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ROOTED IN PLACE: REGIONAL INNOVATION, NATURAL ASSETS, AND THE POLITICS OF ELECTRIC VEHICLE LEADERSHIP IN CALIFORNIA, NORWAY, AND QUÉBEC

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Rooted in place: Regional innovation, natural assets, and the politics of electric vehicle leadership in California, Norway, and Québec

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In the media, Norway, California, and Québec are widely acknowledged as innovative leaders in electric vehicles (EVs). Yet, what does this leadership mean and how did these jurisdictions achieve it? We contend that EV leadership reflects both intentional forethought through early, experimental and innovative policy to promote electric vehicles and the on-the-ground successful outcomes of these policies. All three jurisdictions have embarked on different leadership paths. We argue that these differences are a function of how EV policy entrepreneurs engaged unique pre-existing local assets and activated similar political mechanisms of normalization, coalition building and capacity building. When policy actors harness mutually reinforcing political and industrial dynamics, EV policies can scale up. Eventually, these dynamics may lead to new industrial path development and the decarbonization of the transportation sector.

KEYWORDS: Electric vehicles, Electromobility, Transport, Energy transitions, Experimental governance, Regional Innovation Systems

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1.0 Introduction

Norway, Québec, and California are popularly regarded as leaders in electric vehicles [1-3]. These three jurisdictions—which all lacked passenger vehicle manufacturing capacity but otherwise had three very different political economies—pursued and implemented market-creating electric vehicle (EV) policy earlier and with greater on-the-ground success than their neighbours, resulting in a significant number of EVs on the road (Table 1) and EV-related economic growth. In 2020, EVs, battery and plug-in hybrid, commanded a 75 per cent market share of new vehicle sales in Norway, while Québec and California represented 45 per cent of national EV registrations in the U.S. and Canada respectively [4-6]. Beyond creating markets for zero emission transportation, these three jurisdictions are nurturing domestic manufacturing with California producing passenger EVs [7], Quebec producing medium and heavy duty EVs [3], and Norway producing electric maritime vessels [8]. Despite many individual case studies on each of these jurisdictions, to date, no academic study has compared these three countries using a single analytic framework.

How did California, Norway, and Québec achieve this innovative leadership, which combined both experimental EV adoption policies and related industrial policies?

Many studies exist which attempt to explain EV adoption rates. Sierzchula et al. [9], using a regression analysis of 30 countries and several socio-economic factors, found that consumer financial incentives, charging infrastructure, and the local presence of an EV company (i.e., global headquarters or production facilities) to be significantly and positively correlated to national EV market share. Other researchers have considered the influence of instrumental EV attributes (e.g., model availability, driving range, charging network, purchase price), demographic factors (e.g., driver age, gender), geographic factors (e.g., location, commuting distance), and self-identity on EV adoption rates [10-13]. However, many of these EV adoption studies do not account for the role pre-existing local assets (i.e., political economy factors, such as the role of incumbent industries, legacy organizations or institutions, or local environmental factors).

Another strand of research examines the development of EV manufacturing and linkages with existing industries, technologies, and labour pools [14-18] but—with several notable exceptions [19-21]—rarely considers the politics of EV policy development and implementation. Consequently, very few studies scrutinize the dynamic interplay of local assets with the politics of EV manufacturing and adoption. Given that 80 per cent of light-duty EVs are purchased in the regions they are produced [22], understanding this interaction is important for regions seeking to become EV leaders.

Early efforts to advance transportation electrification are a form of climate governance experimentation. More generally, these bottom-up experimental initiatives to disrupt societal dependence on fossil energy are proliferating across regions and economic sectors [23, 24]. Governance experimentation is happening, particularly at the subnational level with on-the-ground attempts at problem-solving [25]. While these myriad experiments interact to make a complicated governance situation even more complex, they hold potential to create more inclusive and sustainable forms of place-based development [26, 27].

Bernstein and Hoffmann [28] attempt to make sense of the politics behind experimental initiatives, such as an ambitious EV policy regime, and how these interventions can spur additional decarbonization elsewhere. They argue that such discrete governance interventions can scale up, potentially leading to a trajectory of transformative decarbonization in a previously carbonized system, when they activate three political causal mechanisms: capacity building, normalization, and coalition building. First, capacity building works through changing the material, institutional and cognitive capacities of actors [29-31]. Second, norm change shifts expected appropriate behaviour. These expectations represent a key driver of public policy change and actor interests and are mediated by local politics and institutions [30, 32, 33]. They also transform EVs into potent political and technological symbols of change [34-36]. Third, coalition building identifies and links winners and can neutralize losers. It works through empowering and incentivizing certain actors, broadening and formalizing constituencies, and using market forces [28, 37]. These three mechanisms help governance experiments to scale up, expanding over time in size and scope, and potentially cause actors to seek decarbonization in other related economic sectors or subsectors.

While this approach provides a general framework for analyzing the dynamics of experimental governance, it provides less insight into the development of trajectories for particular experiments. The political mechanisms of normalization, capacity building and coalition building are at work in all three cases; however, they do not explain the variation in what EV leadership looks like *in specific places*. We argue that this can be rectified. By focusing on the regional political economy and the distribution of economic incumbents, this paper develops a greater understanding of cooperation, conflict, and trajectories in three noteworthy cases.

In short, the analysis of experimental trajectories needs to be grounded in the particulars of place. To do this, we draw on insights from evolutionary economic geography and the regional innovation system (RIS) approach. Trippl *et al.* [38] have created a framework that explains how regional preconditions enable and constrain green path development through local asset modification. These often-powerful assets include RIS structures such as pre-existing industrial structures, organizational support structures, and institutions, as well as natural assets. Following MacKinnon *et al.* [39], this approach interprets assets as products of the RIS. This conceptualization of the regional political economy complements Bernstein and Hoffmann's approach and responds to a dearth of socio-technical transition studies that consider how incumbent firms promote or constrain technological or business innovation [40, 41].

In turn, Bernstein and Hoffmann heed Trippl *et al.*'s [38] call to orient their framework towards broader contextual conditions, in this case the politics of governance experiments and the ultimate goal of decarbonization. The explicit focus on causal mechanisms by Bernstein and Hoffmann enables the analyst to examine the complexity of asset modification, and firm and system-level agency. Bernstein and Hoffmann also consider counter-coalitions and oppositional politics and in doing so can investigate the competition between old and new economic activities, as raised by Trippl *et al.* [38].

By synthesizing these two discipline-specific frameworks, we ask: How did the unique political economy of California, Québec, and Norway shape the pursuit of EV leadership?

We argue that pre-existing local assets condition how EV governance experiments activate the causal forces of normalization, coalition building and capacity building. In turn, this interaction can lead to scaling of the experiment. EV leadership therefore requires policy entrepreneurs to harness these political causal forces in a manner that takes strategic advantage of existing local assets. In short, this article provides a new way to think about the preconditions for EV leadership. It also represents the first comparison of the politics behind EV policies in California, Norway, and Québec.

This article is organized as follows. Section 2 details the combined green industrial path development and decarbonization policy pathway model. Section 3 presents the case studies of Norway, Québec, and California. Section 4 uses the model to compare across cases and Section 5 highlights policy implications, study limitations, and key areas for future research.

2.0 Combined Model and Case Selection

By uniting the insights from Trippl *et al.* [38] with Bernstein and Hoffmann [28], we create a new framework that combines political pathways to decarbonization with an understanding of local assets (Figure 1). To begin, a governance experiment is proposed in a context endowed with local assets. These assets represent crucial parameters that shape what is possible for the political mechanisms of normalization, capacity building and coalition building. Over time these political mechanisms may recursively modify local assets and propagate the systemic effect of scaling. Ultimately, this scaling and asset alteration could lead to a new regional green industrial path and place that industry on a broader decarbonization trajectory. However, for the cases examined here it is premature to conclude if a new industrial path has been created or if the industry has shifted to an unambiguous trajectory of transformative emission reductions. Consequently, this analysis focuses on the political dynamics illustrated in Figure 1.

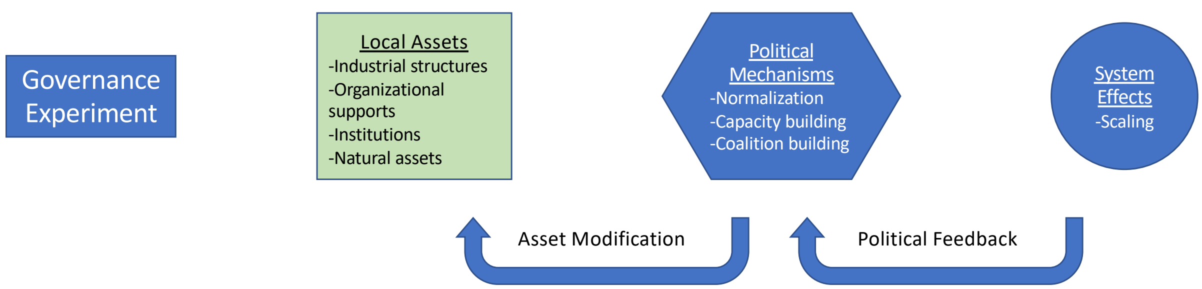

Figure 1: Combined framework modified from Bernstein and Hoffmann [28] and Trippl *et al.* [38]

RIS structures comprise an important part of a governance experiment's broader context. These structures can be favourable or unfavourable and change over time. They represent vital preconditions for the scaling of an experiment, developing a broader green industrial path, and altering an emissions trajectory.

