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THE INFLUENCE OF INCUMBENT INDUSTRIES ON MISSION-ORIENTED INNOVATION POLICY TARGETING CARBON LOCK-IN

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EXECUTIVE SUMMARY

Mission-oriented innovation to address climate change, a moonshot or Manhattan project for climate, is an approach that promises to address climate change by achieving net zero carbon emissions. However, even with significant technical advances, successfully reaching this goal would dramatically reduce the market for fossil fuels. A climate mission must overcome carbon lock-in — the dependency on fossil fuels and the inertia that this dependency can create in policy development.

This paper explores how mission-oriented innovation potentially impacts and is impacted by incumbent industries and describes how in the case of Alberta's fossil-fuel industry, regional incumbents influenced the establishment of a mission they saw as a direct threat to their market. For example, advancing in-situ production from the oil sands happened only after the industry saw its development as market rewarding. It suggests like other examples that any policy that would be market destroying is unlikely to succeed.

One barrier that policy design faces is that significant reductions in fossil-fuel consumption are required to reach net zero, but the industry prefers approaches and technologies that do not limit their markets. Systemic change throughout the industry is necessary for tackling climate change, and identifying new markets or disruptions that could benefit the industry will be difficult unless companies accept this necessary change.

Since the industry can exclude or limit the potential of many mission-oriented innovation policies that would decrease their markets, innovation policy risks failure by promoting wasteful spending or supporting policies that ignore the dramatic changes that are required. Instead incumbents have responded to what they see as a threat by supporting innovation policies based on defensiveness or blocking innovation policies.

Globally, the fossil-fuel industry has lent strong support for carbon capture, utilization and storage (CCUS), as CCUS is market rewarding. CCUS may have a role to play in addressing carbon emissions in some industrial processes, but it is insufficient to limit warming and does not address the decline needed in the consumption of fossil fuels. The industry has clearly signaled a disinterested in the reduction of consumption despite support for achieving a net zero goal.

Still, there are at least two approaches that could be taken. One approach would be to

focus new policy on markets that do not have an incumbency. For example, in Alberta this could include missions such as decarbonizing industrial heat or decarbonizing cities through leveraging technological, engineering and project management competencies from the oil and gas sector. Another approach would be to design policy so that it mitigates or balances the asymmetries in the incumbent industry's power. By demonstrating an appreciation of the threat the industry perceives, policy-makers would still be able to identify where the market will decline due to technological limitations or a shift in consumer preferences and complementary policies being implemented by governments.

There is renewed interest in mission-oriented innovation as a means of addressing climate change. A more careful consideration of the potential for carbon lock-in during the mission- setting process could ultimately help achieve less waste and better defined goals.

POLICY RECOMMENDATIONS

- The design of mission-oriented innovation policies to address climate change must consider the difficulty in implementing policies that disrupt the incumbent fossil-fuel industries; failure to do so will result in a waste of public funds and risk negative outcomes from the energy transition.

- One approach would be to have the mission-oriented innovation policies focus on industries and markets that are not dominant in a given jurisdiction, but that rely on adjacent competencies of the dominant incumbents. Here, a different set of innovation priorities would be identified that do not threaten the existing incumbent. Different levels of government could provide support for this mission.

- A different approach to developing mission-oriented policies could be built around a common understanding of the threat. Protecting incumbents from external threats would start by identifying trends that will decrease a market's size and then proposing solutions on how to preserve the existing industry.

- Alternatively, a more direct approach would be to limit the impact of incumbents during the mission-oriented policy-setting stage through mechanisms designed to mitigate the power held by incumbents.

ABSTRACT

In this paper, we explore how the power wielded by regional incumbents has impacted subnational innovation agendas. Our findings suggest that the design of mission-oriented innovation policies should be more attentive to regional innovation policies and their relationship to how innovation may serve to bolster incumbents and not undermine them. We use a case-study of innovation in fossil fuels.

Recently, innovation policy literature has explored innovation policy and global climate as a major topic. On the one hand, carbon lock-in has been used to explain why there has been such difficulty in reducing carbon emissions, in many cases, despite an increasing emphasis of mission-innovation policies. On the other hand, mission-innovation policies are believed to be a key to the development of disruptive innovations that could break this carbon intensive path dependency. Although the two literatures explore the same problem, there could be more integration. While carbon lock-in is being considered in the mission-innovation literature, it nevertheless has been largely overlooked at the mission-setting stage. On the other hand, the lock-in literature has tended to overlook the findings of mission-oriented innovation literature in offering solutions, which suggests that there is a more productive role for mission-oriented innovations in breaking free of previous constraints to serve in the low-carbon energy transition.

To make our case, we argue it is important to distinguish among the various impacts disruptive innovations have on the market shares of incumbents'. We propose the following three schema: new market, market rewarding and market destroying. By variegating the potential impact of innovations, we suggest that mission-oriented innovation polices may be designed to only support certain types of innovations that do not directly undermine the market share of incumbents.

