

Figure 2: Total number of EVs (light blue) and plug-in hybrids (purple) registered in Norway.



Source: Norsk elbilforening/Motorvognregisteret. Updated 31. December 2017.

The EV revolution in Norway is not the result of an initial grand masterplan (Asphjell et al. 2013). Instead, it should be seen as the result of a number of coincidences and partly un-intended result of lobbying efforts from environmental NGOs, niche actors and other activists exploiting the political cleavages in Parliament over climate policies. In brief, the EV success case can be explained by five factors: 1) Niche developments and support from the political institutions at the political landscape with the aims of creating a viable car industry in Norway and reducing emissions; 2) Tax and fee exemptions made when EVs were truly a niche; 3)

Struggles over climate policies and domestic emission reductions in Parliament and political compromises; 4) Technological developments outside of Norway's boarders; and, 5) incumbent regime actors taking the opportunity offered by the political landscape.

Already in the 1980s, EV enthusiasts, environmental groups, and industry actors lobbied policy makers in Parliament and Government for special EV policies. For some of the policy makers, the dream was to establish an electric car industry in Norway, for others it was seen as an option to mitigate emissions in the transport sectors. The only automobiles ever produced in Norway were 15 cars called *Troll* built by *Troll Plastkarosseri og bilindustri* between 1956 and 1958. In effect, there are no incumbent car producers, fighting EVs. All cars sold in Norway are imported and heavily taxed. In modern times, the first EV was imported to Norway in 1989 (a retrofitted Fiat Panda). From then on, the environmental NGOs and EV enthusiasts lobbied the Government and Parliament to get tax and fee exemptions for EVs. Seen from the modified MLP perspective, the environmental NGOs bypassed the regime actors (most notably the state itself – represented by the road authorities) and lobbied the political landscape institutions.

They did so with remarkable success. In 1990, the Government gave EVs an exemption from import tax, and between 1992 and 1994, environmentalists and the environmental NGO Bellona in particular, organized several civil disobedience events in their fight against road fees for electric vehicles. In 1996, EVs were exempted from purchase fees, and in 1997 they were exempted from road taxes. In 1998, free parking for EVs on municipal parking places was introduced. In 1999, EVs got their own license plates, making them more visible on the roads. In 2000, EVs became exempt from VAT, and in 2005 public transport lanes were opened to EVs (Asphjell et al. 2013).

The regulatory framework for EVs gradually developed into a highly beneficial institutional structure for niche development in the period were there were very few EVs in Norway. No one, however, expected what then happened with EVs, primarily due to technological developments outside of Norway. EVs really started taking off in 2010 and onwards, primarily due to new EV models like the Mitsubishi iMiev, the Nissan Leaf and Tesla Roadster (and also the Norwegian Think) (see table 2 above). What had been established incrementally was a support system so generous that the exemptions really make a huge difference on the price of the car. Hence, the rapid penetration of electric cars in Norway is the combined result of *politics* and *political compromises* providing policies that support their diffusion and technological progress making electric cars more affordable and useful (Fagerberg, Laestadius and Martin, 2016).

With GHG emissions increasing rather than decreasing from 1990 levels in Norway, the transport sector -- being the second largest emitter after the oil and gas sector -- became a key concern for climate policies. Two times (in 2008 and 2012) Parliament made climate compromises shielding the support regime for EVs. In the national budget for 2017, the exemption from VAT was guaranteed by the Government to last until 2020, and the exemption from the onetime fee until 2018. What is for sure is that the support system for zero emission cars will be one of the key political struggles in the years to come. What will happen is not easy to predict. On the one hand, some argue that EV policy is a violation of the cost effectiveness principle which has been a key principle in the Norwegian climate policies. On the other hand, the transport sector is the obvious candidate for a transition in the Norwegian context. Norway's indigenous energy resources with a large surplus of renewable electricity is also ideal for EVs. As the pressure increases on domestic GHG emission reductions, the support system will be very difficult to change dramatically in the near future. If it is, it will be decided by the political institutions at the political landscape, in the struggles between the political parties represented in Parliament over climate policies, not by the regime or the niches.