Industrial structures can enable or constrain green path development. Those regions with green industries are likely to create an environment conducive to diversification of those industries [42, 43]. Green industrial paths can also emerge in regions with non-green sectors (*e.g.*, IT firms) and in regions dominated by dirty sectors. Regions with brown sectors can create opportunities for green industries as they attempt to address the environmental legacy of dirty sectors. Assets from incumbent industries can hamper the rise of new paths or the renewal of old paths. These impediments can take the form of vested interests seeking to sustain the status quo. Immature industrial structures or the absence of compatible firms, skills, knowledge, and technology can also negatively impact green industrial path development.

Organizational support structures also shape green path development. These structures include non-firm actors (*e.g.*, educational institutions, intermediaries, policy actors), government departments and agencies, financial organizations, civil society organizations and social movements. The absence or presence of capable organizations can impact green path development [44] and the ability for regional green industries to engage with organizations outside a region [45]. These support structures remain crucial for coalition building and capacity building.

The **institutional set-up** for a regional industry also matters. Formal institutions of laws and regulations that promote green industry or economic incumbents, and the informal institutions of values, visions, and attitudes on sustainability issues comprise important factors shaping RIS structures [46, 47]. Through capacity building and normalization, institutional set-up can lead to broader system effects.

Besides RIS structures, and following Trippl *et al.* [38], we also consider the presence and absence of **natural assets** within a broader suite of local assets. The abundance or scarcity of natural assets (such as clean air or water) can trigger green industrial path development [46]. This linkage to the natural world shapes both RIS structures and the norms invoked by governance experiments.

Bringing these insights together, we argue that pre-existing local assets condition how governance experiments activate the causal forces of coalition building, normalization, and capacity building. For instance, incumbent industrial actors can aid an experiment by leveraging existing coalitions that have influence with policymakers. Conversely, an absence of certain industries that could contest or quash an experiment through counter-coalitions may help the initiative take root and scale faster than if these threatened but powerful industries were present.

Norm-laden stories that leverage and showcase local assets act to enshrine certain narratives about economic development in a given region (*e.g.*, the role of hydropower in catalyzing industrial development or how air pollution necessitates future economic development be green) and to mitigate certain geographic constraints [48, 49]. In turn, governance experiments and political actors can artfully exploit these stories—which may stress already present place-based norms, institutions, or natural assets—to normalize EV leadership and expand supportive coalitions [50].

Meanwhile, existing institutions and organizational supports can condition how experiments take hold. They can enable or constrain these initiatives by providing extant rule-based frameworks on which proponents of these new experiments can tether their efforts. For instance, long-standing research institutions, government-funded innovation agencies, or tax regimes can anchor these experiments to location-specific institutions and *potentially* imbue them with pre-existing legitimacy and authority.

If the political mechanisms generate scaling, then a governance experiment can recursively alter both the structure of local assets and the experiment's political conditions through feedback mechanisms. This modification of local assets can manifest as a) reusing existing local assets through redeployment or recombination, b) creating new local assets or using nonlocal assets, c) destroying old local assets [38]. The process of asset modification relies upon existing local assets and, in part, the political dynamics associated with a governance experiment.

Case Selection

To better understand how existing local political economies shape EV policy development and subsequent EV-related economic development, we select three long-standing leaders in EV policy: the U.S. state of California, the Canadian province of Québec, and Norway (Table 1). Leadership connotes intentional forethought through early, experimental and innovative policy to promote EVs and the on-the-ground successful outcomes of these policies. All three jurisdictions have implemented leading EV policies since the 1980s and early 1990s, such as Norway's EV tax exemptions and support for EV manufacturing, Québec's early research into lithium-ion batteries and electric motors, and California's 1990 zero emission vehicle mandate. In 2020, nearly half of all new EV sales in the United States and Canada were in California and Québec, respectively (Table 1) [4, 6]. Norway has the world's most advanced market for EVs, accounting for 74.7 per cent of new car sales in 2020 [5].

With the important exception of a lack of significant passenger vehicle manufacturing capacity, these three cases have otherwise very different sectoral compositions. Norway is highly dependent on oil and gas extraction, which in 2021 is expected to provide 14 per cent of both gross domestic product and state revenue and 41 per cent of total exports [51]. This extreme reliance on fossil energy makes international leadership to promote and develop a domestic market for a technology that largely eliminates the need for gasoline or diesel all the more puzzling. Québec represents a quintessential case for built-in sectoral bias towards EVs. Québec's hydroelectricity sector plays an oversized role in provincial economic development, even larger than in Norway, which also boasts significant hydropower generation (Table 1) [52]. Crucially, and unlike Norway, Québec lacks any major oil and gas industry presence. California, the epicentre of car culture in the United States [53, 54], is also home to globally significant technology and aerospace sectors [55, 56]. Unlike Norway, the state's senescent oil and gas industry has carried diminished influence over environmental policy over time.

Beyond major differences in sectoral composition, analytically useful variation exists across the cases regarding political institutions and coalitions. California and Québec are sub-national jurisdictions of federated countries, making EV policy somewhat more constrained compared to unitary Norway. Yet both Québec and California exercise a policy autonomy from their respective federal governments not often pursued by other provinces or states, exemplified by their joint greenhouse gas emission cap-and-trade program, the Western Climate Initiative [57]. Further, while Norway's membership in the European Single Market does limit policymaking autonomy, Norwegians have twice rejected attempts to join the European Union to ensure they retain some degree of policy autonomy, especially over fisheries management. The cases also differ in their variety of capitalism: Québec and California are both sub-national regions within liberal market economies, while Norway is a coordinated market economy. In terms of electoral systems, type of legislature, and patterns of party rule, Quebec has a plurality electoral system and unicameral legislature, with a long history of majority governments although held by several different parties (e.g., *Parti libéral du Québec, Parti Québécois, Coalition avenir du Québec*). California has a plurality voting system and a bicameral legislature. The Democratic Party has controlled the state's Assembly and Senate since 1970, with the exception of 1995-1996 when the Assembly was controlled by the Republican Party. Norway has a party-list proportional representation electoral system with multi-member constituencies and a unicameral legislature. Norway is nearly always governed by a coalition government, whose party composition frequently changes and is often anchored by either the *Arbeiderpartiet* (Labour Party) or *Høyre* (Conservative Party).

Table 1: Background statistics for each case

	California	**Québec**	**Norway**
Population (2019)	39.51m	8.49m	5.33m
GDP (USD 2019)	3,133b	293.8b	403.3b

GDP per capita (USD 2019)	79,436	42,189	75,419
GHG emissions (Mt CO2eq; 2018)	425.3	82.6	52.2
GHG emissions per capita (Mt CO2eq; 2018)	10.7	10.1	10.1
Average annual hydroelectric generation (TWh, 2020)	34	223	136
Total EVs (2020)	704,068	91,826	489,779
New passenger EV market share for jurisdiction (%, 2020)	7.73	16.9	74.7
National share of new EV registrations (2020)	45%	45%	n/a

Sources: [4-6, 58] [59-61] and authors' calculations. [62]

Note: To compare across cases, EV includes BEV and PHEV only.

The cases are comparable in many ways—including the absence of significant passenger vehicle manufacturing capacity—but vary in terms of their assets, their size, the market share of EVs, and to a lesser extent, their policy autonomy. They were selected on the basis of their EV policy leadership and not on their industrial makeup or subsequent EV-related economic development. Selecting three successful cases inductively aids in theory development [63], but makes theory testing difficult due to confirmation bias. To more robustly test this theory, future research could explore the political economy dynamics in regions with incumbent passenger vehicle manufacturing, especially those where automakers were not early leaders in electric vehicles (e.g., Ontario, Michigan, Baden-Württemburg). The cases presented here are used to inform the framework and aid in hypothesis generation for future applications.

Evidence for identifying the local assets, causal mechanisms, and system effects are drawn from 23 semi-structured interviews with key policy and industry participants and observers of electrification efforts in California, Norway, and Québec (Table 2). We obtained research ethics clearance for these interviews from the University of Ottawa Research Ethics Board. In addition, a range of secondary sources informs the analysis, including government documents, databases and websites, reports from non-governmental organizations, and media articles.