Using a detailed case study of the Province of Alberta, Canada, we then explore the role of the province's mission-oriented policy in the development of technology to produce the Canadian oil sands. The case study illustrates how incumbents influenced the establishment and direction of the mission's goal. Shifts in incumbency opposition toward the province's mission-oriented innovation policy coincided with the changing impact of the innovation from being market destroying to market rewarding. We suggest that future research should be more attentive to the role of incumbents in influencing mission-oriented innovation policy and the importance of their influence at the mission-setting stage. Furthermore, we suggest that to meet the grand challenge of addressing climate change through mission-oriented innovation policies, these policies must be designed to break free of these institutional constraints.

1. INTRODUCTION

Mission-oriented innovation policy is most commonly used to refer to when a nation-state clearly defines a problem, or mission, and then provides significant public support for radical technical innovations. Recently, mission-oriented innovation has been proposed as key to address social and ecological grand challenges, especially climate change (Rodrik 2004; Veugelers 2012; Mazzucato 2016). The literature highlights on how, historically, well-defined and well-supported state-backed missions have overcome barriers that stymie innovation in other sectors. Today, this literature argues that there should be mission-oriented innovation energy policies, variously called the climate “moonshot” or “Manhattan Project,” which are essential for energy transition, breaking out of carbon energy dependency and radically implementing a program of achieving decarbonization (Bloomberg 2019; U.S. House of Representatives 2006). In this grand challenge framing of climate change, mission-oriented innovation policy is an all-encompassing goal: It is more specific than an economy-wide emissions-reduction target but much more general than a specific technological advancement. It is about setting a research mission without prescribing the specific sectors of economy, technical approaches, or technological outcomes. The common goal, or purpose of the mission, is to limit global average temperature increases to 1.5 to two degrees, and this entails a dramatic decline in the consumption of fossil fuels, including coal, oil and natural gas (International Energy Association 2021; Edenhofer et al. 2018).

Clearly then, strong mission innovation is proposed as a way to overcome what has been called carbon lock-in. Used to describe a broad range of social, cultural, technical, etc., mechanisms, carbon lock-in describes how and why industrial economies are locked into a dependence on fossil fuel-based energy systems (Unruh 2000; Foxon 2002; Klitkou et al. 2015; Seto et al. 2016). In this literature, there is specific concern with institutional lock-in or how decision-making power shapes the inertia of energy supply and demand as well as energy-related production and consumption around fossil fuels. As Seto (2016, 434) observed:

> “Institutions strengthen the interests of — and, hence, increase the resources available to — those powerful actors, such as oil and energy companies, that wield the most influence over their creation and modification.”

The findings in this literature highlight a particularly thorny problem for the mission-oriented innovation approach to address global climate change. How might the setting of the mission-oriented innovation policy — the selection of a clear direction in the form of a challenge — be impacted by specific carbon institutional lock-in mechanisms, especially as we explore the power wielded by private incumbent fossil-fuel firms?

Although the two literatures, the one of mission-oriented innovation and the one on carbon lock-in, explore the same problem, there could be more integration between them. On the one hand, while carbon lock-in has been considered in the mission-innovation literature, it nevertheless has been largely overlooked during the mission-setting process. In particular, the power of incumbents to suppress disruptions and shape the direction of mission is absent. On the other hand, the lock-in literature has tended to overlook the findings of mission-oriented innovation literature in offering solutions, which suggests that there is a more productive role for mission-oriented innovations in breaking free of previous constraints to serve in the low-carbon energy transition.

Using a detailed case study of the role of mission-oriented policy in Alberta, Canada, we explore the development of technological advances for the production of the Canadian oil sands. This paper:

- Examines the role of institutional lock-in in influencing the process of defining and launching the mission;
- Describes how shifts in incumbency opposition to a mission-oriented innovation policy coincided with the changing impact of the innovation on their industry;
- Suggests mission-oriented innovation policies must be designed to break free of these constraints; and
- Argues this would support the transition to a lower-carbon future.

The paper is organized as follows: We begin in section 2 by reviewing the literature on carbon lock-in and mission innovation and examine different ways disruptive innovation can impact an incumbent's market share. Using the three categories discussed in section 3, we look at a mission-driven innovation policy case study in the Canadian oil sands. We highlight how the policies shaped innovation in Alberta. We look especially at how the mission was created coincident with a change in the characteristics of the disruptive innovation that was targeted; namely, the innovation changed from one category of disruptive innovation to another due to changes in the external environment. Finally, we look at Alberta's current mission-oriented innovation policies and their role in support of the development of carbon capture and storage (CCS) technologies. In the case study, we rely on Alberta government reports and archival materials found in the Glenbow Western Research Centre and the Provincial Archives of Alberta. In section 4, we discuss the observed role of institutional lock-in in mission setting and a conclusion follows with directions for further research.

