CANADA'S ENERGY FUTURE: AN EXAMINATION OF R&D AND INNOVATION MANAGEMENT PRACTICES IN CANADIAN ELECTRIC POWER UTILITIES

by

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Abstract

This thesis examines research and development and innovation management practices in Canadian electric power utilities. The goal is to analyze the approaches and methods that are currently being used by utilities in their transition to sustainable, efficient, low-carbon power systems. The primary research question is: What are the emerging R&D and innovation strategies occurring in electric power utilities, specifically focusing on the Canadian context? The interview questions also examine team structure and composition, partnerships and collaborations, and external knowledge acquisition. Data collection for this study consists of semi-structured interviews with Canadian utility employees and published utility documents. Concepts and models examined include stage-gate model, business model canvass, open innovation, design-driven innovation, lead-user innovation and embedded research. The findings include that research, development and innovation in the Canadian electric power utility industry is primarily conducted through partnerships with external suppliers and vendors, with a focus on short-term, incremental advancement with low risk.

Dedication

I would like to thank the following people who have helped me undertake this research: I dedicate this work to my family who have given tremendous moral support and motivation throughout my time in graduate school. I am grateful to my parents who have always inspired me to work hard and to push through challenges, and to my fiancé who has been a constant source of encouragement. I sincerely thank my grandmother, Sandra Thomson, who I can never repay for the love and support you have given me. I also dedicate this paper to my supervisor Dr. Foord, who has guided me to complete this process, and who has provided consistent feedback, support and endless patience. Without your persistent help, the goal of this paper would not have been realized. Finally, I would like to thank Angeline Ng who has been a tremendous companion throughout this program. You were always there for me when I needed advice, when I had questions, and when I just wanted to talk. You made a substantial, positive impact on my graduate school experience and I deeply value your understanding and your friendship over the past two years.

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1. Introduction

The traditional structure of the electric power system is being challenged through new technology trends, climate change and other environmental concerns, evolving weather patterns, a multiplicity of changing consumer desires, high levels of debt, and regulatory requirements (Aguero et al., 2017). The challenges also include growing demand and the need to increase the security and reliability of the energy supply (Dedrick et al., 2015, Costello, 2016). While the forces at play on electric power utilities come from multiple directions, the primary one is directed to a sustainability transition, defined as a "long-term, multi-dimensional, and fundamental transformation through which the established socio-technical systems are shifting to more sustainable modes of productions and consumption" (Gsodam et al., 2015). The pressures for utilities to adopt sustainable technologies and practices are coming from everywhere – governments, regulators, NGOs, local communities, investors, employees, suppliers, and customers (Gsodam et al., 2015, Aguero et al., 2017).

In the context of this sustainability transition, many experts predict "a transformation of the electric industry from where the utility is an infrastructure and commodity provider to being a platform and service provider; that is, a change from a rigid, unidirectional, and centralized system to a more flexible, networked system" (Costello, 2016, p. 20). The role of utilities may therefor shift, giving them the opportunity to take on the task of coordinating multiple paths of power flows as well as maximizing customer value. Some technologies currently threatening the centralized model are photovoltaic (PV), battery storage, microgrids and smart meters (Kind, 2013). Other new technology trends include distributed energy resources (DERs), electric vehicles (EVs) as well as monitoring, protection, automation, and control devices (Aguero et al., 2017).

In addition to changes in grid configuration, technology, regulation, and consumer demands, electric power utilities are also ripe for disruption in their business models (Tayal, 2016). There is strong support in the extant literature that utilities need to recognize the current disruptive threats to their traditional business models (Tayal, 2017), strengthen their business model innovation capabilities (Richter, 2013), revise their existing traditional business models (Tayal, 2016), and be essential actors in the transition to a sustainable future (Loredo et. al., 2019). Moreover, the International Energy Agency (IEA) suggests that the main barriers to faster innovation are the way the energy sector is structured, organized, and regulated, as well as the current need for innovation in business models (Carlson & Nciri, 2020). Regrettably, however, there is a lack of scholarship on how electric power utilities are managing technological and business model innovation in this transition. To address this gap in the literature I investigated the emerging R&D and innovation strategies occurring in electric power utilities, specifically focusing on the Canadian context.

This gap is especially surprising as the Canadian electric power industry is going through an extensive transformation towards increased electrification, digitization and sustainable clean energy systems. While provincial systems differ greatly on their greenhouse has (GHG) emissions, Canadian electric power utilities share a common drive towards grid modernization, with technological developments being designed by both utilities and their suppliers. Utilities are also looking for ways to integrate new innovations into their current systems. This configuration involves not only the diffusion and implementation of new innovations, but also the restructuring and reconfiguration of the entire energy system in Canada (Rosenbloom et al., 2018). Implementing renewables such as solar power, wind power, and electric vehicles is one area of modernization and innovation management. Policy changes, shifts in regulatory frameworks, consumer behaviour patterns and societal norms all require change in order to successfully transition to a modern, diverse, low-carbon energy grid (Rosenbloom et al., 2018). This creates the need for adaptations in energy institutions, as well as the repurposing of existing infrastructure (Haley, 2018). As a consequence, Canadian utilities have to evolve and revise their organizational structures in order to successfully integrate new technologies into the existing, ingrained energy system. This could involve the formation of new departments, the creation of sub-groups or subsidiaries, the re-allocation of responsibilities, the redesign of branches and division, or other activities that will help utilities shift focus and rethink their priorities and activities. This poses extremely difficult challenges because the energy system is large and entrenched in Canada, making progress within utilities hesitant and slow. "At the core of transition management is the challenge of orienting long-term change in large socio-technical systems" (Meadowcroft, 2009, p. 324). This challenge includes regulatory mandates that prioritize reliability over experimentation, focusing the attention of utilities to incremental changes in business model and technological innovation.

Canadian electric power utilities also provide a particularly interesting context for the study due to its diversity of climates, energy resources, economies and utility organization structures. Electric power production in Canada comes from state-owned companies as well as from an increasing number of independent power producers (Global

Energy Market Research, 2019). Each province and territory within Canada have unique regulations and independent provincial oversight. Common features of Canada's electric power industry include its reliance on energy-intensive industries, low population density, and high standard of living, making Canadians among the world's top energy users (Bagheri et al., 2018). It is estimated that an additional 54 GW of new capacity will be needed by 2040 and 14 GW will be retired (Global Energy Market Research, 2019).

Given the shift occurring in the Canadian electric power utilities industry and the gap in the literature on management of technology and innovation within the transition, this paper examines emerging research and innovation management practices in Canadian electric power utilities. The research has been conducted to identify the approaches currently being used by utilities to transition to an environment that is favourable for innovations contributing to sustainable and efficient power systems. Understanding the various models and frameworks being implemented will lead to a deeper understanding of the energy transition in a Canadian context.

This paper begins with a review in section 2 of the extant literature on widely cited models of research and innovation management, including open innovation, stage-gate, business model canvas, lead-user innovation, embedded research, and design-driven innovation. In section 3 I present the research methodology, including the research question and design to understand the utility management of transformations in the electric power sector. This data collection consists of secondary research through literature reviews and public document examination, as well as primary research through semi-structured interviews with industry experts and Canadian electric power utility employees. The results are presented in Section 4, followed by a discussion in Section 5 of significance of these findings for the research literature and electric power sector. This paper concludes with a summary of findings and suggestions for future research.

2. Literature Review

Background

According to Tayal, there have been no major changes to the structure or the concept of the energy system since the development of the electricity grid in the late 1800s (Tayal, 2017). He argues that although there have been some technology, reliability, and safety improvements, the centralized electric power system, flowing from generation sources to transmission to distribution, still exists today. Likewise, the industry's regulated, monopoly business model is longstanding. According to the Energy Information Administration, historically, utilities have been considered 'natural monopolies' that achieve economies of scale by serving all consumers within a geographic region utilizing a single infrastructure for generation, transmission and distribution of electricity (Energy Information Administration, 2000). This design has served the industry well in the long term in supporting relatively low power rates and reliable service, but has disadvantages for modernization of the electricity grid, such as inflexible regulatory and policy frameworks (Richter, 2013, Zhu et al. 2004), risk averse practices within utilities, and a landscape that lacks incentives for utilities to innovate (Costello, 2016).

R&D is a risky activity for utilities as it can be expensive, difficult to predict, and without immediate benefits (Costello, 2016). One major disincentive to innovation is the concept of socializing the benefits and privatizing the costs. It is discouraging when utilities receive none of the benefits for an innovation, but they are responsible for all of the risks. A poor decision is punished, but a good decision (e.g., one that reduces costs) is not rewarded (Costello, 2016). "A utility unable to recover any benefit from a new technology is unlikely to spend capital on that technology unless specifically mandated to do so" (Costello, 2016, p. 22). The success of a new innovation is not only hard to predict, but can take years before providing any benefit. Therefore, if a utility had to choose between a new technology and a conventional technology that both have the same expected rate of return, they will tend to favor the conventional technology since it has lower risk (Costello, 2016).

One of the few findings on the topic of energy research management in the literature is that there is no positive relationship between firm size and R&D intensity (Costa-Campi et al., 2014). Smaller companies often make a greater effort in R&D and, in interviews conducted by Dedrick et al. (2015), some utilities regard their smaller size as an advantage "enabling them to respond more flexibly and to try out technologies without facing bureaucratic delays" (Dedrick et al., 2015, p. 22). Costa-Campi et al. (2014) also found that younger firms are more likely to perform R&D. They found that R&D intensity in energy industries is mainly related to process innovations that will reduce costs or increase production capacity, leading to overall efficiencies (Costa-Campi et al., 2014).