3.0 Case Studies

3.1 Norway

Norway represents a curious case of EV leadership. Rarely are major oil and gas-producing countries innovators in electrifying transportation. However, after several failed attempts to build domestic EV manufacturing from scratch, Norway laid the policy groundwork to develop a consumer market for EVs. Once this EV market scaled, policy actors modified local assets to spur electrification in maritime transport, providing growth opportunities for the domestic shipbuilding industry. In 2020 battery EVs (BEV) and plug-in hybrid EVs (PHEV) commanded a 75 per cent market share of new passenger car sales, the highest in the world (Figure 2). The recent widespread adoption of EVs has caused passenger transport GHG emissions to fall just below 1990 levels [64].

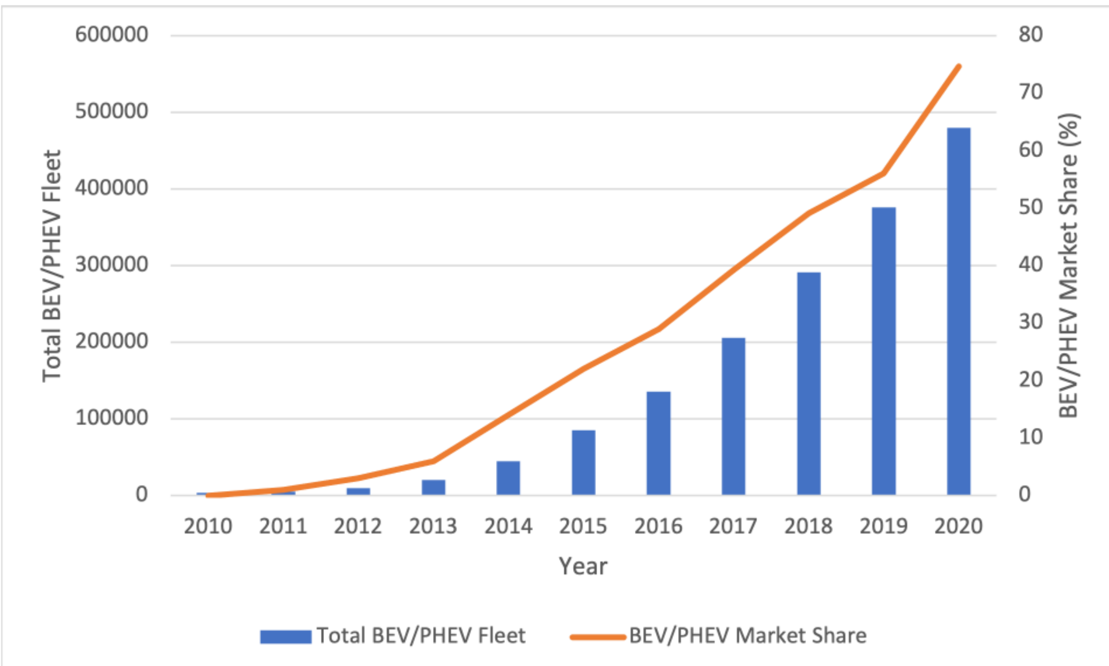

Figure 2: Total battery electric and plug-in hybrid electric passenger vehicle fleet and market share in Norway (2010-2020). Source: [5]

Local Assets

Norway's regional industrial structure provided a strong enabling environment for transportation electrification. Stagnant growth in the country's oil and gas industry encouraged business leaders and politicians to look for growth opportunities in other sectors. Norway lacked an incumbent auto manufacturing industry and boasted a sizeable shipbuilding industry that was looking to diversify away from building supply ships for the offshore oil and gas industry [65]. A strong organizational support system facilitated the development of EVdriven economic development. Since the 1970s and the development of its oil and gas industry, Norway has become a wealthy state with a history of state-led innovation [66, 67]. Moreover, its environmental movement has played a crucial role in shaping environmental policy, regardless of the ruling coalition [68]. Over time, the institutional environment for EVs evolved as local assets were modified by, among other things, earlier EV policy interventions.

In the 1970s and 1980s the state supported R&D for domestic manufacture of EVs. In the 1990s, the government pushed to commercialize EV manufacturing through support of Oslo-based Think Motors and started implementing a suite of EV purchase and use incentives. In the 2000s, the EV market in Norway suffered from sporadic supply as domestic attempts to manufacture EVs ceased. However, policymakers continued to layer additional EV purchase and use incentives (*e.g.*, use of bus lanes, tax reductions for corporate fleets). In the 2010s, the state built an EV charging network throughout Norway and used the growing domestic market to test EV technologies and policies at scale. Norway also has abundant natural assets, in the form of virtually emission-free, low-cost hydroelectricity. The Norwegian government has long used this energy source, which harnesses Norway's topography and weather patterns, as a vehicle for regional industrial development (*e.g.*, alumina refining, chemical manufacturing) [69]. Taken together, these assets created an enabling environment for the development of EV policies and EV-related industry. In the 2010s, deteriorating local air conditions from increased road traffic in Oslo provided an additional impetus for vehicle electrification [70].

Political Mechanisms

Normalization and capacity building mark two key political causal mechanisms that drove the broader success of Norway's EV policies and related economic development. Capacity building focuses on the ability for initiatives to teach how to act on climate change and sometimes to provide the direct financial or political resources to the governance initiative and groups that support it. EV policy of the 1970s and 1980s provided direct financial support for EV manufacturing R&D. In the 1990s state support shifted to providing financial incentives to purchase EVs through reduced taxes. During the 2000s, as large international vehicle manufacturers began to dominate the nascent Norwegian EV market and domestic EV manufacturing collapsed, government policy focused on making EV use easier. Free charging, parking, toll roads and ferries all reduced the operating cost and increased driving convenience for EV users.

The EV user group, *Norsk elbilforening*, founded in 1995, beyond building coalitions with environmental groups and municipalities also built societal capacity, especially of its membership, through public education on the benefits of EVs. It offers insurance, legal advice, educational resources specifically targeted to electric vehicle users, and maintains an open access database of EV charging stations.

Upfront EV incentives constitute the main driver of EV adoption. Once in place, a suite of EV policies effectively made the price of electric vehicles the same as conventional vehicles [71], making it much easier for Norwegians to choose green. A May 2018 survey conducted by *Norsk elbilforening* of 9520 of its members with BEVs found that 63 per cent of respondents would not have purchased a BEV without exemptions for the value added tax and purchase tax [72]. These policies designed to reduce the upfront cost of a BEV comprised a much greater determinant of EV adoption than the many policies designed to make EV use more convenient or the technology's environmental attributes. This finding suggests that capacity building represents a more powerful determinant than normalization on EV adoption rates in Norway. In this case, a logic of consequences has primacy over a logic of appropriateness [73], where rational cost-benefit calculations are placed above social norms in guiding vehicle choice for Norwegians.

Norms nonetheless remain a crucial catalyst in the success of Norway's EV policies. Some norms predate EV policy in Norway and others have resulted from the EV policy itself. Norwegian society has long had strong environmental norms. These pre-existing norms strengthened from the 1970s through the 1990s. The 1973 oil crisis spurred a new interest or normative shift among highly industrialized countries in energy conservation that lasted until the 1980s. This energy efficiency norm helped catalyze some research and development efforts in EVs in Norway during this period. The rising concern of global warming in the late 1980s and early 1990s was aided by Norway's Prime Minister Gro Harlem Brundtland, who chaired the World Commission on Environment and Development [69].

EV policies themselves helped normalize EV adoption. Seeing other Norwegians use EVs provides powerful demonstration effects, where "keeping up with the Johansens" materially translates into purchasing a zero-emission vehicle. A 2016 survey of 8000 vehicle users in Norway found peer-to-peer influence particularly important for EV adoption compared to internal combustion enging vehicles (ICEVs); family and friends proved more influential than information from car dealers or advertising [1]. A 2017 survey of EV users replicated these findings. Seventy-two per cent of respondents inspired at least another friend, family member or acquaintance to purchase an EV [72]. These evident demonstration effects further normalized EV adoption and use. Another study found that Norway's EV policies created a norm of collective responsibility for decarbonizing the transport sector [74].

Significantly, Norway's EV policies faced minimal contestation or opposition. Policymakers did not have to worry about driving up costs for non-existent local manufacturers and suppliers of ICEVs and eroding their competitiveness. Because of these existing industrial structures, and the capacity building and normalization of EV policies present in Norway, no ruling political parties have successfully opposed EV policies. Meanwhile, costly domestic EV policies were acceptable and even advantageous to the country's powerful export-oriented oil and gas industry, as it redirected the energy of Norwegian environmentalists and a "green" state towards a less controversial target. Thus, for a consensus-minded society, it was easy to say yes to EV policies.