2. LITERATURE REVIEW

2.1 CARBON LOCK-IN

The difficulty of achieving transformative change to meet a lower-carbon energy future has been explained as a result of carbon lock-in. Carbon lock-in, a specific form of the more generalized path dependency, is the process by which industrial economies are locked into a dependence on fossil fuel-based energy systems (Unruh 2000; Seto et al. 2016). An analytical framework of lock-in mechanisms identifies nine distinct mechanisms (Klitkou et al. 2015). Of particular importance in mission setting is political power, where stronger political actors are able to impose changes on the direction of policies to align with their interests (Foxon 2002). In the case of mission setting, Klitkou et al. (2015) observed this in practice, in the development and deployment of alternative transportation vehicles.

Recent scholarship has incorporated the dimension of political power in studies of socio-technical transitions, focusing primarily on later stages of development and deployment of new technologies. For instance, Geels (2014) explored how firms influence policy-makers and found that electricity generators in the United Kingdom's electricity system have resisted pressure and tried to ensure the system remains fundamentally unchanged despite state efforts to reduce emissions. In his examination of climate policies, Mildenberger (2020) argues that the influence of high-carbon businesses and workers impose significant constraints. Finally, Breetz, Mildenberger and Stokes (2018) examined how policies and intervention from incumbents change as technologies move along a learning curve, becoming cheaper and more competitive with incumbent technologies. They find that resistance from incumbents grows as new technologies are deployed and begin to pose a direct threat to the incumbents (Breetz, Mildenberger and Stokes 2018). While these scholars do not suggest it, we demonstrate how these types of concern were present in the mission-setting stage of Alberta's mission-oriented innovation policies.

2.2 MISSION-ORIENTED INNOVATION

Public innovation policies have been divided into mission-oriented and diffusion-oriented types (Ergas 1987). Mission-oriented approaches, built around a specific problem articulated by a public authority, are focused on identifying and supporting radical technical innovations that solve a clearly defined problem. In the diffusion-oriented approach, meanwhile, the public authority facilitates ongoing and incremental innovation that arises from the innovation system. Mission-oriented innovation policy, first introduced by Ergas (1987), is defined by its centralization and the narrowness of policy support for innovation. Significantly, Ergas's framework has continued to garner interest and modification. For example, Cantner and Pyka (2001) extended this framework to consider both the technological specificity as well as the distance from market.

Proponents of mission-oriented policies to solve the grand challenge of global climate change point to the approach's past successes in producing massively disruptive innovations, but they also recognize that the new grand challenges are significantly more complex than previous ones (Mowery, Nelson and Martin 2010; Mazzucato 2018). A key complication is that new grand challenges seem to require systemic changes as opposed to sector ones. For example, the amount of decarbonization required by the mid-21st century to successfully mitigate global climate change requires more than incremental improvements. It entails significant replacement of existing infrastructure across the electricity, industrial, transport and building sectors with alternatives that are dramatically lower in CO2 (Davis et al. 2018). For mission-oriented innovation to successfully address this grand challenge, it must be able to break through and deliver a wide range of disruptive technologies. For example, Hekkert et. al. (2020) use the mission-oriented innovation systems (MIS) framework to describe the networks of agents and sets of institutions that undertake mission-oriented innovation and try to answer how MIS is developed. One key step in the creation of a MIS, they identify, is the selection of a clear direction for the challenge that can be supported with a long-term, publicly backed financial commitment. Importantly, they build on previous work that investigated the conditions under which mission-oriented policy was sustained at sufficient levels over sufficient periods (Foray, Mowery and Nelson 2012; Mowery 2012; Wright 2012; Sampat 2012; Leadbeater 2018). These studies also identified some common elements across very different examples of mission-oriented innovation. Two of the most salient elements singled out were champions and a broad range of constituents who benefit from the mission. For example, Leadbeater (2018) considers how social movements can create the demand for mission innovation and also shape the mission.

2.3 THE THREE WAYS THAT MISSIONS IMPACT INCUMBENTS

To solve the grand challenge of climate change, it is not enough to make innovations and commercialize them; there must be systemic transformation. Schot and Steinmueller (2018) argue that innovation policy should target transformative change, entailing systemic socio-technical changes, and such massive change will create winners and losers (Geels 2014; Turnheim and Geels 2012). By definition, disruptive innovations produce significant changes; however, their impact on existing markets and incumbencies will be uneven. In some cases, they will benefit incumbents, and in other cases they will not, or they may even have no impact (Aghion, Akcigit and Howitt 2014; Yu and Hang 2010; Christensen, Raynor and McDonald 2015). In the second case, the destruction of existing markets is a significant factor that negatively impacts the incumbent industry but positively benefits newcomers.

To describe how disruptive innovations driven by mission-oriented innovation have variegated impacts on the size of an incumbent's market share, we propose the following continuum from new market to market rewarding to market destroying; this diagram spans from most beneficial to most harmful for incumbents (see Figure 1).

Figure 1. The Impact of Disruptive Innovations on the Size of an Incumbent's Market Share Spans the Continuum from Beneficial to Harmful

Certainly, the incumbents in an industrial sector are not a monolithic group, and particular firms may be better placed to capture or adapt to the benefits of innovations than others. Firms differ in their strength as organizations, their ability to transform their core operations, etc. However, across the different examples we consider, the impact of disruptive innovations can be grouped into one of three types for most firms.