5. Concluding remarks: Politics and technology as transformational keys

The argument put forward here has been simple. It is possible to decarbonize the energy system and the best way to accelerate sustainability transitions is to capture the political institutions that control the state and the state apparatus through *politics*. State interventions and support policies can be extremely efficient and probably the most effective means to accelerate sustainability transitions. States have an enormous repertoire of instruments to effect change. By deploying regulation, market instruments, taxation and subsidies, public education and information campaigns, they can spur technological development and deployment, and financially penalize and delegitimize incumbent high carbon technologies. They can deliberately support emergent industries to build the economic power (and hence also the political power) of low carbon business enterprises.

Although it is often forgotten in discussions of technological development -- where the role of technological innovators and firms is usually given pride of place -- states have played a critical role in earlier socio-technical transitions (Moe, 2007). They have ‘tilted the playing field’ toward technologies deemed to be of strategic interest or with the potential to confer major economic advantage. This was so, for example, with the advent of steam ships, nuclear aircraft carriers, the automobile, the ICT revolution, satellite technologies and much more. States provide financial help to emergent technologies, break up the monopolies of incumbents, change regulations, provide indemnity against liability, appropriate land and other resources, fund research and development, establish national firms, and so on. Economic and business proponents of novel solutions, as well as the incumbent firms and technological complexes, are well aware of this, and struggle in the open and behind the scenes to capture segments of the state and harness them to buttress or their options. Discursive struggles cut straight into the underlying conflicts of interest (Rosenbloom et al., 2016).

Of course, ‘capturing’ segments of the state is by no means an easy task; but it can be effective when it succeeds. Multiple avenues of support can contribute to this end: pressure from social movements; inputs from science and the scientific community; sympathy from the bureaucracy who can see the public interest arguments in support of emerging pathways; pressure and encouragement from the international realm; as well as the societal influence and economic clout of businesses associated with emerging socio-technological configurations (real investments, jobs, export earnings -- with the potential of more in the future). But without the capture of *political parties* it is impossible to reconstruct the political institutions at the political landscape into a configuration that decisively supports change.

Such a politically focused analysis helps understanding of why the United States, despite its potential technological leadership in many areas of the green economy, and the decline in the GHG intensity of its economy (and indeed absolute emissions reductions) has been unable to establish a solid national climate change policy framework despite twenty years of effort. The United States lies at the core of the global carbon economy; its firms gain most from the existing energy system; and the country has secured geostrategic advantage from the global oil economy. Fossil fuel interests still predominate in a national political system that is particularly vulnerable to manipulation by established interests; rife with veto points (because the founders feared majoritarian change); with a modern political culture deeply sceptical of the role of the state in re-organizing society.

Socio-institutional explanations that emphasise political dimensions – contrary to techno-economic analysis -- ‘refer more to the shifts in allegiance of social groups like policymakers or wider publics, whose defection from old to new systems may lead to major changes in policies or discourses’ (Geels and Sovacool, 2016, p. 235). Sovacool and Geels' hypothesis is that ‘socio-institutional changes prepare the ground for techno-economic tipping points and are thus likely to precede actual accelerations by several years’. The argument is that prices and costs are always shaped and influenced by broader social forces including policies (taxes, subsidies, loans), which again are determined by politics. Taken together, opportunities created by technological developments, political will and business support do accelerate transition dynamics.

This again, requires a redefinition of societal interests and this implies political engagement to build reform coalitions, create new centers of power, buy off powerful lobbies, isolate die-hards, compensate losers, and so on. These struggles involve not only established political actors (such as political parties, incumbents and major economic groups) but also emergent forces associated with new technologies, experimental practices and social movements. And since sustainability transitions may take decades, there will be repeated cycles of interaction, with all sides drawing lessons from previous rounds (Meadowcroft, 2011).