System Effects

Conducive political and economic dynamics enabled early simple scaling (*i.e.,* when an initiative increases its activities), as the number of EV policies, charging stations, companies with EV-related business lines, and EV market share increased. This scaling of Norway's EV policies has taken place despite many successive changes in government, between Labour and Conservative-led coalitions, including most recently with the September 2021 election. Once the success with EVs became entrenched, it fostered secondary scaling (*i.e.*, when an initiative spawns further initiatives as other groups begin to occupy the niches created by the original initiative), in other modes of transportation, particularly maritime transport. This secondary scaling, along with the simple scaling of EV policies, through political feedback and asset modification, reinforced Norway's efforts to electrify transportation.

Several environmental groups emerged as key actors promoting the creation of new decarbonization niches: notably Zero and Bellona. For instance, Bellona—which successfully advocated for the first EV purchase incentives—had an explicit strategy to push for decarbonization in other sectors once progress was achieved on EVs (NO01). In 2010, Zero released its first report on battery electric ferries and successfully pressed politicians to fund a prototype [75]. The 2011 national budget allocated funding for a development contract tender for a low-emission ferry (NO03). This tender led to the development of the fully electric MF Ampere, which would save its owners, Norled, one million litres of diesel fuel per year. The Ampere provided a strong demonstration effect to parliamentarians that this intervention could be scaled and, crucially, that Norwegian shipyards could build these new vessels [76]. In 2015 the Norwegian Parliament passed legislation requiring all tenders for new passenger ferries to contain low or zero-emission propulsion. According to the Norwegian Centre of Expertise for Maritime CleanTech, this decision led to an “electric revolution in the Norwegian fjords” [77]. Beyond tendering policies, the government further encouraged electric maritime transport; it lowered harbour taxes, increased taxes on fossil fuels, required all ports to have shore-to-ship power infrastructure, and provided direct financial support for innovative projects.

These incentives and new technology appear to be working [8]. The battery electric technology which debuted in the Ampere will be in 72 ferries in Norway by 2022. Norled is scheduled to pilot a hydrogen-electric ferry in 2022 in Rogaland, Norway. Hydrogen fuel cells remain more effective for longer distances than current battery technologies. The success of EV policies and electric ferry demonstration projects emboldened the Norwegian government to set the goal of electrifying two-thirds of all passenger and vehicle ferries by 2030 [78].

This electrification ambition extended beyond ferries to later include much larger and more polluting cruise ships. In 2018 the Norwegian Parliament adopted a resolution, the first of its kind in the world to prohibit greenhouse gas emissions from cruise ships and ferries entering Norwegian fjords and harbours by 2026 [77]. The 2018 decision and other electric maritime transport policies are spurring investment decisions from local boat operators and shipyards and large international companies. For example, Siemens opened a highly automated and digitized manufacturing facility in Norway in 2018 to build batteries for marine and offshore oil applications [79]. Hurtigruten, one of Norway’s largest cruise lines, is retrofitting nine cruise ships with a combination of battery power, liquified natural gas, and liquified biogas from fish processing plants along the coast [80]. In 2019, the company launched the world’s first purpose-built hybrid electric cruise ship.

Like with EVs and hydroelectricity, proponents for electric ships link back to pre-existing and culturally important industries. In 2017, Ketil Solvik-Olsen, Norway’s then Minister of Transport from the far-right-wing Progress Party, pledged his strong support for electrifying maritime transport and noted how this built on Norway’s strong tradition of shipbuilding and leadership in maritime shipping. This shift to electrifying maritime transport proved a lifeline for Norwegian shipbuilding companies experiencing declining contracts related to offshore oil and gas service and supply boats.

3.2 Québec

Like Norway, the Canadian province of Québec is a long-standing EV leader. The provincial government's approach to electrifying transportation harnessed regional industries and promoted economic development. Local policymakers created institutional ecosystems for regional innovation in transportation electrification and built businesses across the complete value chain, from raw materials to manufacture and use to recycling. Over time, these initiatives modified local assets and helped create the political and economic environment for EV leadership. With the rapid drop in technology costs and growing demand, local firms quickly increased their market share.

Local Assets

Québec's regional industrial structure provided a fertile environment for the development of electric vehicles. Like Norway, it lacks a major auto industry. GM closed its Sainte-Thérèse plant—the last passenger vehicle assembly plant in the province—in 2002. The fossil fuel industry has a minimal and shrinking footprint in the province, with no domestic production and two refineries. Of note, the province hosts a major commercial and recreational vehicle manufacturing industry. Québec constitutes a key supplier of school buses, transit buses, coaches, dump trucks, ambulances, snowmobiles and motorbikes to the North American market. Also, like Norway, the electricity sector played a key role in the province's economic development. Since the province started nationalizing the sector in 1963 to form *Hydro-Québec*, policymakers used the public monopoly to promote local industrial development and reduce residential electricity costs [52]. In 1967, as part of its economic development mandate, *Hydro-Québec* created the *L'Institut de recherche d'Hydro-Québec* (IREQ). The largest utility-based research centre in North America, IREQ has 500 scientists, engineers, and technicians and an annual budget of over $100m. As a result of the 1973 oil price shock, IREQ initiated research into batteries and electric motors [3]. *Hydro-Québec* later formed spin-off companies based on its solid-state lithium battery (now Phostech Lithium) and electric motor wheel technologies (TM4 Dana), which has helped shape the province's industrial structure. The utility also now owns *Circuit Électrique*, the largest public EV charging network in Québec and Eastern Ontario.

A highly supportive and dense organizational ecosystem exists in Québec that facilitated vehicle electrification. Since the 1970s, Québec has developed a robust regional innovation system, in part due to its quest for greater economic and cultural autonomy within the Canadian federation [81]. The province also benefitted from an influential environmental movement that helped provide public education and popular support for various EV initiatives.

Québec's institutional set-up also contributed to a nurturing environment for EVs. Through

Hydro-Québec, the state began by funding R&D for EV components in the 1970s and 1980s. Shortly after California adopted its market-creating 1990 ZEV mandate, *Hydro-Québec* sought to commercialize its EV technologies [3]. In 2006, Québec provided a purchase incentive for EVs and moved to adopt California's vehicle efficiency standards [57]. Strategic five-year planning documents from *Hydro-Québec*, beginning in 2009, and the provincial government starting in 2011, included vehicle electrification targets, purchase incentives for passenger and commercial vehicles, additional funding for research and cluster development, along with the design and construction of an electric bus. In the mid-2010s, the province implemented additional EV use incentives (*e.g.*, access to HOV lanes, charging facilities) along with a ZEV mandate. Québec's abundance of low-cost and low-emission hydropower forms a strategic natural asset to fuel the electrification of transportation.

Political Mechanisms

Policy entrepreneurs activated normalization, coalition building, and capacity building to strengthen Québec's EV policies and associated economic development. Québec-based EV proponents accessed long-standing cultural norms about hydropower. *Hydro-Québec's* promotion of transport electrification leveraged its historic role in promoting independence, emancipation, and technological sophistication [52]. Quebeckers sought greater economic control over their own developmental pathway and endeavoured to reduce dependency on polluting oil imports, deepening the environmental stewardship norm in Québec. A 2019 survey of the members of Québec's EV user association, *l'Association des Véhicules Électriques du Québec* (AVEQ), found that 75 per cent of respondents chose an EV for ecological reasons [82]. Other EV advocates—whether from various political parties, the mining sector, or commercial vehicle manufacturing—invoked these widely held norms about their electricity supply and environmental stewardship to promote expansion of electrified transport. In this context, electrifying transportation became common-sense—a norm that emerged over time from various EV initiatives. Due to its widespread acceptance, additional EV governance experiments encountered little opposition from the public, politicians, or the private sector.

Capacity building remained a key element throughout Québec's engagement with transport electrification. Early EV policy in the 1970s and 1980s focused on government-funded R&D through *Hydro-Québec's* research centre IREQ. Subsequent state efforts formed centres of innovation and regional clusters to test and commercialize EV-related technologies. In the 1990s, *Hydro-Québec* created research collaborations primarily with French and

American companies. In the 2000s, many Québec-based commercial vehicle manufacturers produced EV prototypes but, until the late 2010s, could not commercialize these models due to the high cost and limited range of batteries. Meanwhile, environmental organizations (*e.g.*, *Équiterre*) and later Québec's EV user association, AVEQ, educated the public, media, and policymakers on the merits of electrifying transportation. A growing suite of policies reduced the cost of ownership (*e.g.*, purchase incentives) and made using EVs more convenient (*e.g.*, charging networks) further building capacity. A 2020 survey of Quebeckers, commissioned by *Équiterre*, AVEQ, *Vivre en ville*, and the David Suzuki Foundation, found 78 per cent of respondents were in favour of EV purchase incentives [83].