New market: Some innovations could create an entirely new market and incumbent firms may also be positioned to capture a portion of this new market. Two commonly cited examples of mission-oriented innovation policy creating a new market are the moonshot (Hall 1992) and the Manhattan Project (Groves 1962). For the moonshot, the initial goal of putting a person on the moon did not displace an existing product or service offering (e.g., another approach to space travel), but rather targeted a new market of space travel, which until recently, was a single purchaser (the U.S. government). A number of innovations, which were not the focus of the original mission sprang from this effort and ripped across a wide variety of sectors, ultimately spawning new technologies and markets. These innovations may have been disruptive to an incumbent, but as they were not the mission's initial focus, they were largely unforeseeable when the mission was created. Another example is mission-oriented innovation in pharmaceuticals which, importantly, is significantly different from the Manhattan Project or moonshot because the innovation's impacts were more directly foreseeable when the mission was created. For example, Lichtenberg (2006) showed that new priority drugs (those that represent an advance over available therapy) expanded the total market for drugs in that class, increasing total drug sales within the industry virtually one for one. Unsurprisingly, the pharmaceutical industry is strongly in favour of mission-oriented public research, such as that conducted by the United States' National Institutes of Health (NIH) (Sampat 2012).

Market rewarding: An innovation could compete directly with existing products and services and even appear to threaten incumbents but actually benefit them relative to a trajectory without innovation. In one case, incumbents have benefited from mission-oriented innovations developments that compete with their existing products and services because they were the owners of the mission-developed innovation. For example, one of the main drivers of change in agriculture over the past century was the increasing productivity, or yield, of key crop species. Wright (2012) described how mission-oriented innovation policy led to new techniques and technologies that were truly disruptive but despite this, incumbents were the primary beneficiaries because they owned the new innovations. In other cases, the mission-oriented innovation competed with incumbents' products and services in an existing market, but the mission impacted a different region than the incumbents. Here, SEMATECH is a relevant example. Founded as a government and industry collaboration, SEMATECH's mission was creating the technological and manufacturing innovations needed to support a U.S. semiconduction industry. It was successful and resulted in the U.S.'s dominance in semiconductors, ultimately surpassing Japanese incumbent firms (National Research Council 2003, 95; Browning, Beyer and Shetler 2018).

Market destroying: An innovation that threatens an incumbent because it competes directly with their core existing products and services. To date, there are not good examples of mission-oriented innovation policy in this category, which raises the question of the feasibility of implementing such policies. For instance, the policies implemented in Norway that have accelerated the adoption of electric vehicles represent a market-destroying innovation that competes directly with the country's incumbent oil industry (Figenbaum 2017). However, as Mildenberger (2015) demonstrated, it was a niche support that was implemented when the policy's potential impact was believed to be quite limited. Hence, it was an insignificant mission-oriented innovation policy. Moreover, it differed from mission-oriented innovation policy in both level of support and intended impact. We conjecture that the carbon lock-in may be precluding mission innovation of this type to meet the grand challenges associated with global climate change in fossil-fuel production regions.

3. CANADIAN OIL SANDS CASE STUDY

In this section, we will use a historical case to show how a mission-oriented innovation policy in Alberta was successfully created only after an external shift moved the innovation targeted from market destroying to marketing rewarding for incumbents. While the case is one in which innovation ultimately led to an increase in carbon emissions, it is relevant as an example here because it demonstrates changing response to a potential mission. In a concluding section, we note how current support for mission-oriented innovation policy in Alberta to meet the grand challenge of global climate change only targets innovations that are market rewarding for incumbents and how this may be a public policy failure.

Given the decline in consumption of fossil fuels necessary to meet climate goals, the tensions posed by institutional carbon lock-in for setting mission-innovation policies to address climate change may be especially salient in jurisdictions that are dependent on the continued revenues from the extraction of fossil fuels. In some nation-states, dependency on the extraction of fossil fuels has distinctly shaped their patterns of regional development and direction of their public policy (Kennedy 2014). While this is usually applied to a small group of nation-states, it has also been used to describe a select number of subnational regions such as Alberta, Scotland and Texas (Goldberg, Wibbels and Mvukiyehe 2008; Shrivastava 2015). Here, we focus on the Canadian province of Alberta and examine how regional incumbency creates an institutional carbon lock-in, one that has influenced the province's mission-oriented innovation policy.

The case study is related to the development of Alberta's oil sands through advances in the in-situ oil sands extraction technique. It may seem odd to include this case as it is one that is carbon intensive and was developed prior to a global concern about, or efforts to address, climate change. Nevertheless, the case study illustrates the importance of Alberta's fossil-fuel incumbents, highlighting the attenuation of their resistance to the mission-oriented innovation's goals. We suggest that external circumstances changed the mission's impact from being market destroying to market rewarding. In the conclusion, we return to the oil sands and reflect on the more recent efforts at carbon capture and storage under the proposed framework.