The existing literature also identifies a trend to decreases in energy spending on R&D. According to the International Energy Agency, publicly funded R&D has decreased from 11% of global research budgets in 1981 to 4% in 2015, with renewables less than half of that (IEA, 2015). This is also the case within utilities, where they spend extremely low portions of their revenues on R&D (Costello, 2016), and in the past several decades, have pursued a perilous downward path in R&D expenditures (Jones, 2019).

Despite the decreases in R&D funding, if utilities are to become more innovative, they will have to reexamine their existing business models to create more effective strategies for R&D and innovation (Tayal, 2017). According to Osterwalder et al., (2005) business models are conceptual tools containing a set of objects, concepts, and relationships which are designed to express the business logic of a specific firm. They play a critical component in technology diffusion and disruptive innovation in bridging the gap between value proposition and customer segment. Costello (2016) has highlighted the role of regulated public utilities in diffusion in "filtering the benefits of new technologies developed by third parties to retail customers" (Costello, 2016, p. 20). Flaherty (2017) encourages utilities to build distinct internal capabilities combined with parallel directed future investment in order to position themselves for innovation. Overall, utilities need to play an active role in their business model transformation.

Regulators and policymakers also have an important role to play in stimulating R&D and fostering a more innovative environment for utilities. The operation of utilities is heavily tied to the advancement of public policy objectives such as safety, reliability, energy security, energy efficiency, affordability, and shifting to a cleaner environment (Costello, 2016). Therefore, policymakers should take a strong interest in shaping the future of the energy system. Tayal (2016) discusses how policymakers need to adopt a long-term view to ensure stability and investment certainty and create the appropriate investment environment. Regulators also need to examine their ability to impact the innovative environment. Regulators should revisit their current ratemaking and other practices to determine whether utilities need more motivation to innovate in ways that would benefit their customers. Incentivizing utilities to conduct R&D and to innovate is another important activity that will help foster innovation in the energy space. This could include providing a more favourable risk-reward environment that does not heavily discourage risk taking from utilities. Costello (2016) suggests three ways for motivating utilities to innovate. They are (1) to allow utilities to profit from new technologies, (2) to avoid discouraging utilities from conducting pilot programs and other R&D activities, and (3) to eliminate any second guessing of utilities activities on R&D previously approved by regulators (Costello, 2016).

National level studies of electric power system innovation in Austria, Germany, Spain, and the United States demonstrate the challenges utilities face in innovation and the need for new business models. According to Dedrick et. al, (2014), “Aging infrastructure, obsolete technology, costly power outages, and public resistance to location of new generation and transmission facilities characterize the electric utility sector in the U.S. Furthermore, the industry is regulated by a patchwork of federal and state regulation that hampers efforts to create coherent national objectives, policies, and standards” (Dedrick et. al, 2014, p.18).

Dedrick et al. (2015) completed a study on 12 utility companies in the electric utility industry in the United States. This study spanned across ten states with varying regulatory environments. The purpose of their research was to identify (1) what factors determine the motivation and ability of utility companies to adopt to smart grid innovation, (2) how the highly regulated nature of the electric utility industry affects adoption, and (3) how the regulated nature of the industry influences the impacts of other factors on adoption? They applied the technology, organization, and environmental framework, or TOE, to smart grid adoption among regulated utilities in the United States.

They identified the following factors that influenced adoption: the relative or perceived benefits of an innovation, cost, compatibility with current technologies, complexity to implementation, uncertainty of technology paths, trialability, and observability. They identified organizational factors as firm size, financial resources, technical skills, centralization of management functions, top management support, and presence of change agents or champions for a technology. Finally, they described the environment factors impacting smart grid adoption. These included competitive pressure, customer relationships, industry structure, regulatory requirements, and pressures from various external stakeholders. One detrimental factor they found to the adoption of smart grids was the possible loss of revenue due to energy savings, since the revenues of utilities are often based in part on the volume of power sold. As others have observed, public utilities are often only accepting of new technologies if they increase their profits or mandates require them to (Costello, 2016). When the main focus of the utility is to maintain low costs and reliable energy for their customers, innovations can seem too risky. The TOE framework was also studied and applied to the utility industry by Kossahl et al. (2012). Kossahl identified seven factors that influence adoption: (1) perceived benefit, (2) barriers, (3) cost, (4) regulatory support, (5) need for standardization, (6) internal knowledge, and (7) dedicated staff (Kossahl, 2012).

In a study of Spanish electric power utilities, Loredo et. al., (2019) contributed to discussions on internal determinants of innovation. They suggested that innovation strategies in electricity utilities are characterized by incrementalism and path dependencies, and that far-reaching technological changes were driven by external stimuli (Loredo et. al., 2019). Common to other existing literature, they state that utilities show a low propensity to introduce product innovation, but that process innovations were more common. Their specific research questions focused on what innovation activities utilities engage in to generate innovations in a liberalized environment, and, if sustainability-orientation is a driver of innovation in the utilities industry. The main findings of their research were:

i. The acquisition of disembodied knowledge does not play a relevant role for utilities.

ii. Non-formal search processes are central to product innovation.

iii. Some markets for technology-external R&D and technology embedded in equipment-are determinant factor for process innovation.

iv. Sustainability orientation increases the likelihood of generating both product and process innovations. (Loredo et. al., 2019)

Gsodam et al.'s (2015) study of renewable energy in the Austrian power sector addressed electric utilities affected by the energy transition. They agreed with the extant literature that a change in business models is needed to integrate renewable energy, but they also identified that the electricity sector faces problems concerning structural reform relating to new technologies, changes in the policy landscape, and the presence of more demanding customers.

Richter (2013) studied business models for renewable energy though in-depth interviews with German utility managers. His study concluded that utilities have developed viable business models for large-scale, utility-side, renewable energy generation, but they lack adequate business models to commercialize small-scale customers-side renewable energy technologies (Richter, 2013). His study also suggested that utilities favour investments in large-scale projects over small-scale projects as they are bound to their traditional way of business. The study's main conclusion was that "utilities lack the business model innovation capabilities to successfully master the fundamental changes of the energy transition" (Richter, 2013, p. 1235). Ritcher suggested two approaches to improve busines model innovation.

1. Organizational structure – Establish separate ventures or independent specialized units for renewable energy.
2. External partnerships – Accumulate knowledge and capabilities by cooperating with external stakeholders like universities, suppliers, research centers or NGOs (Richter, 2013).

The following sections build on this prior literature in identifying approaches to research and innovation management, such the aforementioned use of external partnerships (Richter, 2013). In addition to the survey of the literature on and external partnerships, I also present open innovation, stage-gate, business model canvas, lead user innovation, and design-driven innovation. Each of these are incorporated in the research design, presented in the following section.

External Partnerships

A common conclusion in the extant literature is that external collaborations and partnerships are particularly useful in enhancing R&D and innovation practices in the electric power utility space. Developing partnerships with suppliers, software developers, and vendors can enhance or speed up the development and adoption of new technologies (Aguero et al., 2017, Dedrick et al. 2015, Richter, 2013). Academic partnerships, including work with universities, colleges, research centers and professionals, have been found to be extremely helpful with collaboration and knowledge acquisition (Aguero et al., 2017, Dedrick et al., 2015). Utilities can further supplement their internal capabilities by working with external organizations such as venture capitalists, start-ups, original equipment manufacturers, partners and acquisitions (Flaherty, 2017). Moreover, they can work with other utilities to gain more industry knowledge. “Because large utilities operate essentially as government-sanctioned monopolies, many of them have few or no competitors. This means that utilities can ‘collaborate, not compete’ working on joint research and development for their mutual benefit” (Jones, 2019, p. 16.). These formal and informal networks can help utilities learn and understand successful practices that are emerging in a wide range of activities and can help them overcome knowledge limitations they may have.

Not only is it important to provide incentives for utilities in the energy system, but incentives should be put in place for other groups within the industry networks, such as potential entrants, vendors, and manufacturers (Costello, 2016). For instance, many of the technologies in electric power utility operation come from third parties, yet these third parties often require access to expensive utility infrastructure to conduct needed experimentation and demonstration. The mutual investment in research, development and innovation creates opportunities for incentive systems among all contributors. Regulators should ensure these parties have access to the utility space and take caution to avoid any barriers that may be disincentivizing them to innovate (Costello, 2016).

Open Innovation

The concept of open innovation involves the distribution of knowledge through the sharing of ideas and the transcending of organizational boundaries within an innovative ecosystem (Chesbrough et al., 2018, Bogers et al., 2018). It can be a useful tool in creating value for organizations and can lead to effective societal change (McGahan et al., 2021). Open innovation differs from an external partnership in that open innovation is often used to create opportunities that cannot be quantified financially, at least in the short term (McGahan et al., 2021). It involves both an inflow and outflow of knowledge and ideas. Companies that source external knowledge by working with outside participants, such as suppliers, customers, and other groups, and that also transfer their internal ideas with outside environments, can increase their innovativeness and bring ideas to market faster (Enkel et al., 2009). These activities lead to co-creation through joint ventures, cooperation in projects, and strategic alliances where "give and take are crucial for success" (Enkel et al., 2009, p. 313). This new approach to innovation was introduced by Chesbrough in his 2003 book *Open Innovation: The New Imperative for Creating and Profiting from Technology* (Chesbrough, 2003). This form of innovation works best when people operate in boundary-spanning roles and work closely with multiple organizations (Chesbrough, 2012). This allows for more efficient connection of knowledge from various sources (Chesbrough, 2012). Overall, the main objective of open innovation is to expand and increase an organization's value creation through practices of openness (Chesbrough & Appleyard, 2007).