Many of the key capacity building organizations also fostered coalitions. AVEQ, formed in 2013, has become a significant force in bringing together the public to increase EV use. Environmental organizations created the *Coalition zéro émission Québec* in 2014. Unlike other jurisdictions with deregulated electricity markets, the state-owned utility monopoly, *Hydro-Québec*, faced fewer coordination challenges related to electromobilty. Within the provincial government, the iterative five-year strategic planning process has brought together a broad range of departments and agencies to advance transportation electrification. A broad range of industrial players have sought to enlarge the pro-EV coalition in Québec. *L'Association de l'industrie électrique* (AIEQ) developed a coalition within the broader electricity sector to promote transport electrification. *Propulsion Québec* represents a central organization that promotes intelligent and electric transport through joint projects among its 210 members. Heavy industry, like mining and aluminum, along with many medium and heavy-duty vehicle manufacturers vocally support EV adoption and the manufacture of medium and heavy-duty EVs in Québec.

Like in Norway, no significant counter coalitions emerged to resist EVs. The typical opponents of EV policies, passenger vehicle manufacturers and oil companies, had a small regional presence and could not block or weaken EV policies. Meanwhile, Québec's EV policies did not penalize conventional vehicle owners through a bonus-malus system, further limiting popular resistance. Crucially, political parties abstained from using EVs as a wedge issue. Instead, a cross-party consensus exists that Québec should lead in electrifying transportation. Long-held regional norms about electricity and the environment, and EV policies that built capacity and enlarged existing hydroelectricity-led economic development coalitions, help explain the absence of counter coalitions. Electromobility advocates and innovators easily gained membership within these established policy networks, which in other jurisdictions may have blocked or ignored these actors.

System Effects

Working together, the causal forces of normalization, capacity building, and coalition building helped scale up EV policies in Québec and catalyze related economic development. Québec's policies have remained relatively stable. Despite many changes in government over the last decade, from *Parti libéral du Québec,* to *Parti Québécois,* to *Coalition avenir du Québec,* the EV purchase and use incentives and the ZEV mandate have been maintained. In contrast, the neighbouring province of Ontario cancelled many EV policies after a 2018 change in government. Ontario's new Progressive Conservative government quickly announced the termination of the EV purchase incentive, valued up to 14,000 CAD, which led to a rush to buy EVs before the incentive was officially removed. In 2019, Ontario's EV sales plummeted by 48 per cent in 2019 compared to 2018.

Beyond avoiding retrenchment, Québec's efforts to electrify transportation expanded. The increased funding allocated to EV programs, such as the purchase incentive, procurement of electric buses, the expansion of the public charging network, or the growing number of EVs on Québec roads, all exemplify simple scaling (Figure 3). Besides strengthening existing policies, new policies are becoming more ambitious. In 2020 the provincial government announced a ban on the sale of fossil-fuelled passenger vehicles by 2035, mimicking a Californian policy announced earlier that year. Also in 2020, Montréal announced plans to ban ICEVs from the city's downtown core by 2030. While a goal from the mid-1990s of passenger EV manufacturing never came to pass [84], Québec-based manufacturers now produce a wide variety of commercial EVs (*e.g.*, electric school buses, transit buses, coaches, mining vehicles, utility vehicle, ambulances) and supply equipment for EVs (*e.g.*, charging stations, battery management systems). Since the late 2010s, Québec-based recreational vehicle and boat manufacturers have produced electric models (*e.g.*, snowmobiles, motorcycles, jet skis, powerboats, golf carts, and bicycles). The reduced input costs for specialized EV parts—a result of the global scaling of passenger EVs—enabled these companies to create commercially viable electric models. Specifically, improved battery range and energy density allowed these manufacturers to move beyond prototypes to commercial models.

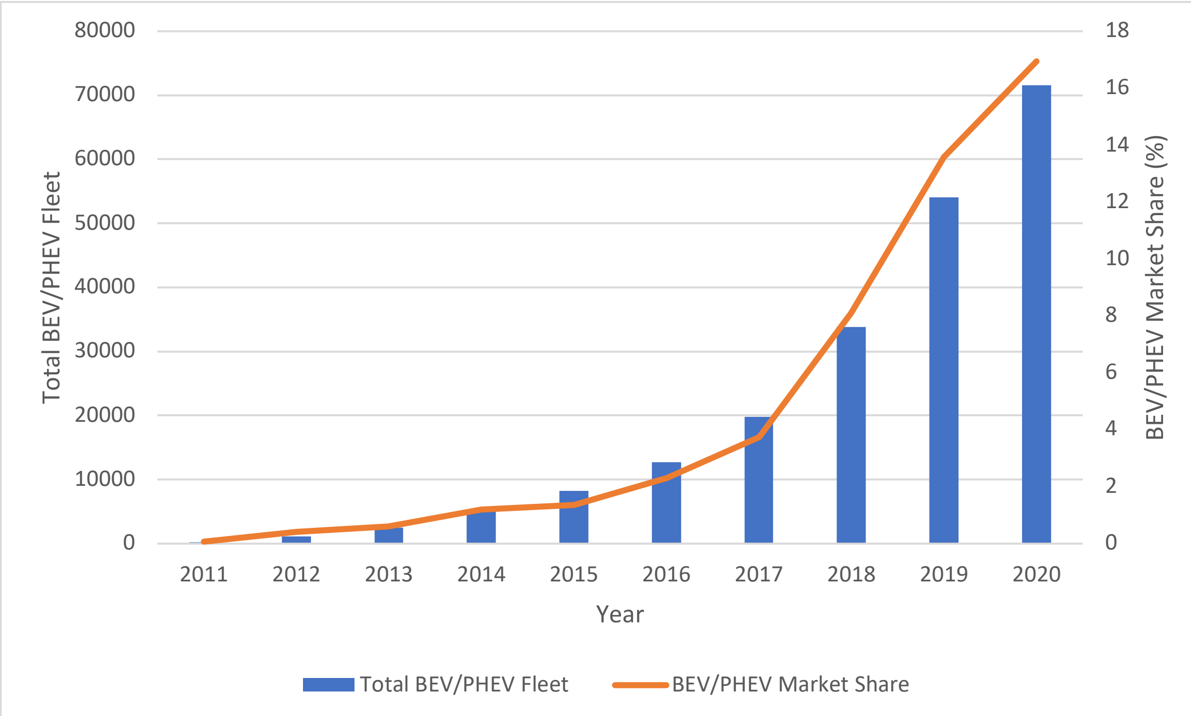

Figure 3: Total battery electric and plug-in hybrid electric passenger vehicle fleet and market share in Québec (2011-2020). Source: [62]

3.3 California

California's efforts to electrify transportation embodies a political and economic response to regional air pollution. The state's market size conferred significant power to environmentally-minded legislators when developing EV policies. Moreover, existing technical capacity from aerospace and other technology sectors provided the competence needed to nurture California-based EV manufacturing. Like Norway and Québec, some early Californian policy efforts failed. However, state-based proponents of EVs continued to push traditional automakers and encouraged the development of new EV manufacturers.

Local Assets

California's EV efforts directly stem from the historic and continued scarcity of clean air. The unique topography of Southern California combined with highly car-dependent communities and heavy industry made the natural asset of clean air in metropolitan areas exceedingly rare beginning in the 1950s [54]. Early policy efforts from the 1950s and 1960s to address chronic air pollution enabled California to acquire unique authority among U.S. states to set stricter emissions standards than the federal standards of the 1970 Clean Air Act. While EV policies only emerged in California in 1990, these early policies benefitted from the institutional legacy from California's air pollution crisis. The California Air Resources Board (CARB) epitomizes this legacy and evolved into an invaluable proponent for electrifying transport [85]. Over time, CARB nurtured an EV policy ecosystem that included a ZEV mandate, GHG emission standards, a low carbon fuel standard, and purchase incentives for both EVs and charging stations. In addition to CARB, the California Public Utilities Commission, which regulates privately owned public utilities such as electricity, and the California Energy Commission (CEC), the state's primary energy policy planning agency, have been central institutions in the development and implementation of EV policies.

California's industrial structure enabled the development of EV manufacturing. Like Norway and Québec, passenger automakers lacked a significant manufacturing footprint in the state. The last ICEV auto assembly plant shut down in 2010. However, commercial vehicle manufacturers (*e.g.*, bus manufacturers) located in California because of the state's significant market size. The oil industry, while historically powerful, faced declining production since 1990 and is now being phased out by the state. In 2021, the California Governor announced his intentions to phase out all oil production by 2045. Meanwhile, the technology and aerospace sectors long remained key sources of innovation for California's economy, even if manufacturing in those sectors largely moved out of state. California's organizational support structure facilitated EV leadership. Empowered regulators, notably CARB and air quality management districts, a strong educational system, access to San Francisco Bay-area venture capital, and capable environmental organizations all provided crucial resources to sustain and expand EV policies and related economic development in California.