Development of conventional oil and unconventional Alberta oil sands

Alberta's oil sands have been a major contributor to the province's recent economic development; they are a major source of resource rents (royalties), employment and taxes (Mansell and Schlenker 2006; Tretter 2020). Unlike sources of conventional oil, the oil sands are bituminous; they consist of a heavy oil, mixed with a combination of sand, clay and water. Producing the oil means it must be separated from this mixture. Of the 165 billion barrels of established reserves in Alberta's oil sands, it is estimated that about 20 per cent is recoverable through a surface mining process more akin to mining than drilling, sometimes called bitu-mining. However, the majority, about 80 per cent, is too deep and requires varying in-situ recovery methods (Alberta Energy Regulator 2019).

The commercial development of the oil sands was an on-and-off process for about a century. Attempts at commercially developing the oil sands began in earnest only in the 20th century, but these efforts were largely abandoned in the late 1940s. Still, Karl Clark's work at the Alberta Research Council in the 1920s on development of a process for separating mined bitumen from sand demonstrated the potential for development of oil sands mining. Moreover, at great public expense, in 1949 the Bitumount plant successfully extracted tradeable oil, but no large-scale commercialization followed and the province's commitment to further research also declined (Chatsko 2004; Ferguson 1985; Government of Alberta 2019). Instead, the oil sands were largely eschewed as prospecting moved to other oil reserves in Alberta following the discovery of large pools of conventional oil in and around the initial Leduc discoveries in the late 1940s (Breen 1992, 245–46).

Growing conventional oil production in Alberta caused a supply glut, which was amplified by limited transportation options, and this ushered in a crisis in Alberta's conventional oil industry. As a result, by 1951 about half of the productive capacity was shut in (Chastko 2004, 79). Any additional source of oil developed at that time would have caused more strain. The oil sands were, in fact, specifically named as a source of concern. As Chastko (2004, 123) noted, the Alberta government was "concerned about the deleterious effect that excessive production from the oil sands would cause the conventional industry." Given that the oil sands were specifically identified, it is noteworthy that, in this respect, they should be cast as competitors to conventional oil producers (McKenzie-Brown 2017, 208). Still, the Alberta Energy Conservation Board (AECB), the quasi-governmental organization that regulated oil and gas production in Alberta, responded to the oversupply crisis by imposing a general system of pro-rationing on all oil producers. The effect was to restrict individual projects and to limit production of each project to only a small portion of the total capacity. As a result, the development of the oil sands resources was significantly curtailed because production required relatively high capital investment and an oil sands production facility could not be profitable operating at reduced capacity (Maciej 2011).

By the 1960s, the supply crisis had eased but the province's policies continued to support production only tepidly from the oil sands, prioritizing the protection of the market share of the conventional oil sector. For example, in 1962, then-premier Ernest Manning's Oil Sands Development Policy allowed for the oil sands' development at not more than five per cent of the total market for Alberta crude, and required that "subsequent development be restricted to ensure that market growth enables the conventional industry to produce at a greater proportion of its productive capacity" (Government of Alberta 1962). However, soon after, production in the oil sands began to open up on a limited basis, aided in part by the shift in the policy regime from pro-rationing on an individual project basis to an overall cap on production. Notwithstanding, the Conservation Board reaffirmed the position that oil sands development must defer to conventional oil production and only access markets that were beyond the scope of the conventional industry, rejecting the Cities Service and Shell application for a new oil sands facility on the grounds that it posed a threat to the conventional industry's market share (Chastko 2004, 114). The construction of the first private commercial-scale oil sands facility, the Great Canadian Oil Sands Project (GCOS), was completed in 1967 after a delay in approval due to concerns around its impact on the conventional industry (Desorcy 2012).

Underlying this framework was the idea that the oil sands were not a part of the oil industry at the time. During this period, the oil sands were often referred to as "alternative energy" or "alternative fuel." The Geological Association of Canada's (1974) significant conference report shows this clearly. Moreover, throughout the 1970s, the oil sands were not considered oil reserves. The Conservation Board had started to include "ultimate remaining recoverable reserves" from "crude bitumen" in its reserve estimates in the early 1970s. In 1973, the board estimated them at 267 billion barrels but noted that 250 were "in place reserves" and "not yet proved by commercial operations" (Energy Resources Conservation Board 1973). Although the National Energy Board relied heavily on the Conservation Board's estimate, and despite protests from Alberta, it resisted including most of these in its estimates of Canadian reserves during the 1970s, and only started including them in the 1990s (National Energy Board 1975, 1978). Moreover, as late as 1979, the governments of most countries were not collecting data on the oil sands, its reserve estimates or its production; the same was true for heavy crude. The American Petroleum Institute in the United States did not even compile statistics on heavy crude and oil from the oil sands (Meyer and Steele 1981). The conceptual difference between the oil sands and the conventional industry was also reflected in the relationship between the conventional producers and those in the oil sands business in major public settings. For example, members of the Calgary Petroleum Club attempted to get an "oil miner," as oil sands developers were then referred to, thrown out of the club in the 1960s (Maciej 2011). Moreover, this distinction was maintained by the provincial government in the 1970s, reflected in how it described its policies of diversification. Allan Warrack, the minister of Lands and Forests in the Peter Lougheed government, said:

> [O]ur perspective at that time was that a fuller development of the oilsands would be economic diversification, because at that time, of course, there was crude oil and natural gas that was very prevalent ... But particularly seeing the development of the oilsands as economic diversification, looking back from today it seems like the dominant activity, but it wasn't at that time.