There are two main activities involved with practicing an open innovation strategy. They are: 1) inbound open innovation, which is the purposeful inflow of external inputs, contributions, and knowledge, and 2) outbound open innovation, which is the purposeful outflow of an organization's internal knowledge and business models (Bogers et al., 2018, McGahan et al., 2021). This strategy is in contrast with traditional closed models of innovation where projects and ideas can only enter at the beginning of the company's internal base and can only exit by going to market (Chesbrough, 2012). Open innovation differs in that external knowledge can enter the innovation process at many different stages and can also enter the market in various ways (Chesbrough, 2012), which increases innovativeness and reduces time to market (Enkel et al., 2009).

Accumulating additional external resources leads to a growing source of value creation through the pooling of knowledge. This calls into question the traditional business strategies emphasis on having ownership over the value-creating resources (Chesbrough & Appleyard, 2007). Rather than relying on solely internal ownership and control, open innovation transcends boundaries and creates an "ecosystem where people, organizations, and sectors can foster co-creation" (Bogers et al., 2018, p. 10). Serious competitive disadvantages can occur for an organization if interorganizational innovation collaboration is already taking place in an industry and they are not participating (Enkel et al., 2009).

Stage-Gate

A stage-gate system manages new product development from idea to launch (Cooper, 1990). It brings structure and checkpoints to product innovation that can typically be disorderly and chaotic (Grönlund et al., 2010). The stage-gate process consists of stages or phases that outline a set of deliverables and essential activities, and gates, which are considered quality control checkpoints (Cooper, 1990). Each stage in the system is comprised of multifunctional, prescribed, and parallel activities (Cooper and Kleinschmidtm, 1993). The process is cross-functional, involving people from varying groups and functional departments in an organization (Kitsios & Kamariotou, 2020).

There are typically four, five, or six stages in a standard stage-gate process (Kitsios & Kamariotou, 2020; Cooper and Kleinschmidt, 1993; Cooper,1990). It offers a blueprint for managing and enhancing efficiency in new product development (Cooper, 2008) that can also energize and speed up a firm's new product development process (Grönlund et al., 2010). Stage-gate systems have been shown to provide quality focus and high standards of execution while clearly outlining a roadmap for organizational leaders and their teams. It defines critical activities, quality standards and expected deliverables, while providing a clear vision of the overall steps and goals of the project, which has a profound impact on the innovation process (Cooper, 1990).

Activities, such as discovering opportunities and generating ideas, are outlined in early stages, while concept development, testing, commercialization, and product launch take place in later stages (Grönlund et al., 2010; Kitsios & Kamariotou, 2020). They decrease project risk by gathering the required information and reducing the number of unknowns and uncertainties between phases (Smolnik & Bergmann, 2020; Grönlund et al., 2010; Cooper,1990). Gates occur between each stage and are the points in which go/kill decisions are made (Cooper, 2008; Kitsios & Kamariotou, 2020; Cooper and Kleinschmidt, 1993). They have a set of deliverables or inputs, a set of exit criteria, an output (Cooper,1990) and they consist of criteria that must be passed for managers to choose whether to continue investing in a project.

Although the stage-gate process continues to adapt and be enhanced, the basic concept has been retained. "The advanced next generation processes should be more agile, flexible, dynamic, accelerated, and simultaneously leaner, faster, more adaptive, and risk-oriented" (Smolnik, & Bergmann, 2020, p. 46). This is consistent with recent research which has found that a more flexible application of the model is commonly used during technology development (Högman, & Johannesson, 2013). Some of these flexible strategies include "employing loop backs over stages, delaying gates, redefining projects, conducting development, and using the model recursively" (Högman, & Johannesson, 2013, p. 284). Flexibility is helpful, especially in technology development where high levels of uncertainty is common, and where individualized needs of the organization can be met.

Business Model Canvas

The business model canvas or lean startup approach is a holistic concept created by Osterwalder and Pigneur and used to outline and clearly state the main business model of an organization. The business model canvas includes nine building blocks: customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, and cost structure. "This tool resembles a painter's canvas - preformatted with the nine blocks – which allows you to paint pictures of new or existing busines models" (Osterwalder et al., 2010, p. 41). The right-hand outlines value distribution factors and the left hand focuses on the value creation side of the business (Gaus & Raith, 2013). The model is both simple and practical, allowing for a clear and concise overview of the critical components of a business model. It allows for a stronger breakdown and understanding of the overall functions of a business, which can strengthen the value proposition and simplify the understanding of the business model. This can be used to determine the desirability, feasibility, and viability of a business idea (Osterwalder et al., 2020). It acts like a blueprint and covers the four main areas of a business, which are customers, offer, infrastructure, and financial viability (Osterwalder et al., 2010). This clear, simplified, universal template detailed in nine blocks can provide a much-needed, clear picture of the business model and its components.

The foundational step in the lean startup / business model canvas method is to articulate the value proposition and customer segments. This is central to the business model. The intention is to clearly state what value the company will provide to their customer segments through its new products and services. The aim of the value proposition is to solve a problem or to satisfy a customer need. The customer segments are typically identified narrowly within niches so as to understand the common customer's needs (Kyllikki Taipale-Erävala et al., 2021). In contrast to earlier approaches to entrepreneurship education that de-emphasized customer influence on the innovation process (Timmons et al., 2004), this approach embraces customer discovery as the base activity that underlies everything else in innovation.

With the value proposition identified in context of the customer niche, the remaining blocks can be mapped. On the right side of the canvas, focused on revenue generation, practitioners address plans for customer acquisition and retention, channels to deliver products and services, the revenue model and pricing. The left side of the canvas, containing the expense side, identifies the business operations, resources (physical, financial, intellectual, human and core competencies) and partners, such as suppliers, strategic alliances, and coopetitors.

According to Spanz (2012), the three main positive features of the business model canvas are its simplicity, its practice-orientation instead of academic palaver, and its plug-and-play principle (the possibility to start from scratch). Some criticisms of the model include the lack of analysis of: competition; business goals, external environment;

key performance indicators and performance measurement (Spanz, 2012). Kraaijenbrink's (2012) three main criticisms of the business model canvas are the: exclusion of strategic purpose, including mission, vision, and strategic objectives; the exclusion of a notion of competition; and the mixing levels of abstraction. Another criticism presented by Maurya (2010) describes a lack of problem identification in the model, a lack of solution identification and the lack of key metrics. Maurya also suggests adding a box for unfair/competitive advantage. (Maurya, 2010).

Embedded Research

Embedded research occurs when researchers are co-located with the team they are studying as a way to improve research impact and to undertake and implement a collaborative research agenda (McGinity & Salokangas, 2014). "It is attracting growing interest as an example of a joined-up approach to knowledge production and use, which takes account of context and stakeholder interests" (Cheetham et al., 2018, p. 164). Both the researcher and the host-organization benefit from this practice. The researcher gains greater access, allowing for better understanding of their research topic, while the host-organization has direct entry into academic knowledge and networks. There are different levels of embeddedness and the application can be highly structured or casual, both allowing for the development of personal relationships which can heighten idea generation and give the researcher deeper community and organizational knowledge. This can lead to better linkages between research outputs and policy implementation (Jenkins et al., 2012). Embedded research involves more than just having researchers physically located at an organization's location. The quality and types of relationships between researchers and staff is also important in fostering successful collaboration.

These relationships and linkages lead to co-production of knowledge, which is the main purpose of the practice (Vindrola-Padros et al., 2017).

Embedded research has been carried out across many differing organizations and industries including education, health, judicial systems, social care and science policy. (Vindrola-Padros et al., 2017). Embedded research studies have also been completed in cybersecurity, anthropology, criminology, science and technology, and engineering (Foord & Kyberd, 2020). The goal of the researcher in each of these settings would be to conduct research studies and share findings in the specific context of each organization, focusing on their individual needs and unique culture (Vindrola-Padros et al., 2017).

Cheetham et al. (2018) conducted a year-long study using embedded researchers in a local authority setting in England. Their findings described embedded researchers as acting as a 'sounding board' with a fresh set of eyes and different insights. Embedded researchers in this study were also considered catalysts for change and improvements, as tools to build research capacities, as facilitators and as knowledge brokers who are able to bring different stakeholders together. They argued that embedded research provides opportunities for shared learning and for 'conversational spaces' (Cheetham et al., 2018).

Embedded researchers differ from 'knowledge brokers' and 'boundary spanners. Although they may conduct some of the same activities, their main purpose is to coproduce knowledge. (Vindrola-Padros et al., 2017). Foord and Kyberd, P. (2020) outline four characteristics of embedded research.

> "1. The researcher is usually affiliated to both an academic and a non-academic host organization.

2. The researcher develops relationships with staff and is seen as part of a team.

3. The researcher generates knowledge (in conjunction with local teams) which corresponds to the needs of the host organization.