Political Mechanisms

California began its EV governance experiment with significant capacity amassed from decades of battling air pollution. CARB boasted strong technical expertise and relative independence from political influence [2]. The regulator improved coordination among public and private sector actors, engaged in strategic planning, and shared expertise. It administered key policies that built capacity for EV adoption (*e.g.*, ZEV mandates, a GHG emission cap-and-trade system, a purchase incentive program called the Clean Vehicle Rebate Project, fleet emission standards, a low carbon fuel standard, air quality programs, and binding policy roadmaps). Of note, purchase incentives, funded by cap-and-trade proceeds, brought EVs within reach of many households. Similar to Norway, two-thirds of EV owners surveyed by the CEC found the state plug-in EV purchase incentives to be very or extremely important in the decision to acquire a plug-in EV [86]. Beyond consumer incentives, the Low Carbon Fuel Standard (LCFS), which intends to decrease the carbon intensity of transportation fuels and encourage less polluting alternatives, also built capacity. EV manufacturers can earn valuable credits, paid by sellers of transportation fuels who do not reduce the carbon intensity of their products [87]. Along with revenue from the state ZEV mandate, these regulatory credits have helped to nurture an EV manufacturing industry that has historically struggled with profitability.

Beyond CARB, other state agencies are also involved in building EV capacity. For instance, the CEC and the California Public Utilities Commission both fund programs to install EV charging facilities. However, state policies do not exist in a vacuum. Many other capacity building initiatives from federal and municipal governments, metropolitan planning organizations, utilities and NGOs layered upon state policies. For example, The Electric Power Research Institute (EPRI) is non-profit research organization headquartered in Palo Alto that has conducted EV-related research since 1986 [15]. With a membership of electricity sector stakeholders, it has played a role similar to Québec's IREQ in supporting EV research and development. Also, the utility Southern California Edison, partners with community stakeholders to install EV charging stations and provides rebates for the purchase or lease of new and used EVs. VELOZ (formerly the PEV Collaborative) is a public-private partnership that promotes knowledge diffusion within industry and the broader public. California also funds university-based EV R&D and EV-related workforce training program. The Governor's Office of Business and Economic Development (GoBiz) established a ZEV market strategy. The Los Angeles Economic Development Corporation (LAEDC) works with industry to promote EV-based economic activity in the region and the Los Angeles Cleantech Incubator promotes companies advancing transportation electrification [88].

California's EV policies pushed incumbent automakers to manufacture EVs and created market space for entrants (*e.g.*, Tesla, Lion Electric, GreenPower), accelerating EV adoption in the state. According to Judy Kruger, senior director at the LAEDC, "the state environmental goals brought this [EV] market to California. The environmental goals and policy attracted market solutions" [89].

Compared to Québec and Norway, California's large population and economy complicates coalition building. However, EV proponents established broad coalitions representing a diverse range of interests among incumbent industries, public sector and NGO actors. Organizations such as the Coalition for Clean Air and CalSTART played integral roles. Because of this broad support, long-ruling Democrats steadfastly supported the state's EV policies. The California Public Utilities Commission, which regulates the electricity sector, has become a key agent in coordinating the highly fragmented market. During the Trump administration, the federal government sought to block California's efforts to reduce air pollution and grow an EV market by attempting to rescind the U.S. Clean Air Act waiver. Albeit unsuccessful, this action created uncertainty that hindered EV investment in the state.

Unlike the other cases, counter coalitions did emerge to successfully weaken and delay EV policies in the 1990s and early 2000s; however, their influence waned with subsequent policies. While the US auto industry did not have a large manufacturing presence in California, they did successfully organize, along with the oil industry, to weaken and delay early attempts for a ZEV mandate [2]. In 2010, Proposition 23 threatened to retrench California's climate policy regime. This largely oil industry-organized plebiscite would have suspended a major climate law, AB 32, that through a cap-and-trade system funds many of the state's EV-related initiatives. However, Californians strongly defeated this ballot measure by a 23 per cent margin.

In California, EV proponents relied on long-standing regional norms that valued clean air and reinforced Californians' love affair with cars. According to a 2020 survey of Californians, 80 per cent of respondents said that widespread EV use would help reduce air or climate pollution [90]. Mary Nichols, CARB director, described the 2012 Advanced Clean Car Program as "a new chapter for clean cars in California and in the nation as a whole. Californians have always loved their cars. We buy a lot of them and drive them. Now we will have cleaner and more efficient cars to love" [91]. Over time, policymakers sought to include environmental justice norms in state EV policies, partly in reaction to most EV policies disproportionately benefitting higher income and predominantly white households [92]. Now public EV charging stations installation programs target historically underserved communities (*e.g.*, California Electric Vehicle Infrastructure Project). In 2016, CARB, through the CVRP, modified EV purchase incentive programs to have an income cap [93].

The story of California's ZEV mandate and its interaction with regional industrial structures exemplifies the political and economic dynamics captured in our model and warrants closer examination. In 1990, GM unveiled the Impact, its battery electric prototype, and announced production plans [94]. The Impact resulted from the technical capacity acquired by GM's acquisition of California-based aerospace and defence contractor Hughes Aircraft in 1985 and was built in close partnership with another California-based aerospace and defence contractor, AeroVironment, and local electronics engineer Al Cocconi [95]. In 1996, a heavier and slower version of the Impact came to market as the EV-1.

GM's 1990 move, along with the 1988 South Coast Air Quality Management District plan that called for EVs to reduce air pollution, signalled to CARB that California-born EV technology was close to commercialization and that it could count on crucial regional support [2]. Later that year CARB launched a mandate for zero-emission vehicles (ZEVs) as part of its Low Emission Vehicle (LEV) program. The ZEV mandate required that 2 per cent of all new cars sold in California by large automakers must be ZEVs by 1998, with stringency increasing over time.

The ZEV mandate was a technology-forcing regulation. Automakers quickly responded by investing into ZEV-related research. The number of battery patents filed by original equipment manufacturers after 1990 skyrocketed [96]. However, many automakers could not commercialize and profit from this technology fast enough to allow them to meet the ZEV sales targets and subsequently sought to defang the mandate. In 1996, following formidable pressure from oil and auto companies, state legislators eliminated interim targets [21]. Subsequent lawsuits by automakers further stalled implementation until 2012 when California adopted a new, more successful ZEV mandate. Despite the lack of success with the early ZEV mandate [97], it did cause widespread deployment of hybrid engine technology [96]. CARB's adaptive and iterative approach to the setting of the ZEV mandate demonstrates the challenge and importance of using regulation to accelerate technology adoption and stimulate economic development.

Despite the overt failure of the 1990 ZEV mandate and GM's Impact/EV-1, the existing assets leveraged by automakers and policymakers were modified and later put to use, with great success, by subsequent innovators. In 2010, Tesla Motors began production in Fremont, California at the former New United Motor Manufacturing, Inc. (NUMMI) plant—the only auto plant in the state. NUMMI was a joint venture (1984-2010) between GM and Toyota and provided, among other things, an opportunity for GM to learn about Toyota's manufacturing approach [98]. Tesla chose to produce battery electric passenger vehicles in California so that it could a) easily serve the country's biggest EV market—thanks to layered purchase and use incentives and GHG emission and clean fuel standards, b) receive generous federal funding and state grants, and c) draw from the local availability of clean tech and aerospace engineers. Tesla's decision to locate in California and its subsequent commercial success helped launch an EV industry in California. Tesla also benefitted from the technological innovation spurred from AeroVironment contractor Al Cocconi, who—after his work on GM's Impact prototype—founded California-based AC Propulsion in 1992. Tesla acquired its original intellectual property from AC Propulsion for its early Roadster model [95].

System Effects

Like Norway and Québec, California's early EV policies developed in fits and bursts and experienced some notable retrenchment. However, over time many EV policies established themselves and increased in ambition. EVs were allowed access to HOV lanes in 2000 and in 2002 the state began regulating tailpipe GHG emissions. In 2007, CARB established a low carbon fuel standard and began offering purchase incentives for electric vehicles. The 2012 Advanced Clean Cars Program strengthened several ZEV-related policies, including a mandate for 15 per cent of passenger vehicles sales to be zero emission by 2025. In 2016, California modified its EV purchase incentives to target lower and middle-income households. In 2020, the CARB adopted a ZEV mandate for medium and heavy-duty trucks (*i.e.*, Advanced Clean Trucks regulation), which requires increasing sales of electric trucks until 100 per cent of new truck sales are electric by 2045.

As EV policies have scaled up so too has the number of EVs on Californian roads. In 2020, 559,969 BEV/PHEVs were registered in the state and these zero emission vehicles comprised 7.7 per cent of all new car sales [99] (Figure 4).

Through asset modification and political feedback mechanisms, these EV policies stimulated related economic development in the state (e.g., EV design and manufacturing, including medium and heavy duty EVs), enhancing local assets and further reducing the political barriers for EV adoption.