Note that for Warrack, oil sands development was a form of diversification. A similar refrain is found in policy reports even into the 1980s. For instance, in their influential report, Mansell and Percy (1990, 6), in making a case for developing the oil sands, contended that:

> With regard to diversification, we conclude that it is unrealistic to focus strictly on the development of new industries characterized by low variance or negative covariance with those that form the province's economic base. Instead, the adoption of a very broad definition of diversification — one that includes diversification of markets and expanded product lines for existing industries, vertical integration, and resource upgrading, along with "industrial diversification" — in which the objective is to broaden and expand, rather than to change, the province's economic base, seems much preferable.

From today's vantage point, it seems odd that commercial development of the oil sands was perceived as a threat to the oil incumbents in Alberta. For nearly 30 years, greater production from the oil sands was "market threatening" to the "real" oil industry. There was strong resistance to its development and a lack of enthusiasm for state-backed financing of innovations that increase production, especially from in-situ recovery techniques (Hester and Lawrence 2010). For many, the threat was real, as overproduction had been endemic and additional barrels of oil from the oil sands could displace the dominance of conventional oil or lower the value of a conventional barrel. Moreover, the development of the oil sands might also take capital and labour that were required in the sector. Incumbents successfully pressured the state institutions to limit the development of the oil sands resource (both mined and in-situ) by lobbying the government to limit production and framing the oil sands as an expensive and risky alternative (Chastko 2004).

The launch of an unconventional oil sands mission

Much has been written about the profound impacts of the oil shocks and crises in the 1970s and their ramifications for oil production and consumption (Yergin 1991; Bridge and Le Billon 2012). There is no point is repeating them here, except to emphasize that two local factors between 1971 and 1973 pre-dated these external events and were especially important in shifting the provincial government and the oil industry towards development of the oil sands: the declining projections for conventional oil reserves in Alberta and Lougheed's election as premier with a majority Progressive Conservative government in 1971 (the first change in the ruling party in 36 years).

By the early 1970s, conventional oil reserves in Alberta were declining. For the first time in more than two decades, in 1972 production outpaced reserve additions in Alberta (Canadian Petroleum Association 1973), fuelling expectations that production would soon decline. The supply-and-demand forecasts for Canadian crude from 1971–1980 were used by a special Oil Sands Development Policy Committee of the Canadian Petroleum Association (CPA), which was constituted to review and make recommendations on provincial policies about oil sands development. Formed in 1952, the CPA's membership in 1965 included companies representing 97 per cent of Canada's petroleum production (Doig 1965). In 1972, for the first time, CPA requested that "the province … release … all restrictions on further oil sands development" (Canadian Petroleum Association 1972). The committee referred to the waning threat that the oil sands posed to conventional producers because of an expected decline in conventional production.

Although overt resistance to the commercial development of the oil sands was lessening, there was still not strong support from the oil industry for development. Instead, in Alberta, most of the petroleum industry's more overt support was for innovations that supported the further exploitation of conventional oil with a focus on what was known as enhanced oil recovery (EOR), or tertiary recovery. Coined in the early 1960s, EOR has been used to describe a broad range of methods that increase the recovery of oil from a conventional reservoir beyond what was previously recoverable through older techniques like pressure (i.e., primary recovery) or fluid displacement (secondary recovery). By augmenting or replacing natural and artificial pressure systems or the injection of water or gas by new techniques such as thermal recovery and gas or chemical injections, EOR can produce more oil. One telling indicator was the financial support that industry provided the Petroleum Recovery Institute (PRI), which was formed in 1966 as a partnership between industry and the Alberta government (Alberta Oil Sands Technology and Research

Authority 1990, 136–138). Originally housed on the main campus of the University of Calgary, it was later located in a building near the university's Research Park. PRI (or PRRI, as it was first called) was established as a Canadian centre to advance research on mechanisms to enhance oil recovery from conventional reserves. While PRI's budget remained about $1.5 million annually during the 1970s, the financial support and the number of industrial partners varied. For example, in 1975 it partnered with over 30 companies, who directly contributed funds making up roughly half of the organization's budget, and in 1980 there were more than 20 industrial partners contributing only about $200,000 annually (Nowell 1975; PRI 1980). Although the province always provided the lion's share of its funding, and later corporate contributions comprised an ever-smaller portion of its annual budget, what is notable is no similar corporate funding partnership existed for the primary research authority, AOSTRA (discussed below), which led to the widespread commercial development of the oil sands.