It is therefore important to develop an understanding of how political actors (understood broadly) can construct linkages between economic, social and environmental reform agendas; how sustainability transitions can exploit the ups and downs of the economic cycle; which strategies are most successful for building impetus for reform in specific societal subsystems; what forms of political alliance are most conducive to encouraging sustainability transitions; which kinds of reform create positive feedbacks driving further reform; what resistance strategies are most popular with transition opponents, how they can be countered by proponents; and so on (Meadowcroft, 2011). This means that politics is at the heart of sustainability transitions.

So too with technology. Krantzberg (1986, p. 545) formulated his ‘First Law’ of technology the following way: ‘Technology is neither good nor bad; nor is it neutral’. What actually constitutes sustainable technology is disputed, precisely because it envisions different futures and different options for sustainability which are highly political and interest based. Hence it echoes Krantzberg's 'Fourth Law': 'Although technology might be a prime element in many public issues, nontechnical factors take precedence in technology-policy decisions' (Krantzberg, 1986, p. 550), and '[t]echnologically "sweet" solutions do not always triumph over political and social forces' (Krantzberg, 1986, p. 550).

Already, the fossil fuel industry is under a huge pressure not only from political forces, but also from emerging technological transitions in electricity generation, transportation, heavy industry, buildings, energy efficiency and cleaning up GHG emissions. In the power sector, coal – the dominant source of electric power since the industrial revolution – has been beset on multiple fronts. While this energy source continues to account for nearly 40% of power generation (International Energy Agency 2017), it is facing increasing challenges from shale gas development, new renewables, and policy interventions driven by health and environment considerations. Coal phase-outs are now becoming commonplace, with governments across the globe embarking upon accelerated transitions away from this source. Finland, Denmark, and the Netherlands have announced plans to be coal free within the next decade and a half. Canada has plans to shutter coal facilities that are not employing carbon capture and sequestration by 2030 (though some provinces may have slightly relaxed timelines). The United Kingdom has taken steps to close all coal plants in the next several years. And, France is planning to eliminate coal within the next three to four years. The apparent success of these regulatory measures demonstrates how the machinery of the state, wielded through politics, can in a relatively accelerated fashion open more sustainable pathways of societal development. This is to say nothing of the billions in government spending on the uptake of alternative power sources such as new renewables.

Fossil fuels in the transport sector may be the next target for alternatives and state intervention. Over the past eighteen months the idea of introducing a legal cut off date for the sale of new gasoline and diesel power vehicles has increasingly gained international attention, with France and the UK recently proposing 2040 targets. To many, this seems ridiculously far into the future. After all, Norway has set a 2025 target and India adopted 2030. And many analysts suggest the tipping point for EV adoption will be within the next decade. So a cut-off twenty years in the future seems remote. *But the very fact of discussing an explicit end for the sale of diesel and gasoline powered vehicles represents a political shift of seismic importance*.

Once the principle is accepted, the date can be adjusted. Its significance can be seen in the reaction of the dominant auto companies whose strategy for more than twenty years has been to demonstrate EVs, develop small niche markets, while maintaining liquid petroleum driven vehicles as their core profit centres. Immediately after the election of President Trump automakers petitioned the EPA to relax fuel efficiency standards to which they already had agreed years before. Mary Bara, the Chairman and CEO of General Motors has been in Beijing urging the Chinese government to delay any cut-off for gasoline vehicles. Matthias Muller CEO of Volkswagen launched a major media offensive predicting a 'great future' for diesel automobiles for decades to come. He was replaced by Herbert Diess in 2018 following the 'Dieselgate scandal'.

Today, appreciating that the threat is real, the incumbents are mobilizing. And in a sense that is good news. It suggests that finally transport is beginning to enter the game. Transport (and not power generation) is the real core of the fossil fuel regime, because dependence on fossil power for cars, trucks, planes, and ships has been virtually absolute. Because of this the EV transition is vital because of the economic and political damage it can do to fossil energy incumbents. Every percentage of market share that shifts from gasoline and diesel towards EVs weakens the economic and political strength of the oil industry -- threatening stagnant and then declining demand, weakening capital inflows, eroding balance sheets and sealing its fate as a sunset industry.