Outside of the state, California is a national pacesetter for vehicle electrification policies, which have been adopted in part or in whole by many other jurisdictions. Section 177 of the U.S. Clean Air Act enables other U.S. states to adopt California's stricter emission standards. As of 2021, 14 US states have implemented California's ZEV mandate or low-emission vehicle criteria pollutant and GHG emission regulations—a classic case of Vogel's "California effect" [100].

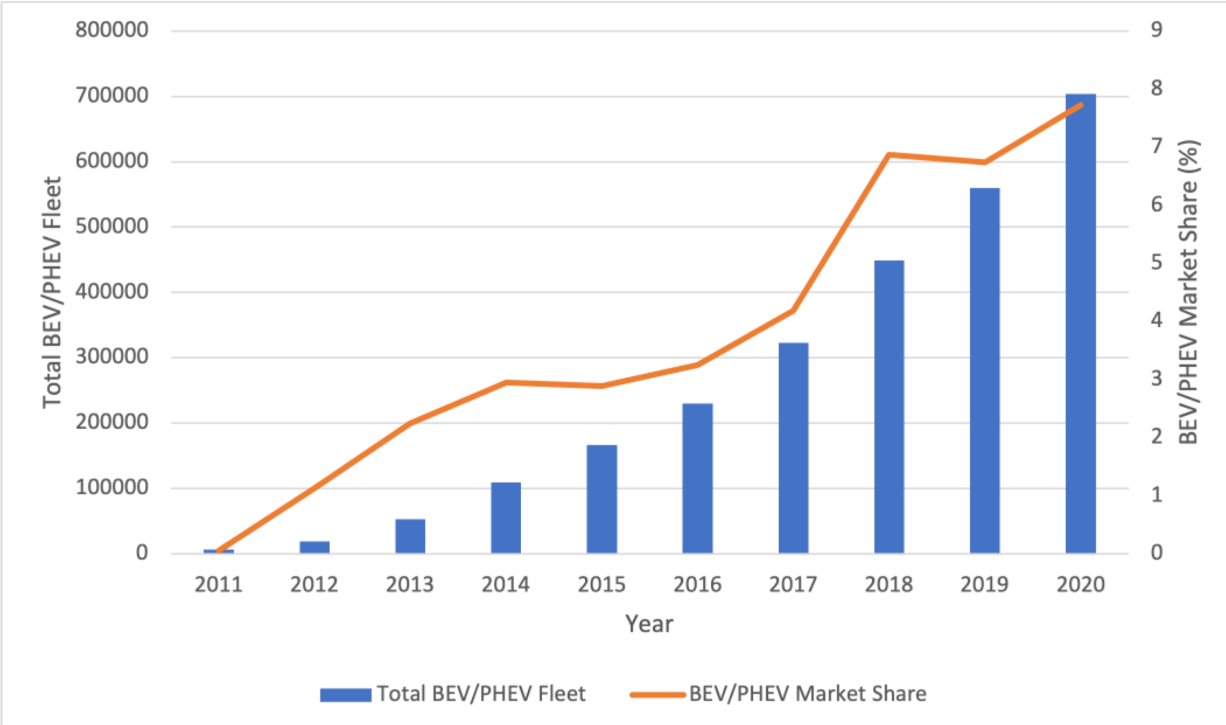

Figure 4: Total battery electric and plug-in hybrid electric passenger vehicle fleet and market share in California (2011-2020). Source: [99].

4.0 Comparative Analysis

Despite the multinational nature of the auto industry, its globalized supply chain, and shared exogenous events—such as the 1970s oil shocks—EV governance experiments occur within local contexts. Existing industries, organizational support, institutions, and natural assets all condition how EV policies take hold or not in a region. Eventually, these policies may shape regional industrial development and decarbonization policy pathways. Table 3 summarizes how California, Norway, and Québec map onto the model framework. Some similar local assets exist. Importantly, incumbent passenger automakers did not have a major presence in all three cases. Norway and especially Québec have supportive state-owned hydroelectric utilities. Norway and California's oil industries, which faced stagnant or declining production, could not block EV policy development. Meanwhile, California's aerospace and technology sectors provided key skills that successfully attracted passenger EV manufacturing. Institutionally, all cases benefitted from early, strong, and durable EV policies. In particular, Norway benefitted from a unique pre-existing tax structure for ICE vehicles. All three jurisdictions boasted facilitative organizational support structures. California's powerful air pollution-fighting institutions, notably CARB, turned towards vehicle electrification. Québec policymakers rallied Hydro-Québec's deep resources, monopoly power, and long-standing interest in regional economic development to overcome coordination challenges and pursue transportation electrification. Norwegian politicians directed the country's state-led innovation system to promote the economic opportunities associated with electrifying transportation. In all three cases, influential environmental groups played an instrumental role in advancing EV policies and promoting regional economic development. Natural assets also loomed large. In Québec and Norway, cheap and relatively green hydropower proved a crucial natural asset. In California, it was the scarcity of clean air that drove the adoption and use of EVs.

Table 3: Model framework applied to California, Québec, and Norway

	California	Québec	Norway
Local Assets			
Regional Industrial Structure	Enabling: Limited auto sector presence, declining oil production, presence of significant aerospace and tech. sector	Enabling: Absence of auto sector, public utility monopoly (Hydro-Québec) to support R&D and implementation	Enabling: Absence of auto sector, declining/stagnating oil production, established shipbuilding industry
Organizational Support Structure	Facilitates: empowered regulator, strong educational system, VC capital, NGO support	Facilitates: empowered utility, significant environmental movement, established innovation organizations	Facilitates: highly resourced state with history of state-led innovation, influential environmental movement
Institutions	Early, strong, durable (emission stds, ZEV mandate, EV purchase and use incentives), passenger ICEV sales ban	Early, strong, durable (emission stds, ZEV mandate, EV purchase and use incentives), passenger ICEV sales ban	Early, strong, durable (EV purchase and use incentives), passenger ICEV sales ban
Natural Assets (abundance or scarcity)	Scarcity of clean air	Low cost, low emission, abundant hydropower	Low cost, low emission, abundant hydropower
Political Mechanisms			
Normalization	Tackling air pollution, car culture	Economic development through hydropower, strong environmental values	Strong environmental values and leadership, visual presence of EVs
Capacity Building	Complex layering of EV manufacturing, purchase, and use incentives	Sustained state investment in R&D, reducing EV costs and encouraging EV use, commercializing EV-related startups	Significant support to reduce upfront costs and encourage EV use, extensive public charging network
Coalition Building	Broad coalition intersects with many existing sectors. Declining counter coalitions over time.	Broad coalition across EV supply chain and lifecycle. No counter coalitions.	Leveraged existing broad coalitions. No counter coalitions.
System Effects			
Scaling	Simple scaling (ZEV mandate, emissions stds), secondary scaling (MDVs, HDVs, aerospace)	Simple scaling (purchase and use incentives, ZEV mandate), secondary scaling (MDVs, HDVs, motorized recreation vehicles)	Simple scaling (purchase and use incentives), secondary scaling (maritime transport)

Taken together, these pre-existing local assets conditioned efforts to promote EVs through the causal mechanisms of normalization, coalition building and capacity building. Norms informed the rationale for engagement, be it the need for clean air in California, historic environmental leadership in Norway, or hydro-powered economic development in Québec. Over the last decade, as EV policies multiplied and EVs became more common, norms around electrifying transportation emerged and reinforced related governance experiments. Capacity building, given the often nascent and expensive EV technologies, remained crucial in all three jurisdictions. All cases employed EV purchase and use incentives. California, due to its institutional legacy and large population, had a complex layering of EV policies with those at the federal, regional, and municipal levels. Norway created an extensive public charging network and subsidized EVs to the point of cost parity with ICEVs. Québec has long built regional capacity for EV-related R&D and technology commercialization. Evidence for capacity building mechanisms is not limited to discrete EV policies but also includes the fruits of efforts by EV user associations and other non-state actors to advance electrified transportation. In all three cases, broad coalitions engaged local industries and environmental groups and secured multi-party political support. The minimal to non-existent presence of incumbent passenger automakers reduced the potential for and strength of counter-coalitions.

All three cases experienced some retrenchment from early EV policy experimentation (*e.g.*, California's 1990 ZEV mandate, Québec's early R&D support, or Norway's early manufacturing incentives). However, each of these early "failures" resulted in some positive outcomes. In California, the early ZEV mandate created the impetus for hybrid engine technologies. Québec-based companies like Dana TM4 and Nordresa continue to benefit from state-funded R&D from the 1980s and 1990s. Some engineers that designed Think EVs in Norway subsequently built electric-powered ferries.