While industry support for investment in developing the oil sands was lacking, its decreasing opposition allowed Lougheed to act to support the development of technologies necessary to greatly enhance the production of oil from the oil sands, specifically by funding research on in-situ techniques. He too justified the need for greater action by pointing to an expected decline in oil from conventional crude production. For instance, in 1974, he told the Calgary Chamber of Commerce and conventional oilmen that "[B]asic facts simply cannot be ignored. The conventional crude oil resources and reserves in Alberta are estimated to last only another twelve years" (Lougheed 1974b). Moreover, David Redford (2013), an oil sands researcher with AOSTRA, recalled Lougheed's explanation for why he was committed to commercializing the oil sands:

> We have all these royalties coming in and land sales coming in from conventional crude. But, it's limited. It's going to start going down. We have this huge resource out there. Everyone knows how much is there because of the work of the Alberta Research Council. We know that we have one of the largest hydro-carbon resources in the world, if not the largest. But, it's all in-place reserves. It's not proven reserves. We don't know how to produce the in-situ material and that's the largest part of it … So, [Lougheed] said, "Why don't we take some of this revenue that we've got coming in from the royalties and invest it in the development of the technology which will make the in-situ recovery possible and make the mine material economic?"

In 1974, Lougheed announced the Energy Breakthrough project and the creation of the Alberta Oil Sands Technology and Research Authority (AOSTRA). The description of the authority's mandate shows how it was a mission-innovation approach; it targeted the creation of disruptive innovation technologies to produce the in-situ oil sands resource and was significantly state-supported and financed. As the press release announcing AOSTRA's creation stated, it was charged "with the important and major responsibility to achieve as rapidly as possible the breakthrough in research and technology that is essential to guarantee production of that part of Alberta's Oil Sands that cannot be recovered through a surface mining process" (Lougheed 1974a). Moreover, the press release stated that AOSTRA was necessary "since it now appears that supplies of conventional crude are becoming increasingly more expensive and more difficult to find and develop." Over time, the Alberta government's investment in technology development through AOSTRA amounted to over $1.4 billion (2019 dollars) and resulted in the successful development and commercial viability of an in-situ production method (Hester and Lawrence 2010; Hastings-Simon 2019).

The development of the Alberta oil sands should be characterized as a successful example of a mission-driven innovation, but we suggest that the mission only became feasible when it moved from being a market-threatening innovation to one that was market rewarding. It is notable that the mission was only created after the threat to the incumbent market share subsided. As production of conventional oil outpaced the finding of new reserves, the primary threat to the conventional oil industry shifted from an internal competition for market shares, transportation capacity, financing, labour, etc. to a threat of reserve depletion. With conventional production expected to decline, there was no longer a threat from the growth in production from the oil sands; thus the potential in-situ recovery technology shifted from threatening to rewarding. If produced, the in-situ oil sands resource would provide a new source of fossil fuel for the industry to augment the loss in production from the decline in its conventional reserves. As the statements and policy positions adopted by the CPA showed, the industry had relaxed its opposition to oil sands development. However, the incumbent industry was not monolithic. Unlike conventional production, which was accessible to very small producers with a limited capital budget, the oil sands development, whether from in-situ or surface mining, has required significantly larger magnitudes of capital, which has effectively prevented the very small producers from ever taking advantage of these advances (Urquhart 2018). In considering the industry position towards oil sands development, we focus on the larger producers that make up the CPA.

5. CONCLUSION AND POLICY IMPLICATIONS

Mission-oriented innovation has been proposed as an approach to address climate change. It is argued that previous examples of mission-oriented innovation demonstrate their ability to deliver disruptive innovations. Therefore, climate missions will similarly be able to meet the present grand challenge of global climate change and surmount carbon lock-in. However, if successful, the pathways that new technologies create would enable net zero carbon emissions by mid-century universally by dramatically reducing the consumption of fossil fuels (International Energy Association 2021; Rogelj et al. 2018). As a result, mission-oriented innovation policies that support a net zero target must reduce the market size for fossil fuels globally, making them market-destroying.

By considering examples of mission-oriented innovation in the context of their impact on incumbent industries, we have provided a case that suggests that regional incumbent priorities did influence the establishment of missions that directly threatened their incumbency. The mission to advance in-situ production from the oil sands, evidenced in the Alberta case, occurred only after the market conditions had changed and their development would become market rewarding. Hence, the incumbents were able to influence when it was able to become viable and the direction of mission-oriented innovation policy. It underscores the problem: The lack of successful examples of mission-oriented innovation in the category of market threatening suggests it might be impossible to create such a mission.

The implications for policy design in the case of climate mission-oriented innovation policy are immense. One problem is that a significant reduction in the consumption of fossil fuels is still necessary across all net zero pathways, yet entrenched opposition from fossil-fuel incumbents continues to favour approaches and technologies that do not reduce the market for fossil fuels. It may be possible to identify new markets or disruptions that will benefit these incumbents but the potential to do so will depend on the degree to which addressing climate change requires systemic changes among these incumbents. In the case of fossil-fuel firms at the moment, this is unlikely.