For these particular firms (GM and Volkswagen), of course, the stakes are very real. Volkswagen had bet heavily on diesel and hoped to continue down this path despite the havoc wrought by the emissions scandal. General Motors has assumed that there will be two to three decades of hybrid power trains before full EV adoption. Each company holds the dominant patents for their favoured technology and stands to lose literally tens of billions of dollars if the EV transition accelerates.

Carbontracker now speaks of the transitions risks for oil and gas in a low carbon world, the end of the road for coal and gas, and a possible fossil fuel demand destruction by low-carbon technologies. In support of the position that there might be a difference between historic and emergent transitions, Krantzberg's second Law might give some comfort: 'Invention is the mother of necessity'. And contrary to the belief in *Limits to Growth* that developments in renewables ‘would probably come too late to avert demographic or environmental disaster’ and ‘probably would only delay rather than avoid crisis’, it might come soon enough- or delay the crisis long enough for humanity to adapt. In that sense, we are still struggling with the second key concept formulated in *Our Common Future*, ‘the idea of limitations imposed by the state of technology and social organization on the environment’s ability to meet present and future needs’ (WCED 1987, p. 43). But parts of the world might just be moving in the right direction.

From this, the following key policy and research agenda stands out:

1. Technological change is necessary. Although not sufficient, the energy transition cannot do without further technological developments. But these are in need of protected spaces and supportive selection environments which only *the state* can provide. 2. Policies to support renewable and low carbon energy technologies are key to the acceleration of energy transitions. Change in the personal transport sector in particular is important to weakening the hegemonic reach of the fossil regime (its ideological and economic power). Policy support for rapid change in this sector is critical. 3. Policies *are ultimately determined by politics*. Exploiting the opportunities at the political landscape is difficult but not impossible. Capturing the political institutions at the political landscape level necessitates work through *political parties*. 4. But governments change, and policies will change with them. Ensuring continuity of support for energy transitions requires: - development of groups with a material interest in accelerating change (including allied economic interests); - the establishment of 'arms length' institutions (bodies with independent mandates and funding) that can implement different dimensions of transition support (innovation support; public education; monitoring; analysis and policy advice; implementation funding, etc); - development of substantial public understanding of, and support for, the overarching goals of the low carbon transition 5. Although it is possible to achieve cross-party support for the goals of low carbon energy transitions, the continual shift in economic, political and social circumstances; the changing phases of these transitions; the protracted time scale over which they will play out; the very different ways interests will be impacted at different points in the process; and the competitive nature of the political system mean that *acute political struggles will remain a permanent feature climate and energy transition policies*. 6. Important elements for research include the constitution of political coalitions, the use of visioning and pathway processes to encourage innovation and build political support, and the deployment of policies to weaken and undermine dominant high carbon interests.

References

Asphjell, A., Asphjell, Ø. and Kvisle, H. H. 2013. *Elbil på norsk*. Transnova.

Avelino, f. and Wittmayer, J. M. 2016. 'Shifting Power Relations in Sustainability Transitions: A Multi-actor Perspective.' *Journal of Environmental Policy & Planning*, 18:5, 628-649.

Bataille, Chris, Dave Sawyer, and Noel Melton. 2015. *Pathways to Deep Decarbonization in Canada*. Sustainable Development Solutions Network & Institute for Sustainable Development and International Relations.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S. and Rickne, A. 2008. 'Analyzing the functional dynamics of technological innovation systems: a scheme of analysis.' *Research Policy*, 37, 407–429.

Bromley, P. S. 2016. 'Extraordinary interventions: Toward a framework for rapid transition and deep emission reductions in the energy space.' *Energy Research & Social Science*, 22: 165-171.