Most subsequent EV policies in all three jurisdictions demonstrated resilience with many key policies enduring successive changes in government and scaling up with time: greater purchase incentives, larger public charging networks, additional benefits of driving EVs. Electromobility initiatives spread from the original focus on passenger EVs to promoting solutions in other transportation subsectors. In California, this secondary scaling manifested in public procurement policies for public transit authorities and school boards, which caused electric bus manufacturers to locate in the state. Similarly in Québec, transit authorities are establishing zero-emission targets and local manufacturers of medium and heavy duty vehicles and recreational vehicles are commercializing electric models. In Norway, success in electrifying personal transport spilled over to maritime transport as new policies seek to create emission-free fjords.

The systemic effects of EV governance experiments hold the potential to alter a region's decarbonization trajectory. Currently, this potential remains most uncertain with California and Québec. However, Norway's combination of policies, targets, political coalitions, new assets, and declining GHG emissions in the passenger transportation sector suggest the country has begun to move along a transformative pathway (Figure 5). Regardless, the EV leadership realized in these three jurisdictions has yet to disrupt broader trends passenger transportation. These trends, such as growing population, urban sprawl, consumer preference for larger vehicles, increased household consumption, all make decarbonizing the transport sector exceptionally difficult [101, 102]. If anything, this finding shows how EVs are not the panacea for the transportation sector. EVs do not necessarily alter land use patterns or dimnish traffic congestion, and sometimes may worsen urban sprawl and commute times [103]. Public transport and active mobility can also create additional economic opportunities, as California and Québec illustrate, by encouraging higher density communities and healthier, more active lifestyles. Moreover, the forthcoming ban on sales of passenger ICEVs in all three cases provides a terminal event horizon for fossil fuelled private vehicles—a horizon that is most imminent in Norway. As the vehicle fleets turn over and the proportion of EVs increases, the likelihood of transformative decarbonization also increases.

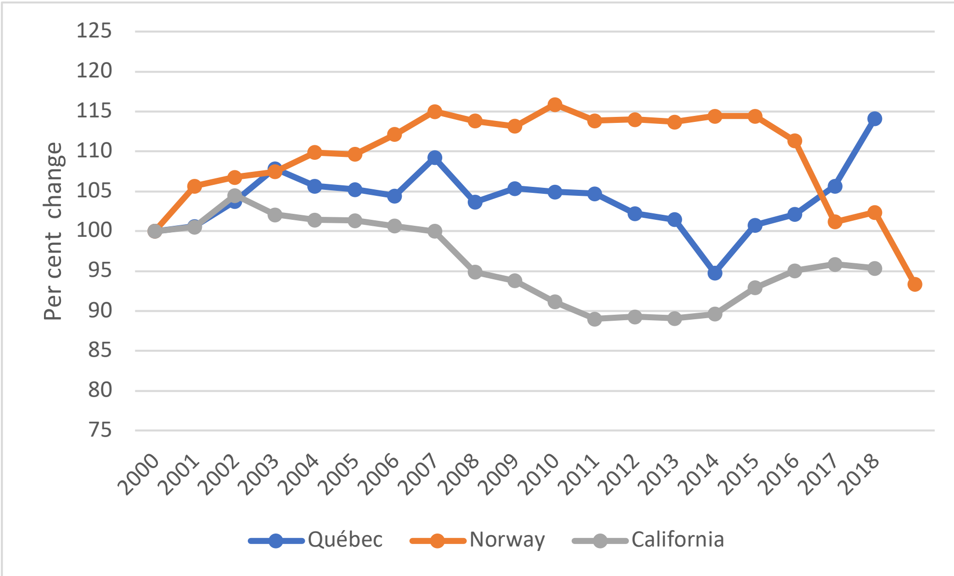

Figure 5: Per cent change in passenger transportation GHG emissions from California, Norway, and Québec (100 = 2000). Source: [64] [104] [105]

5.0 Conclusions

This study examined how California, Norway, and Québec came to be innovative leaders in vehicle electrification. By synthesizing two different analytical frameworks into one interdisciplinary framework, we explain the development of leading EV policies and related industrial policies in these three cases. In this final section, we will a) suggest two policy implications, b) provide three contributions to scientific knowledge, and c) creates a new avenue for future research.

Policy implications

Following Trippl *et al.* [38]—who identify that more work is needed to understand the policy implications of their model—our combined model generates two broad implications for policy actors.

1) Leverage local assets: Existing regional innovation systems and natural assets may empower policy actors and cause governance experiments to scale up. Depending on their makeup, these extant assets can be harnessed to overcome path dependency and oppositional political forces. For these cases, an absence of incumbent passenger vehicle manufacturers minimized the potential counter coalitions, reducing potential resistance to EV policies. If major stakeholders continue to integrate resources and coordinate regional activities, these local assets may help ensure long-term EV leadership [106].

2) Short-term policy failures can net long-term success: Feedback from early failed attempts to implement EV policy may subsequently enhance local assets. When the modified local assets are eventually re-engaged, the policy outcome can be much more successful (*e.g.*, Tesla buying IP developed from earlier efforts to meet California's 1990 ZEV mandate; Québec-based companies using early IREQ patents). Beyond policy learning, this recursive asset modification carries economic implications by creating new commercial opportunities for incumbent, emergent or non-local economic actors.

Contributions

This article generates three main contributions. First, it represents the first comparison of the politics behind EV policies in California, Norway, and Québec—three jurisdictions widely recognized as EV leaders.

Second, it synthesizes two analytical frameworks from two discrete disciplinary bodies of study (*i.e.,* regional innovation systems and climate politics) and brings to bear a new interdisciplinary perspective on the development of EV policies, creating a new way to look at the preconditions of vehicle electrification. In particular, it responds to the call by Trippl *et al.* [38] to operationalize their framework and apply it to different regional contexts. In doing so, the analysis foregrounds the role of incumbent economic actors. California's tech and aerospace industries, Norway's shipping industries, and Québec's commercial vehicle manufacturing all played an instrumental role in shaping the EV policy pathways in their respective regions. In turn, this study refines Trippl *et al.*'s (2020) framework by including the political dynamics emphasized by Bernstein and Hoffmann [28], while conceptually grounding Bernstein and Hoffmann's work in local political economy. Following Hassink *et al.* [107], this hybridized approach uses qualitative research methods to untangle the complex process of asset modification and examine the role of non-firm actors, infrastructure, institutions, and natural resource endowments.

Third, this study confirms a central argument regarding experimental climate policy governance, namely that supportive institutions have a key role in jointly exploring policy solutions with public and private actors and in scaling up successful policies [25]. California's Air Resources Board retooled the early ZEV mandate, after closer consultation with industry, with the new version directing valuable ZEV credits to EV manufacturers, notably Tesla. Over time, this policy has been scaled up in ambition, applied to more vehicle classes, and adopted by other jurisdictions. Norway's policymakers emboldened by success with EVs and prodded by local NGOs, created a national market for electrified maritime transportation. Associated policies generated revenue for local shipyards reduced costs for ferry companies and have subsequently been scaled to encompass cruise ships visiting Norwegian fjords. In Québec, long-term private sector collaboration and funding from public institutions enabled early experimentation in R&D and the eventual commercialization of EV-related technologies and manufacture of electric commercial and recreational vehicles.

In all three cases, policymakers and other policy actors, through great uncertainty, iteratively and collaboratively attempted to advance the dual mandate of increasing EV adoption and promoting regional economic development. As Sabel and Victor {, 2015 #212} stress, a key driver of successful experimental governance—what motivates actors to engage—is the threat of sanction. Transport manufacturers in all three jurisdictions faced a penalty default: payments for ZEV mandate credits, exclusion from lucrative ferry routes, or promised prohibition from selling polluting busses to transit authorities or fossil-fuelled passenger vehicles to households. For economic incumbents, the potential cost of inaction brought them to collaborate with other policy actors to pursue the electrification of transport.

Limitations and Future Research

In addition to secondary sources, this study relied on interviews, which limits its explanatory power. Semi-structured interviews, while excellent at probing deeply into questions that are difficult to locate in documentary sources, face inherent challenges of representativeness and replicability [108]. Future research could increase sample size and broaden the diversity of interviewees. It could also employ a representative survey to collect data on the relationship between regional political economies and EV leadership.

This study did not explore which combination of local assets will lead to certain political and industrial development outcomes. In part, this is a “too few cases/too many variables” problem [109]. Future research can apply our framework to more diverse cases of EV leadership, especially those with major incumbent industries whose business as usual is challenged by EV policies. Subsequent analysis could investigate EV policy engagement in those regions with established passenger vehicle manufacturing capacity, like Baden-Württemburg, Michigan, and Ontario.

Lastly, while this analysis can assess the role of local assets and political dynamics of developing and implementing EV policies, more research and time is needed to determine if the EV governance experiments underway in the three cases, most notably California and Québec, have conclusively led to new industrial paths or placed them on a transformative decarbonization policy pathway. Following Skeete et al. [110], future efforts to assess the political, economic, and environmental impacts of EVs should also include end-of-life considerations (e.g., battery waste and recycling).

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