The power of these fossil-fuel incumbents to effectively exclude or limit the potential of many mission-oriented innovation policies that would lead to the decrease of their market increases the risk that a public innovation policy would fail in at least two important ways: by promoting wasteful spending or encouraging policies that ignore dramatic changes. The first is evident in mission-oriented innovation policies that are limited to a defensive posture and do not have a broader goal; the latter is evident by not setting any clear mission-innovation policies and is based on denial.

An example of this kind of defensive innovation is carbon capture, utilization and storage (CCUS). The development of CCUS technologies enjoys strong support among a number of large petroleum incumbents globally (van Alphen et al. 2009; Stephens and Jiusto 2010; Shojaeddini et al. 2019), and among nearly all petroleum firms based in Alberta. Today, Alberta leads in supporting CCUS and comparisons are being drawn from the success of the AOSTRA program. Nothing is perhaps more revealing than a recommendation from the Alberta Public Inquiry into Anti-Alberta Energy Campaigns (Allan 2021, 18) that called for a "highly focused initiative, similar to Alberta's historically successful Alberta Oil Sands Technology and Research Authority [that focuses on] advancing Alberta as an international leader in energy science, technology, and innovation to produce low-cost, low carbon energy supplies and technologies for the world."

Currently, Alberta is using a significant portion of Emissions Reduction Alberta funding towards CCUS, in the hope that it will substantially reduce emissions from oil and gas production (Emissions Reduction Alberta 2019). One major CCUS project is the Alberta Trunk Line, a CO_2 pipeline that is designed around existing industrial operations and will draw on the potential for captured CO_2 to be used to increase oil production through enhanced oil recovery (Cole and Itani 2013).

CCUS in Alberta is increasingly being developed in the framework of a mission-oriented innovation but it is important to stress that it is market rewarding or creating rather than destroying. The current development of CCUS, if commercialized, is proposed as a solution to the problem of carbon emissions at the point of extraction that would leave upstream oil and gas production systems largely unchanged. Moreover, it may create a new market for the capture, transportation and storage of carbon dioxide, and the technology and expertise from the incumbent fossil-fuel industry in Alberta could allow incumbents to play a significant role in all components of the CCUS value chain. Categorizing CCUS as either market rewarding or market creating also helps to account for why it has received strong levels of research support across Canada. The federal and provincial governments have invested a combined $1.8 billion in CCUS research, development and deployment (Government of Canada n.d.; Mitrović and Malone 2011) and leading Canadian oil and gas companies have called on Ottawa to fund 75 per cent of CCUS facilities (Nickel 2021).

It is likely that some amount of carbon capture or removal technologies, either from waste streams of industrial processes or directly from the atmosphere, will play a role in realizing the emissions targets to limit warming to 1.5 or two degrees by mid-century (International Energy Association 2021). However, it is also clear that deployment of these technologies will not be sufficient to limit warming and they must be combined with dramatic declines in the consumption of fossil fuels. Yet, the necessary decline in fossil-fuel demand is largely absent from the incumbent industry support for achieving a net zero goal from CCUS. For example, Pathway Alliance's (n.d.) Oil Sands Pathways to Net Zero initiative, which is made up of the companies operating approximately 95 per cent of the oil sands production in Canada, has proposed an approach to reduce emissions that is predominately based on CCUS and other technology, while reiterating the need for continued and growing oil production.

The second important failure mechanism is that the innovations will simply fail to be pursued and implemented in regions that are threatened but will deny there is even a threat. Rodrik (2004) observed that successful "industrial restructuring rarely takes place without significant government assistance." In regions with dominant incumbent fossil-fuel industries, this lack of industrial restructuring could be catastrophic.

Nevertheless, the framework we propose also provides guidance to policy-makers looking to design successful mission-oriented innovation policies that are market rewarding or market creating. One potential approach would be to focus mission-oriented innovation policies on addressing markets that are currently insignificant in a given jurisdiction and therefore lack an existing local incumbency. Leveraging a region's adjacent competencies, an approach which has been previously proposed (Markard and Hoffmann 2016) would identify a set of innovation priorities that are distinct from the regional incumbents rather than on innovations in markets where the region is already dominant. In Alberta's case, this could include missions such as decarbonizing industrial heat or decarbonizing cities where adjacent competencies from the oil and gas sector could be leveraged, for example in expertise in information technology, project management and subsurface engineering.

Still, a different approach aimed at protecting markets from external threats would start by identifying areas where the current trajectory is likely to decrease market size. Encompassing a number of factors, this decrease could be due to physical/technological limitations, movements that shift consumer preferences, complementary policies implemented by governments, etc. Here, a key part of the mission-setting process would then be to arrive at a common and realistic appreciation of the threat. To further overcome the risk of lock-in, this approach could be augmented by direct efforts to limit the impact of asymmetries of power during mission setting, for example through policy design mechanisms that mitigate or balance stakeholder power.

The renewed interest in the role of mission-oriented innovation and direction-setting entrepreneurial states as a policy approach to addressing the grand challenge of climate change makes these considerations more important. A more careful consideration of the potential for lock-in during the mission-setting process could result in missions that are more sustainable, and ultimately more successful at achieving defined goals.

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