Cundiff, Brad. 2015. *Ontario's Coal Phse out: Lessons Learned from a Massive Climate Achievement*. Toronto: Ontario Cliean Air Alliance Research. http://www.cleanairalliance.org/wp-content/uploads/2015/04/CoalPhaseOut-web.pdf.

Dryzek, John, S. 2013. *The Politics of the Earth. Environmental Discourses*. Oxford University Press. Third Edition.

Duit, A., Feindt, P. H. and Meadowcroft, J. 2015. 'Greening Leviathan: the rise of the environmental state?' *Environmental Politics*, DOI: 10.1080/09644016.2015.1085218

Foxon, T. J., Hammond, G. P. and Pearson, P. J. G. 2010. 'Developing transition pathways for a low carbon electricity system in the UK.' *Technological Forecasting and Social Change*, 77(8), pp. 1203-1213.

Geels, F. W. 2002. 'Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study', *Research Policy*, 31(8/9): 1257-1274.

Geels, F.W. 2011. 'The multi-level perspective on sustainability transitions: Responses to seven criticisms.' *Environmental Innovation and Societal Transitions*, 1(1), 24-40.

Geels, F. W. 2014. 'Regime resistance against low-carbon energy transitions: introducing politics and power in the multi-level perspective, *Theory. Cult Soc*, 31(5), 21–40.

Geels F. W. and Kemp, R. 2007. ‘Dynamics in socio-technical systems: typology of change processes and contrasting case studies.’ *Technol Soc*, 29(4):441–455.

Geels, F. W. and Schot, J. 2007. ‘Typology of sociotechnical transition pathways’, *Research Policy*, 36(3), 399-417.

Geels, F.W. and Schot, J.W. 2010. ‘The dynamics of transitions: a socio-technical perspective’, in: J. Grin, J. Rotmans, J. Schot (Eds.), *Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change*, Routledge, 2010, pp. 9–87, in collaboration with Geels F.W. and Loorbach D.

Foxon, Timothy J., Peter J.G. Pearson, Stathis Arapostathis, Anna Carlsson-Hyslop, and Judith Thornton. 2013. “Branching Points for Transition Pathways: Assessing Responses of Actors to Challenges on Pathways to a Low Carbon Future.” *Energy Policy* 52 (January): 146–158. doi:10.1016/j.enpol.2012.04.030.

Geels, Frank W. 2014. “Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective.” *Theory, Culture & Society* 31 (5): 21–40. doi:10.1177/0263276414531627.

Grubler, A. 2012. ‘Energy transitions research: Insights and cautionary tales.’ *Energy Policy* 50, 8–16.

GWEC, EREC and GreenPeace. 2015. *Energy [r]evolution. A sustainable world energy outlook*. 5th edition 2015 energy scenario.

Kern, F. and Rogge, K. S. 2016. ‘The pace of governed energy transitions: Agency, international dynamics and the global Paris agreement accelerating decarbonisation processes? *Energy Research & Social Science*, 22: 13-17.

Harris, Melissa, Marisa Beck, and Ivetta Gerasimchuk. 2015. *The End of Coal: Ontario’s Coal* Phase-Out. https://www.iisd.org/GSI/sites/default/files/ffs_ontario_lessonslearned.pdf.

Hekkert, M., Suurs, R.A.A., Negro, S., Kuhlmann, S. and Smits, R. 2007. ‘Functions of innovation systems: a new approach for analysing technological change.’ *Technological Forecasting and Social Change,* 74, 413–432.

International Energy Agency. 2017. Key World Energy Statistics 2017. Paris: OECD/IEA.

Jacobson, Mark Z., Mark A. Delucchi, Zack A.F. Bauer, Savannah C. Goodman, William E. Chapman, Mary A. Cameron, Cedric Bozonnat, et al. 2017. “100% Clean and Renewable

Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World.” Joule 1 (1): 108–121. doi:10.1016/j.joule.2017.07.005.