4. The researcher builds research capacity in the host organization" (Foord & Kyberd, 2020, p. 222).

Overall, embedded research allows for a connection between research, practice, and policy. The embeddedness can increase the impact of research and bridge gaps between research outputs and policy change (Jenkins et al., 2012). There are, however, challenges to the embedded research approach. These include competing pressures, lack of support or understanding of the researcher's role, not belonging in either organization, and ethical or ontological issues (Cheetham et al., 2018). Even with these challenges, this form of research leads to interactive, collaborative knowledge production involving various groups, providing a benefit for all those involved.

Lead-User Innovation

Eric Von Hippel (2005) defines lead users as those who face the same needs as the rest of the marketplace, but much earlier. They are also described as those who can greatly benefit by finding a solution to their needs (Januska & Spicar, 2016). "A lead user is motivated to innovate to solve his or her problems rather than to sell a product or service" (Von Hippel, 2005). Lead users can be firms or individuals, and they have needs beyond what is currently available in the market, which is why they choose to modify a product or to create a new one (Eisenberg, 2011).

Innovation has traditionally been thought of as producers who create a product or service and then sell it. Eric Von Hippel's research, and the extensive studies that have followed, has now highlighted and identified users as a valuable source of innovation. Individuals or firms who create a product or service to use it are lead user innovators (Gambardella et al., 2017). The lead-user innovation approach is said to minimize a firm's risk associated with innovating new products and offers advantages such as accelerated diffusion rates (Hassan, 2008). Many radically new products and services have been pioneered by lead user innovators. For example, sports such as skateboarding, mountain biking and windsurfing were all developed by users who participated in those activities (Leary & Kaulartz, 2019). Other examples include surgeons creating new medical devices (Gambardella et al., 2017), important oil refining innovations (Enos, 1962), and scientific instrument creation and semiconductor processing (von Hippel, 1988). In Von Hippel's view, the best innovations that win in the marketplace tend to come from lead-users (von Hippel, 2005).

Studies have also shown that individual lead users do not have to be outside the boundaries of the firm. They can be employees within organizational boundaries (Wu et al., 2020), as well as embedded lead users (Schweisfurth & Raasch, 2015). Wu et al. (2020) finds that employees can be lead users with regard to internal work processes and can be a valuable source of innovation. Some examples include: Tim Berners-Lee who created the World Wide Web because of unsatisfied work-related needs; John Gibbon, who developed the heart-lung machine as a physician; Robert Borkenstein, a frustrated police officer who invented the breathalyzer; and Betty Nesmith, a bank secretary who created typewriter correction fluid (Wu et al., 2020). "All these innovations emerged in the workplace and were driven by individuals experiencing limitations in their jobs" (Wu et al., 2020, p.2).

Embedded lead users (ELUs) are employees who are lead users of their firm's products or services (Schweisfurth & Raasch, 2015). Schweisfurth and Raasch further extend lead user theory by demonstrating the significant role played by internal user innovation. ELUs have use expertise and they span organizational boundaries, which can benefit a firm. Embedded lead users offer high quality new ideas and demonstrate favorable organizational behaviors (Wu et al., 2020). A study completed by Schweisfurth (2017) concluded that "internal lead user's ideas are of higher quality than those of ordinary employees and users, but – unexpectedly – are of lower quality than the ideas of external lead users" (Schweisfurth, 2017, p.1). This limitation, they argue, is caused by internal lead users' entrenchment in organization-specific knowledge, which reduces their creative input (Schweisfurth, 2017).

Energy transitions and power systems are unique in how they relate to lead user methods. Users as citizens in the public sector context are not only individuals but responsible members of a collective, and "they are not always sovereign actors but restrained by existing structures" (Rosenthal and Peccei, 2007, p. 4). Martiskainen et al. (2021) discuss how users have a role to play throughout the entire period of energy transitions, not just as adopters or consumers. They created a typology of five different user categories: user-producers; user-legitimators; user-intermediaries; user-citizens; and user-consumers. User-producers experiment with technology and create organizational solutions, making them pivotal in the start-up phase. User-legitimators provide legitimation by making developments more digestible and accessible. User-intermediaries “create space for the appropriation, shaping and alignment of the various elements of emerging socio-technical systems, such as products, infrastructures and regulatory frameworks” (Schot et al., 2016, p. 4). They are important in the acceleration phase of transitions. User-citizens focus on creating regime-shifts and reforms and are active supporters for a particular niche. Finally, user-consumers help to embed the new regimes into daily practices. They attribute symbolic meaning to new technologies and enable stabilization (Martiskainen et al., 2021).

Design Driven Innovation

Design-driven innovation focuses on the radical innovation of meanings (Verganti, 2009). Instead of the traditional technology-push and market-pull strategies, design-driven innovators search to create new meanings related to the psychological, emotional, and sociocultural aspects influencing why a person buys a product (Verganti, 2009). This approach is not initiated from users’ perceptions, but instead is “derived from a cross disciplinary team of visionary thinkers who are able to more intuitively discover what users want” (Hadlock & McDonald, 2014, p. 16). Design-driven innovation involves ‘making sense of things’ (Verganti, 2008). It reflects why people do things and how values, beliefs, and aspirations evolve (Gasparin et al., 2020), as well as how user’s desires change when exposed to possible new meanings and how society can change with it (Hadlock & McDonald, 2014).

Design-driven innovation can be especially useful for radical innovations (Filippi, & van Oorschot, 2017). Verganti (2009) uses the example of Nintendo, which launched “Wii” and revolutionized the meaning of playing videogames from sedentary to physically active experiences. Another example discussed by Verganti (2009) is the social construction of the bicycle and cycling, initially viewed as dangerous but becoming an acceptable and even healthy form of transportation. Further examples include Artemide, the Italian manufacturer of lighting, Whole Foods Market (Verganti, 2009) and Apple (Hadlock & McDonald, 2014).

Another important element of design-driven innovation are interpreters. "Interpreters are people – such as artists and designers – and organisations – such as cultural organisations and the media – that can provide insight into changing socio-cultural trends and help identify latent meanings, ripe for innovation" (Verganti, 2009). They can include scientists, technologists, executives, architects, firms in other industries, product designers, media, suppliers, universities (De Goey et al., 2019), and more. The process of working with interpreters involves three actions: 1) listening – listening to develop strong relationships with interpreters, 2) interpreting – internal firm process of recombining and integrating the new gained knowledge, and 3) addressing – harnessing the power of interpreters to sway customers and make products more meaningful and attractive (Verganti, 2009).

An article by De Goey et al., 2017, discusses how there has been little research surrounding design driven innovations in areas such as business-to-business and public contexts, where companies need to create value for multiple stakeholders. The results of their study demonstrate the need for companies to balance the varying stakeholder perspectives, and that they need to "understand and address how these stakeholders might interpret product meanings differently" (De Goey et al., 2017, p. 489). There is also an identified need to broaden the focus beyond the end user in these contexts. They also found the value created through design driven innovation is difficult to quantify (De

Goey et al., 2019), but is believed to lead to substantial and sustainable competitive advantage (Verganti, 2009). This can be accomplished through product differentiation (De Goey et al., 2019), and also has the potential to create disruptive new markets (Koomans & Hilders, 2016).

3. Methodology

Research Question

There is limited research that focuses on R&D and innovation in the electric power utility context. Given the existing shift that is occurring in the energy sector, the ongoing technological and organizational changes within utilities, and the increasing pressure for a transition to more sustainable systems, there is a need for further research that addresses R&D and innovation practices within electric power utilities. Further, most existing studies have occurred outside of the Canadian system. Although they offer general insight into current practices, there is very limited research concentrating on a Canadian context. Given these existing gaps, the research question of this paper is: What are the emerging R&D and innovation strategies occurring in electric power utilities, specifically focusing on the Canadian context?

Research Design

To answer the research question, I designed a qualitative study to gather primary and secondary data to understand how R&D and innovation management are practiced and changing in the Canadian electric power utility sector. As a first step, literature reviews were conducted on current R&D and innovation practices within the energy system, specifically within electric power utilities. Article searches were completed on business models, including: business model canvas, stage-gate model, lead-user innovation, open innovation, embedded research, and design driven innovation. This research involved identifying articles which examined each specific model as well as exploring these models in relation to a Canadian electric power utilities context.

Following the literature review and before conducting the primary research, I undertook searches for public documents on Canadian electric power utility R&D and innovation management practices from government websites as well as from other industry organizations. I originally found 100 articles using the search terms such as "electric power utilities and Innovation", "electric power utilities and R&D" and so on. I then conducted searches for each specific model discussed in this paper, as well as their relation to electric power utilities. I then searched for documents directly on the websites of the utilities that were interviewed.

Interviews were conducted to gather knowledge on R&D and innovation practices within Canadian electric power utilities. They were completed between June 2020 to December 2020 using video sessions that normally lasted 60 minutes. Interview requests were sent to over 100 utility employees through email and through LinkedIn. Close to 40 responses were originally received and, in total, 35 interviews were conducted. These interviews were recorded and later transcribed to be analyzed. The participants were from a variety of provinces including Newfoundland and Labrador, Nova Scotia, Prince Edward Island, New Brunswick, Quebec, Ontario, Saskatchewan, Manitoba, and Alberta. 30 of those interviews were with utility employees and the remaining were with industry experts such as employees in start-up companies, academics, and incubator programs. The individuals were all working within the electric power utility industry in Canada, but they were employed in a wide variety of roles, including engineers, business analysts, department managers, presidents, researchers, and others. The 30 interviews conducted with utility employees were used for this paper and the five interviews with industry experts were excluded. This was chosen in order to maintain consistency and uniformity when analyzing the results.