Jacobsson, S. and Johnson, A. 2000. ‘The diffusion of renewable energy technology: an analytical framework and key issues for research.’ *Energy Policy*, 28, 625–640.

Kemp, R., Schot, J. and Hoogma, R. 1998. ‘Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management.’ *Technology Analysis & Strategic Management*, 10: 175–195.

Kranzberg, M. 1986. ‘Technology and History: «Kranzberg’s Laws».’ *Technology and Culture*, Vol. 27, No. 3, pp. 544-560.

Krewitt, Wolfram, Sven Teske, Sonja Simon, Thomas Pregger, Wina Graus, Eliane Blomen, Stephan Schmid, and Oliver Schäfer. 2009. “Energy [R]Evolution 2008—a Sustainable World Energy Perspective.” Energy Policy 37 (12): 5764–5775. doi:10.1016/j.enpol.2009.08.042.

Langhelle, O., Kern, F., Meadowcroft, J. and Rosenbloom, D. 2018. ‘Political conflict as a driver of socio-technical transitions: the political landscape re-visited.’ *Draft, to be submitted*.

Lauber, V. and Jacobsson, S. 2016. ‘The politics and economics of constructing, contesting and restricting socio-political space for renewables – The German Renewable Energy Act.’ *Environmental Innovation and Societal Transitions*, 18: 147–163.

Legislative Assembly of Ontario. 2002. Select Committee on Alternative Fuel Sources: Final Report. Toronto: LAO.

Lilliestam, Johan, and Susanne Hanger. 2016. “Shades of Green: Centralisation, Decentralisation and Controversy among European Renewable Electricity Visions.” Energy Research & Social Science 17 (July): 20–29. doi:10.1016/j.erss.2016.03.011.

Markard, J., Raven, R. and Truffer, B. 2012. ‘Sustainability transitions: An emerging field of research and its prospects.’ *Research Policy*, 41: 955– 967.

McCarthy, Shawn. 2007. “For Liberals, a Fierce Election Takes a Lot of Energy.” The Globe and Mail; Toronto, Ont., September 12, sec. National News.

Meadowcroft, J. 2009. ‘What about the politics? Sustainable development, transition management, and long term energy transitions’, *Policy Sciences*, 42: 323–340.

Meadowcroft, J. 2011. ‘Engaging with the politics of sustainability transitions.’ *Environmental Innovation and Societal Transitions*, 1: 70–75.

Meadows, Donella H., Meadows, Dennis L., Randers, Jorgen, and William W. Behrens III. 1972. *The Limits to Growth. A report for The Club of Rome's Project on the Predicament of Mankind*. London: Pan Books.

Millar, R. J. et al. 2017. 'Emission budgets and pathways consistent with limiting warming to 1.5 °C.' nature geoscience. DOI: 10.1038/NGEO3031.

Ministry of the Environment and Climate Change. 2007. Go Green: Ontario's Action Plan on Climate Change. Toronto: Queen's Printer for Ontario. http://www.climateontario.ca/doc/workshop/2011LakeSimcoe/Ontarios%20Go%20Green%20Action%20Plan%20on%20Climate%20Change.pdf.

Oltermann, P. 2016. 'Germany takes steps to roll back renewable energy revolution.' *The Guardian*, Tuesday 11 October 2016.

Ontario Hydro. 1997. Report to Management: IIPA (Independent Integrated Performance Assessment) / SSFI (Safety Systems Functional Inspections) Evaluation, Findings and Recommendations. Toronto.

Ontario Medical Association. 1998. OMA Ground Level Ozone Position Paper. Toronto: OMA.

Ontario Ministry of Energy. 2015. The End of Coal: An Ontario Primer on Modernizing Electricity Supply. Toronto: Queen's Printer for Ontario. http://www.energy.gov.on.ca/en/files/2015/11/End-of-Coal-EN-web.pdf.

Raven, Rob, Florian Kern, Adrian Smith, Staffan Jacobsson, and Bram Verhees. 2016. "The Politics of Innovation Spaces for Low-Carbon Energy: Introduction to the Special Issue." Environmental Innovation and Societal Transitions 18 (March): 101–110. doi:10.1016/j.eist.2015.06.008.