The interviews were semi-structured and flexible. The goal of the interviews was to determine specific R&D and innovation practices emerging within Canadian electric power utilities. The objective of the interviews was to answer the following questions.

1. What models are currently being used for R&D and innovation?
2. How is innovation initiated, coordinated, and encouraged within the organization?
3. How does the organization acquire new industry knowledge surrounding innovation?
4. How does the organization work with external groups to foster innovation?
5. How does the company think about the future of innovation in the industry, as a whole?

4. Results

4.1 Stage-Gate Model

The specific question asked during the interviews was "Do you use a stage-gate model? If so, can you describe practices with the model?" These questions were asked to determine if the utility implemented a formal stage gate process as defined in the literature (Cooper, 1990). The interviews demonstrated that a formal stage-gate process is commonly used in provincially owned utilities.

Ownership		Practiced?	Comments
Provincial	Utility 1	X	Very formalized stage-gate process. - "Yes. For the research projects we use the stage-gate model. There's a specific definition of those different gates".
	Utility 2	X	Used sometimes. - "Sometimes there is a very structured stage-gate, 'we're going to do this and then evaluate it, and then we're going to do this and evaluate it'".
	Utility 3	X	Used excessively by their I.T. group. - "Typically, when we are doing a partnership, it will be an executive decision item. So, if it makes it through the director's approval, it will be signed off and then submitted to the executive for their approval. By virtue of doing that you're going through a stage-gate".
	Utility 4	X	Yes.
Municipal	Utility 5	X	Same process is used. Not called 'stage-gate'. - "We may not call it stage-gate, but we definitely operate in that way".
	Utility 6		
	Utility 7		Not sure. Unfamiliar with the name. - "Maybe we do, but I might just not know that that's what it's called. It sounds like something we would do". - Use a board approval process called 'back of envelope gate'.
	Utility 8	X	
Publicly Traded	Utility 9		Not formally used. - "Not formally, but I think that's kind of the logic that we tend to use anyway."
	Utility 10		Not used. - "No. We've done more a process of a five-year roadmap. We look at where we are with

			technologies and where we want to be in five years."
	Utility 11		Not used. - "We certainly don't have that formalized on our innovation projects with a stage-gate type format".
	Utility 12	X	Used frequently by their I.T. group. - "Yes. I'd say it is the benchmark for our project management processes".
	Utility 13		They use a milestone component. - "We use milestone components, which maybe is the same as stage-gate".

Table 1: Stage Gate Model Results

4.2 Business Model Canvas

The specific question asked during the interviews was "Do you use business model canvas method?" Because most interview subjects were unfamiliar with this model, and an explanation needed to be given, I typically described the business model canvass, including providing an overview of its history and the meaning of each of the nine boxes in the model.

Ownership		Practiced?	Comments
Provincial	Utility 1		Not used. - "It is similar to our project initiation sheet. I have never heard of that term exactly."
	Utility 2	X	Yes. - "There's a lot of talk about it actually. It's kind of very early stages".
	Utility 3	X	Used in their I.T. group.
	Utility 4		Has never heard the term before. Is not sure if they are using it.
Municipal	Utility 5	X	Yes. business model canvas is used. - "It's very familiar, because to describe the business models that we want to implement commercially, and we want to offer as a service to our customers, those business models have been developed using the business model canvas".
	Utility 6		Not used. - "I'm very intrigued by the concept of business model canvas, we don't use that…".
	Utility 7		Not used.
	Utility 8		Not used.

			- "I am familiar with it. I've seen it and we have had some members of our membership team go through the training with it, but it's probably not something we use in a pure sense. I do really like it".
Publicly Traded	Utility 9		Not used. - "I have not heard of that one."
	Utility 10		
	Utility 11		Not used. Has not heard of it.
	Utility 12	X	Yes. Used while working with their provincial smart grid project.
	Utility 13		Not aware of the model being used.

Table 2: Business Model Canvas Results

4.3 Lead User Innovation

The specific questions asked during the interviews were "Do you use lead-user innovation methods to develop new product, services and knowledge? Are you a lead-user in any R&D and innovation projects?" I described lead-users as those users who identify needs earlier than others, and are motivated to innovate to solve their own internal problems.

Ownership		Practiced?	Comments
Provincial	Utility 1	X	Focus is to solve internal problems first. They have an external subsidiary specifically for innovation. - "We try to innovate where we can help [Utility 1] to achieve it's functions".
	Utility 2	X	Develop software in house. Also conducted through pilot projects Also work with outside companies to innovate. - "We use these small pilot projects to test something out and move forward with it. We've done that several times".
	Utility 3	X	Extensive innovation with suppliers and local networks. Software developed in house.
	Utility 4	X	They have a subsidiary specifically for innovation.
Municipal	Utility 5	X	Extensive innovation through partnerships with vendors. - "We don't do everything in house. We definitely find the right partners".
	Utility 6	X	Conducts lead user innovation with outside partners.
	Utility 7		
	Utility 8		

Publicly Traded Large, Private, Publicly Traded	Utility 9		Do not conduct lead user innovation. They wait until a technology is proven and cheaper.
	Utility 10		Do not conduct lead user innovation. - "Nobody wants to be the first there, because it is new technology and its innovative, it's probably not proven."
	Utility 11		Do not conduct lead user innovation.
	Utility 12	X	Wait to use technologies that are not necessarily proven in their province but are proven elsewhere. They do not do R&D in house.
	Utility 13		

Table 3: Lead User Innovation Results

4.4 Design Driven Innovation

The question asked was "Do you practice design-driven innovation?". Design driven innovation had to be carefully explained during the interviews as, more so than other practices, it was an unknown concept. I described it as the potential to "reimagine what the energy grid could look like", or to reimagine a new meaning for the energy system as a whole. I explained how it is not only about improving the technology, but also adding new meanings to the grid. Examples I gave were the Nest thermostat, suggesting that it changed the meaning of the thermostat from a beige "set-and-forget" device to a colourful, lifestyle app for saving carbon emissions. I also mentioned Apple and how they reimagined the meaning of a number of products in their industries. I described it employing the opposite of a customer focus, as in business model canvas/lean methods, which orients ideation to customer discovery. Instead, in the design-driven innovation model, innovators socialize with other visionaries to come up with new works for customers that they would not have imagined for themselves.

Ownership		Practiced?	Comments
Provincial	Utility 1		Do not use. - "That's something we've experimented with in the past, and it didn't land very well. That doesn't mean that we wouldn't redo it in the future".
	Utility 2		
	Utility 3		
	Utility 4		
Municipal	Utility 5		
	Utility 6		
	Utility 7		
	Utility 8	X	Used to an extent. - "To some extent, especially when you think about what we're doing in the customer's home in terms of bringing smart customer products, trying to reimagine what their experience is".
Publicly Traded	Utility 9		
	Utility 10		
	Utility 11		Does not use. - "That example isn't one that jumps out to me as something we've talked about".
	Utility 12		
	Utility 13		Does not use. Thinks that the utility industry should start thinking that way.

Table 4: Design Drive Innovation Results

4.5 Science-Based Research

The specific question was "Do you conduct or sponsor science-based research with a view to development of new products or services?" Most of the interview subjects indicated they were familiar with this practice, and were able to speak to the question without clarifying questions.

Ownership		Practiced?	Comments
Municipal	Utility 1	X	Work with universities. - "We have research chairs with pretty much every university in the province."
	Utility 2	X	Work closely with local University. - "We rely on the university or other academia for support."
	Utility 3	X	Collaborate with provincial Universities.
	Utility 4	X	Work with universities and industry organizations.
	Utility 5	X	Yes.

Provincial			- "We have engaged with a couple universities where we have tried to have academia come in and provide a deeper technical perspective or provide another angle."
	Utility 6	X	Partnerships with universities. - "We work closely with the university.
	Utility 7	X	Work with provincial university. - "Yes. That's actually one of our best ways to get some more experimental stuff done."
	Utility 8	X	Work with University, National Science Engineering Research Council, Colleges. - "We view [the university] as a very strong partner and collaborator."
Publicly Traded	Utility 9	X	Research with provincial universities - "We've given students a problem that we want solved, and they come in and do some work on it. We've worked a lot with students at [the provincial university]"
	Utility 10	X	Will sponsor research.
	Utility 11	X	Work with provincial universities.
	Utility 12	X	Work with universities and colleges.
	Utility 13	X	They provide internships. They also work with multiple international universities.

Table 5: Science-Based Research Results

4.6 R&D and Innovation Partnerships

The questions asked were "Do you conduct R&D and innovation with external organizations? If so, how are they managed and by whom? Do you use research contracts with statements of work and deliverables? Are there norms on how often you meet with partners? Can you estimate the number of ongoing projects at present? Can you describe the partners involved, e.g., small firm (less than 100 employees), medium sized firms (100-500 employees), large corporations, national R&D organizations, international R&D organizations, energy system modellers, end-users, higher education institutions, regulators, etc.?"

Ownership		Practiced?	Comments
Provincial	Utility 1	X	Difficult for them to partner with start-ups. Most innovation comes from internal. They have a subsidiary that sometimes works with suppliers, software companies, etc.
	Utility 2	X	Work with software companies, Government departments, large suppliers, research institutes. Not so much small companies.
	Utility 3	X	Strong focus on local companies and local economic development. Actively doing supplier development. - "Projects are ranked on their impact to the community, that's something we're intimately focused on."
	Utility 4	X	Industry orgs (EPRI, CEATI, etc.) - "We do a lot of our R&D through organizations like EPRI and CEATI".
Municipal	Utility 5	X	Vendors many times become project partners. Some are global, some are local. Also work closely with small start-ups.
	Utility 6	X	Partner with outside suppliers to develop innovations.
	Utility 7	X	Industry groups like CEATI, EPRI. Strong preference to work with established companies with a track record.
	Utility 8	X	Work with Provincial initiatives, start-ups, large suppliers. A lot of collaboration with outside orgs.
Publicly Traded	Utility 9	X	
	Utility 10	X	Work mostly with local reps for large suppliers.
	Utility 11	X	Large Vendors, community associations. - "There's a trusted partnership type approach. Dealing with large organization with a good reputation who have brought new technology to market and are able to answer our technical questions."
	Utility 12	X	Universities, suppliers, other companies.
	Utility 13	X	Work with governments, policy makers, community groups.

Table 6: External Organizations Results

4.7 Conferences and Events

The interview question was "What conferences and events do you attend to learn about and share new knowledge in the industry?"

Ownership		Practiced?	Comments
Provincial	Utility 1	X	Ex: CEATI, EPRI, IEEE, Distributech.
	Utility 2	X	Ex: CEATI,

	Utility 3	X	Attend national and international conferences. Ex: SIMSA, CEA and Edison Electric Institute.
	Utility 4	X	Ex: EPRI, CEATI, Segre.
Municipal	Utility 5	X	Very important. Conferences, webinars, seminars, etc. - "It's an important way of not just getting intel but understanding what's going on in the industry and who are the people leading something in the industry."
	Utility 6	X	Ex: CEA, Electric Power Research Institute (EPRI)
	Utility 7	X	Sometimes host internal conferences to bring in industry experts. This allows more staff participation. Also attend CEATI, EPRI, etc.
	Utility 8	X	Participate quite heavily in conferences. CEA, National Emerging Issues Committee and Distribution Council.
Publicly Traded	Utility 9	X	CEATI, other conferences. - "I think most people here do attend conferences to understand the technologies that are coming in."
	Utility 10	X	A lot of big trade shows such as Distributech.
	Utility 11	X	Ex: CEATI, EPRI, IEEE, Distributech, Segre, and more. Quite extensive. - "You've got to try to look at all these conferences and pick where the ones you think you're going to get value from or where you've got the most interest in depending on what you're working on. Because otherwise you could be sending people to conferences indefinitely."
	Utility 12	X	Yes. They attend UC events, EUCI, SEPA, CANSI.
	Utility 13		

Table 7: Conferences and Events Results

4.8 Embedded Research

The interview questions were: "Do you use embedded research practices, i.e., embed R&D personnel in operational groups with the goal of co-producing new innovation for the organization? If so, can you tell me about them?" As with design-driven innovation, many of the interview subjects needed further explication of this practice to respond to the questions.

Type		Practiced?	Comments
Provincial	Utility 1	X	Sometimes with University Professors. - "We have some teachers who have their own desk here".
	Utility 2	X	Not used.

	Utility 3		Not used.
	Utility 4	X	Yes, on specific projects. Mainly with large vendors.
Municipal	Utility 5		Not used.
	Utility 6		
	Utility 7		Yes. When implementing a new technology. - “So, we did have them on site working with us hand in hand for the better part of three years to get this thing running.”
	Utility 8		
Publicly Traded	Utility 9		Not used. - “I’m not aware of us having done that to date.”
	Utility 10		Not used.
	Utility 11		Not used. - “I know the relationship you’re talking about, but I don’t have a specific example that would be the same as that.”
	Utility 12	X	Used during some initiatives to increase efficiencies. - “I believe they do that in IT. We lease out that space and a partner will come in and work with our data warehousing team to get a sense of what it’s like inside the company”
	Utility 13		

Table 8: Embedded Research Results

5. Discussion

In this section I present my analysis of the results outlined in the charts above and the implications of the findings. For each model I discuss the responses given in the interviews and describe how the identified practices relate to the existing literature on these models.

Stage-Gate Model

When examining the responses from utilities about use of the stage-gate model as a part of their innovation strategy, all of the provincially owned utilities confirmed their use of it. Two utilities from other ownership structures also use the stage-gate method but, overall, the provincial corporations use it more frequently.

One large provincial utility, listed as Utility 1, follows a very formalized stage-gate process. For this company, stage one identifies what currently exists in the market and whether there is a gap that has not yet been filled. Stage two involves building a prototype, while stage three consists of finalizing the prototype and testing it in the field. Finally, stages four and five involve deploying the innovation into the field. These stages accurately fit the standard stage gate process, where activities, such as discovering opportunities and generating ideas, are outlined in early stages, while concept development, testing, commercialization, and product launch take place in later stages (Grönlund et al., 2010; Kitsios & Kamariotou, 2020). This is an essential part of how Utility 1 sets up their R&D. In between each stage they decide whether to continue with the project or to drop it. The utility employee stated: “When they reach a certain end of a stage-gate, or they reach the end of a budget or they reach the end of a schedule, they’ll have to present the project and say, ‘we’re recommending passing stage two to three’, and a bunch of senior managers and directors will give it the blessing or kill the project." This utility emphasized that the model is very enforced, even using it to show the provincial regulator how many projects are in different stages at a given time. "That's part of showing that the investment is going somewhere".

Other utility employees spoke to their use of informal stage-gate processes. A common first stage in these processes is to identify if the project aligns with their strategic objectives, followed by determining whether the budget is available for the project. The final stages normally involve testing and finalizing the new product. In many interviews, the utilities referred to their gates as "milestones". This differs slightly from the objective of a stage-gate process, but has the same benefit of viewing a project in phases. The informality and flexible use of the model is consistent with research published by Högman & Johannesson, (2013), showing that a more flexible application of the model is commonly used during technology development (Högman, & Johannesson, 2013).

Other utility employees disclosed that they use many stage-gate type processes, just not necessarily with that name. For example, for an innovation project to be conducted at one utility, a business case has to be created and then a manager or director has to give the project a 'go ahead' or it stopped there. The process further contemplated a path in which the project was directed to regulatory review, where it again had the potential to be stopped or continued. Other utility representatives mentioned pathways that distinguished between big and small projects. For instance, gates for big projects may consist of approval or disapproval by a board of directors, called a "back of envelope gate" by one interview subject. In contrast, smaller, less risky projects may only require mid or top-level management approval to proceed to implementation phrase. The reasoning was that more analysis requires a higher cost, which may not be worth it for small sized projects. A representative from Utility 5 stated “Because we are getting external funding from the federal government to an extent, we are required to report on certain things at certain points in time. We develop Gantt charts, milestone dates, so yes, we are very familiar with that approach”.

As discussed in existing literature, stage-gate processes are intended to decrease project risk by gathering the required information and reducing the number of unknowns and uncertainties between phases (Smolnik & Bergmann, 2020; Grönlund et al., 2010; Cooper,1990). Being a risk adverse industry, the frequent use of the stage-gate model or similar processes within electric power utilities is not surprising. The gates act as check points to ensure a project does not involve too much risk or uncertainty, reflecting norms in the industry oriented to reliability, safety and consistency.

Business Model Canvas

The majority of utility employees were unfamiliar with the business model canvas. Utility 1 discussed their use of a similar method called a project initiation sheet. Many employees talked about using proposals and business cases to outline their project concept. Others simply asked the question “can we make money off this or not?” Some managers who did not currently use the model were very intrigued, and others were looking to bring it into their organizational practices.

Again, those who used it were primarily provincial utilities. A representative from Utility 5 familiar with the business model canvas highlighted the importance of using it because their role is not just to complete research on a new project, but it is also to create an implementation plan and a ‘go to market’ strategy. The interview subject said it offered a useful way to implement a project commercially. “It’s very familiar, because to describe the business models that we want to implement commercially, and we want to offer as a service to our customers, those business models have been developed using the business model canvas”.

In general, utilities may not be using this method for two reasons. First, utilities are primarily implementing already proven technologies, and so may perceive that the time has passed when a business model canvas is needed. As the literature states, the business model canvas model in designed to determine the desirability, feasibility, and viability of a business idea (Osterwalder et al., 2020). Utilities may believe that this form of analysis has already been completed prior to the new innovation coming to the utility. Secondly, it may be that utilities are only now starting to think of their business models in a different way, open to innovation like new products and services. Traditionally, utilities were tasked with providing reliable, affordable power. Now, with changing energy needs, new technology developments, and opportunities for new business models, utility managers are acknowledging the benefit of using a tool such as the business model canvas to identify, simplify, and clearly detail their business model components.

Lead User Innovation

Lead user innovation was identified more frequently in provincially owned utilities. A consistent trend seemed to be finding internal problems and developing innovations focused on solving that problem for internal use, most times without commercializing the new development. This trend is consistent with Eric Von Hippels (2005) description that “a lead user is motivated to innovate to solve his or her problems rather than to sell a product or service”. One employee from Utility 1 stated, “We try to innovate where we can help [Utility 1] to achieve its functions”. This often involves software developments by program users to make day-to-day work more time and cost efficient. As an employee from Utility 2 explained, “We’ve developed an automation tool, and it’s a software tool that we’ve used in conjunction with our modeling software. It expands the capability of what we can do, and it makes it a lot faster.” This also supports the current literature explaining that individual lead users do not have to be outside the boundaries of the firm. They can be employees within organizational boundaries (Wu et al., 2020).