Rosenbloom, D. Berton, H. and Meadowcroft, J. 2016. 'Framing the sun: A discursive approach to understanding multi-dimensional interactions within socio-technical transitions through the case of solar electricity in Ontario, Canada.' *Research Policy*, 45(6), 1275-1290.

Rosenbloom, D. 2017. "Framing Low-Carbon Pathways: A Discursive Analysis of Contending Storylines Surrounding the Phase-out of Coal-Fired Power in Ontario." Environmental Innovation and Societal Transitions, November. doi:10.1016/j.eist.2017.11.003.

Rosenbloom, Daniel, Brendan Haley, and James Meadowcroft. 2018. "Critical Choices and the Politics of Decarbonization Pathways: Exploring Branching Points Surrounding Low-Carbon Transitions in Canadian Electricity Systems." Energy Research & Social Science 37 (March): 22–36. doi:10.1016/j.erss.2017.09.022.

Rosenbloom, Daniel, and James Meadowcroft. 2014. "The Journey towards Decarbonization: Exploring Socio-Technical Transitions in the Electricity Sector in the Province of Ontario (1885–2013) and Potential Low-Carbon Pathways." Energy Policy 65 (February): 670–679. doi:10.1016/j.enpol.2013.09.039.

Rotmans, J., Kemp, R. and van Asselt, M. 2001. 'More evolution than revolution. Transition management in public policy.' *Foresight,* 3: 15–31.

Rowlands, Ian H. 2007. "The Development of Renewable Electricity Policy in the Province of Ontario: The Influence of Ideas and Timing." Review of Policy Research 24 (3): 185–207.

Smil, V. 2016. 'Examining energy transitions: A dozen insights based on performance.' *Energy Research & Social Science*, 22: 194-197.

Smith, A. and Raven, R. 2012. 'What is protective space? Reconsidering niches in transitions to sustainability.' *Research Policy,* 41: 1025– 1036.

Smith, A., Voß, J.-P., and Grin, J. 2010. 'Innovation studies and sustainability transitions: the allure of the multi-level perspective and its challenges.' *Research Policy,* 39, 435–448.

Sovacool, B. K. 2016. 'How long will it take? Conceptualizing the temporal dynamics of energy transitions.' *Energy Research & Social Science*, 13: 202-215.

Sovacool, B. K. and Geels, F. W. 2016. 'Further reflections on the temporality of energy transitions: A response to critics.' *Energy Research & Social Science*, 22: 232–237.

Tomain, J. P. 2006. 'Smart Energy Paths: How Willie Nelson Saved the Planet'. *Faculty Articles and Other Publications*. Paper 105. http://scholarship.law.uc.edu/fac_pubs/105.

Trottier Energy Futures Project. 2016. Canada's Challenge & Opportunity: Transformations for Major Reductions in GHG Emissions. Ottawa: The Canadian Academy of Engineering. https://www.cae-acg.ca/wp-content/uploads/2013/04/3_TEFP_Final-Report_160425.pdf.

UK Government. 2017. The Clean Growth Strategy: Leading the Way to a Low Carbon Future. London: Her Majesty's Government.

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/651916/BEIS_The_Clean_Growth_online_12.10.17.pdf.

Verbong, G.P.J. and Geels, F.W. 2010. 'Exploring sustainability transitions in the electricity sector with socio-technical pathways.' *Technological Forecasting and Social Change*, 77 (2010) 1214–1221.

Ward, B. and Dubos, R. 1972. *Only One Earth. The Care and Maintenance of a Small Planet*. New York: W.W. Norton & Company.

Winfield, Mark S. 2012. Blue-Green Province: The Environment and the Political Economy of Ontario. Vancouver: UBC Press.

World Commission on Environment and Development (WECD) 1987. *Our Common Future*. Oxford University Press.