These forms of lead user innovations were rarely commercialized, as the focus was on internal improvement. One response given was

> I think the decision was that we should keep it internally. Partially because if you go out and commercialize it, then you’re responsible for supporting not only the unique cases that come up for [the utility], but the unique cases that come up for all of your end users. It’s not within our mandate to be a software provider for a bunch of other utilities, especially under a government regulated mandate.

The exception to this occurred with large utilities who had external R&D and innovation subsidiaries. Commercialization was still not the focal point of the innovation, but it did occur at times. One utility stated “Our main focus is to help the utility. So, the main focus is not to commercialize. It’s mainly implemented in the company and then once its implemented, we can think about commercialization”. These subsidiary groups also participated in developing patents, for the most part surrounding chemicals or materials. This is not something the rest of the utilities took part in.

Lead user innovation did occur with some utilities involving outside companies. An employee from Utility 2 discussed how their innovation projects were moving forward because of their partnership with an outside supplier who was driving the project. A representative from Utility 3 spoke to their frequent innovative work with vendors. Their lead user innovation practices involved an extensive local network. Another interview subject stated that when they purchase a device from a supplier, the supplier commonly becomes their project partner. “We don’t do everything in house. We definitely find the right partners”. Utility 6 discussed an example of working with a technology company to help innovate. When describing the specific technology, they stated “We were one of the pioneers on the technology. We were on the bleeding edge. We invested quite a lot of our own time into perfecting the product for the vendor and it was a partnership.” This reflects von Hippel’s view of lead user innovators (von Hippel, 2005).

Those who did not conduct lead user innovation cited their small size or risk averse practices as the reasoning for not practicing the model. “You could find yourself three or four years down the road having to go back to the regulator saying ‘Well, that really didn’t work out well. So, we need to replace that now and use this’.” A lead user approach would involve more risk-taking innovative practices, which is why some of the larger utilities have the resources and backing to do so. Other utilities were subsidiaries of large parent corporations, with lead user innovation happening in a separate group within the oversight of the parent firm.

Design-Driven Innovation

Design-driven innovation is another model that was unfamiliar to most interview subjects. Many struggled to grasp or fully understand the concept. This is likely because the model itself is academic in nature, and also because the type of thinking needed to frame innovation in this way is rare within the electric power utility industry. Even when employees attempted to answer the question or provide an example, they missed the main intention of the theory.

One provincial utility discussed their use of this theory in the past, but emphasized that it did not work for them, and they have shifted towards focusing on designing products, which was more aligned with their mandate. A representative from Utility 8 discussed their use of design-driven innovation with bringing in smart customer products into the customer's home. This is a good example of a potential way to implement design innovation and change how society thinks about their energy usage.

The lack of knowledge or use of design-driven innovation in the electric power utility sector is indicative of the deeply engrained, traditional way of thinking within the industry. Design-driven innovators search to create new meanings related to the psychological, emotional, and sociocultural aspects influencing why a person buys a product (Verganti, 2009). This is outside the scope of what utilities have done in the past and how they continue to model their business strategies. This approach is not initiated from users' perceptions, but instead is "derived from a cross disciplinary team of visionary thinkers who are able to more intuitively discover what users want" (Hadlock & McDonald, 2014). One potential detriment is the lack of this cross-disciplinary team of visionary thinkers. The utility industry is largely made up of engineers and busines professionals. There is a missing component required for successfully using design-driven innovation, and that is the absence of experts such as artists, phycologists, and creators. An important element of design-driven innovation is the use of interpreters, which are "people – such as artists and designers – and organisations – such as cultural organisations and the media – that can provide insight into changing socio-cultural trends and help identify latent meanings, ripe for innovation" (Verganti, 2009) Bringing in more interpreters into the energy transition will help shift the traditional way of thinking.

Design-driven innovation could become a useful strategy for the electric power utility industry, as it can be especially useful for radical innovations (Filippi, & van Oorschot, 2017). However, being a public commodity with multiple stakeholders makes design driven innovation more challenging for this industry, and there has been little research in the area of public contexts. Utilities need to create value for multiple stakeholders – their shareholders, regulators, governments, customers, boards, and so on. De Goey et al., (2017) outline the importance to "understand and address how these stakeholders might interpret product meanings differently". This is a critical factor when conducting design-driven innovation in a public space. Another challenge for utilities implementing this concept is that although design-driven innovation is believed to lead to substantial and sustainable competitive advantage, the value created through design driven innovation is difficult to quantify (De Goey et al., 2019). The difficulty of quantifying the value created could be a concern, especially in regulated environment where public approval is required.

Science-Based Research

Almost every utility representative discussed their involvement with science-based research. Whether through university partnerships, industry groups, or government agencies, there was a profound understanding of the importance of these forms of research collaborations. Hiring university students for internships was another commonly used method to embrace academic knowledge. The interviews demonstrate a strong desire for science-based research within the utility space. Working with academics and industry experts was described as "one of the best ways to get some more experimental stuff done". It was seen to provide excellent background into new project ideas at relatively minimal costs. A commonly identified area of concern from interview subjects was the potential mismatch between the academic research and the needs of the utility. Without proper understanding of the direct needs of the industry, some professionals have noticed the presence of 'make work' projects.

This form of collaboration could be considered one part of an overall partnership strategy (discussed in the next section) or open innovation strategy, involving the distribution of knowledge through the sharing of ideas and the transcending of organizational boundaries within an innovative ecosystem (Chesbrough et al., 2018, Bogers et al., 2018). Accumulating additional external resources within utilities may also lead to a growing source of value creation through the pooling of knowledge. (Chesbrough & Appleyard, 2007). The extensive pooling and sharing of knowledge between academic institutions and electric power utilities may also help to create a more innovative environment.

R&D and Innovation Partnerships

Throughout the course of the interview period, it became clear that collaboration and partnerships with external organizations are critical for innovation to occur within in Canadian electric power utilities. As one employee put it, "I think for the regulated space, these third-party entities are critical for us in breaking ground and learning how others are breaking ground." The external organizations ranged from start-ups, suppliers, and vendors to research institutes, government departments, and community groups.

Consistent with the existing literature, most utilities foster their R&D and innovation through these external collaborations and projects. They rely on suppliers often to come to them with existing trends and new technologies. They help the development process by providing resources, space for testing, and industry knowledge. One manager stated, "We will rely on others to develop technology, and then we would commercialize it". This was a common trend for most interviews. New innovation teams are helping with this process.

> With the creation of the innovation team, we are reaching out to innovative companies across North America that are doing different things. We might reach out to a company just to talk about a topic and they'll say something like 'well actually we're already doing something in this field', or 'we want to partner with an energy utility, are you interested?'. So, we've created a few partnerships that way.

Projects are also initiated by organizations such as the Electric Power Research Institute (EPRI) and the Centre for Energy Advancement through Technological Innovation (CEATI), and many utility members participate in these shared projects. One utility interview said, "Some of the power of EPRI and CEATI come from the collaboration from the industry." Almost all utilities discussed their involvement with these organizations and discussed how they operate with them. Another interview subject said, "They have projects that get generated through working groups or interest groups, so we will choose whether or not we are going to participate in those projects."

Partnerships were most frequently created with larger, established suppliers such as Siemens and Tesla. This allowed for a level of trust and reliability for the utilities when entering into innovative projects. Utility 11 stated the benefit of working with reputable organizations is that when the utility goes to them with a request, the supplier can say “Look, we’ve used it here and here”. Larger utilities expressed their lack of desire to work with start-ups or smaller companies and the difficulties that can create. According to Utility 1, “We are not enough in that space. That’s something we’re missing out on”. Utility 2 had a similar view, stating “We do some partnerships with small local companies, but I think for the most part there is a certain reluctance to work with a smaller company”. Some reasons mentioned were worries that smaller organizations would not be able to scale up, concerns about bad public relations if the project was dropped and caused detrimental impacts to small or local companies, and perceptions of unfair selections (corruption). Conversely, other utilities liked to work with start-ups and smaller companies. One interview subject said they tend to focus on partnerships with small start-ups because their processes are less formalized and they have more “intent and hunger”, versus larger firms. This level of interest was shared by some of the smaller utilities, as well as those larger utilities with dedicated innovation groups.

Interestingly, one large provincially owned utility discussed the importance of local economic development to the mandate of their utility. Their approach to working with suppliers, vendors, and outside organizations was premised on a desire to help develop other companies and even individuals within their province. They purchased towers, reclosers and other equipment primarily from provincial companies, with projects ranked by their impact to the local community. They also focused on training and educating local groups and developing a regional network. Their management orientation came from their specific provincial policy, and how their mandate differs from those of other crown corporations in other provinces. “We have a very strong commitment from our executive pushing the local support”. From the interviews, most of the procurement and partnership processes were oriented primarily to choosing companies that provided the best technology and overall value proposition. Utility 8 also discussed their desire to shift to this provincially-oriented strategy, with their representative stating “My hope would be that our utility can be viewed as helping to fuel regional economic development, by being a utility that is start up friendly”.

It was very common in the interviews for utility employees to emphasize the amount of innovation that occurred through work with suppliers or vendors at very early stages of their innovation processes. The partners were often pioneers at the leading edge of technology development. Partnerships were formed with vendors and manufacturers to innovate and to bring a product to the point of commercialization. Some utilities described themselves as the “middleman”, bringing solutions from vendors to customers. The innovative partnerships that were discussed ranged from local start-ups to small developers to larger vendors. The main theme is that the innovation was initiated by the external group, and then supported and enhanced through working relationships with the utilities.

Looking beyond individual utilities to the national power utility eco-system, the extensive overall work with utilities and external organizations in a wide variety of roles has created an ecosystem of knowledge sharing and open innovation within the Canadian electric power industry. This open innovation involves both an inflow and outflow of knowledge and ideas. Utilities source external knowledge by working with suppliers, customers, and other groups, and the utilities transfer their internal ideas to their partners. The partners, in turn, use these ideas and knowledge in projects with other utilities, building further value for their clients. This in turn increase innovativeness and brings ideas to market faster (Enkel et al., 2009). The exception to this process of eco-system development are the utilities with external R&D groups and subsidiaries. They instead actively conduct research and develop innovations internally and, in many cases, retain the knowledge to serve their residential, commercial and industrial customers.

Conferences and Events

Conferences and events were identified as valuable sources of information for discovering current and emerging practices within the energy space. “It’s an important way of not just getting intel but understanding what’s going on in the industry and who are the people leading something in the industry.” This most commonly included conferences and events that were hosted by the Electric Power Research Institute (EPRI), the Centre for Energy Advancement through Technological Innovation (CEATI), the Canadian Electricity Association (CEA), CIGRE, Distributech, Electricity Utility Consultants Inc. (EUCI), the Institute of Electrical and Electronics Engineers (IEEE), and the Smart Electric Power Alliance (SEPA). The perception of many interview subjects is that there are an enormous number of conferences occurring in the industry. One interviewee stated “You’ve got to try to look at all these conferences and pick where the ones you think you’re going to get value from or where you’ve got the most interest in depending on what you’re working on. Because otherwise you could be sending people to conferences indefinitely.” A lot of resource and information sharing occurs at these events. Not only are they opportunities to learn new knowledge, but utilities also go to share their insights and best practices. As one employee shared, “Obviously we need to share our innovations, and we need to learn from other people innovations. It’s sometimes just best practices that are exchanged much more than what we develop.” One employee described the benefit of sharing these best practices as preventing utilities from having to "reinvent the wheel" for every problem that occurs or for every new idea. It also helps in regulated environments. "If you have somebody else who's gone out and done it, it adds a level of credibility to it, if you are putting it in front of a regulator". This ties in with the recurring theme of reducing risk and preferring proven methods and technologies. One small utility described the benefits that these conferences have for them. "It's one way that as a small utility we're able to punch a bit above our weight because we can learn from bigger utilities and we have a much broader network. You really get plugged into what's going on in other parts of the country."

Embedded Research

Embedded research was not something that most utilities practiced. Although their work with external groups and lead user innovation with those groups was extensive, embedded research was not an integral strategy for those projects. One utility spoke about how the lack of use of these partnerships are primarily due to the increasing number of ways collaboration can now occur virtually.

Large utilities sometimes had university professors embedded within their offices. They had their own desk and office space that they could work from when completing collaborative research projects. Other examples included suppliers such as Siemens being embedded within the organization to foster more direct access and knowledge sharing on specific initiatives. Utility 7 discussed their use of embedded innovation when implementing a new technology. They stated about the vendor "We did have them on site working with us hand-in-hand for the better part of three years to get this thing running."

I believe embedded research will increase the amount of innovation and co-production of knowledge occurring in the electric power utility industry. The researcher gains greater access, allowing for better understanding of their research topic, while the host-organization has direct entry into academic knowledge and networks. As discussed in the lead-user innovation, science-based research, and external organizations section, utilities are already extensively co-creating, and they greatly benefit from greater access to knowledge. According to Cheetham et al. (2018), embedded researchers act as a 'sounding board' with a fresh set of eyes and different insights, and are considered catalysts for change and improvements, as tools to build research capacities, as facilitators and as knowledge brokers who are able to bring different stakeholders together. All of these elements are needed in the energy sector while transitioning to more sustainable models.

Structure of R&D and Innovation Groups

There was a wide range of responses from utility employees when asked about the structure of R&D and innovation groups within their organization. Some responded that there were no separate groups for R&D and innovation and that it was spread out within various company departments. Others pointed out that they do not have any formalized plan or policy around R&D and innovation, which often times had to do with their smaller size or their structure. Overall, the general responses demonstrated a lack of defined structure. Comments like "No, I would say that we don't have a formal plan or policy around R&D" were common.

Utilities with parent companies often relied on their larger counterparts to form innovation centered groups and to share their knowledge with their subsidiaries. "We leverage the size of [the parent company], and there we look at technology as a common group as opposed to doing it all individually. We share best practices, new technologies, successes and failures, and as a group we learn from each other."

Other utilities, mainly large provincially owned, have non-regulated external groups, or subsidiaries, that were created specifically for the purpose of innovation and R&D. The main branch of the utility would funnel research projects through the subsidiary, which would either complete research or make a product that solves the specific problem for the utility. One interview was conducted with an employee of one of these external subsidiaries. They emphasized how successful they believe the structure is in developing innovations. They work directly with the main utility to understand their needs, so the close relationship allows for better understanding of specific problems and potential solutions. It also allows for more long-term research to be conducted. The day-to-day short-term focus of the utility continues, but the external organization has more freedom to explore long term innovations - an area lacking in the utility space. They concluded that there "really needs to be different buildings and independence between the two groups, because otherwise there would not be any research projects with long term views". It also creates more space for differencing of opinions and information sharing. Some smaller utilities like this strategy, explaining "What we would like to do is have the regulated utility as one entity and then we would like to have subordinates or affiliates that operate in the unregulated space".

At times, larger companies have multiple groups, or 'hubs', within their organization which are focused on different innovation projects. These groups range anywhere from 2 to over 40 people, depending on the size of the utility and their strategy.

They were specifically designed to explore what is occurring in the industry and to research, ideate, create pilot projects, and explore new innovations.

6. Conclusion

The goal of this paper was to answer the research question "What are the emerging R&D and innovation strategies occurring in electric power utilities, specifically focusing on the Canadian context." After completing literature reviews and conducting industry interviews, the main conclusions of this study are as follows.

Innovation in the Canadian electric power utility industry is primarily conducted through partnerships with external suppliers and vendors. One interviewee said:

> As regulated utilities, we are obligated to provide least cost service to customers, so if you have an innovative product, like most innovative things, it's probably not least cost today. But in five years' time, when there's more market acceptance of that product, and the price comes down, it is going to be least cost. So, it's difficult to be an early adopter of some technologies, because an early adopter to technology is expensive.

The pathway to R&D and innovation in the Canadian electric utility space appears to come from external suppliers, vendors, start-ups, and other groups. This occurs either through implementing already proven technologies, or by participating in lead user innovation in early stages of technology developments. One interview subject stated clearly "we will rely on others to develop technology, and then we would commercialize it. We're not making any bets on sort of un-commercialized stuff at this point in time." Another said, "We don't do R&D in house." The use of external organizations for technology innovations is still relatively unstructured and varies between utilities. Utilities can enhance their proficiency by becoming more familiar with and implementing business practices such as open innovation, boundary spanning and embedded research to improve their effectiveness in partnering with external organizations.

Second, utilities in Canada are primarily focused on short term, incremental innovations with low risk, and are still inhibited by mature, established systems. "We do definitely look at the incremental innovations. We do look at systemic changes, but not now, that's for sure. I believe that is changing rapidly". Consistently, utility employees described their innovation practices as focusing on incremental improvements. They shared a desire to begin to include larger, more disruptive innovations, but the strategy was just not there yet. They also described their practices as 'conservative' and 'risk averse'. One interview subject said: "I would say as a regulated utility there's not a lot of crazy risky projects that come through. I certainly don't want to diminish any of the work that we do on the innovation side, but it's not exactly cutting edge that's going to change the world overnight." Many disincentives to innovate are out of the control of the utility itself and have more to do with regulatory and policy frameworks. There is an identified need for regulatory regimes to shift in favor of fostering innovation within utilities. "Essentially we're dissincented to innovate and that's something we need to fix in the regulatory construct in order to unlock innovation." Another problem is with existing assets that last a long time, which can lead to slow movement in business model changes. "It's an evolution over time. A lot of times you're trying to migrate legacy systems that are based on old software into more modern times". Another employee put it this way.

> It's an old industry and the problems that we're facing are hard problems. It's so hard to make change, because the industry is so entrenched, so established, and change is risky. You're dealing with big systems, very costly systems, so that you want to go with something that's proven. You don't want to take a risk because, for example, your nuclear power plant might not continue to operate the way it's supposed to. So, there's a legitimate reason for risk aversion.

As mentioned throughout the various interviews, addressing this culture of risk aversion is an extremely challenging task. This is why the current transition occurring within utilities is so difficult. Utilities are entering unknown territory that will require significant modifications in business models, considerable policy change, and serious ingenuity and resourcefulness. An adjustment in the mindset of utility managers and policy makers is needed to think 'outside of the box' and to move away from the deeply entrenched system.

Further, most utilities, especially in regulated environments have a mandate to provide reliable, least cost services to customers. This disincentivizes risks in favour of prudent, safe spending. By working with the entire energy system to include policymakers, regulators, utilities, and other stakeholders in the transition conversation, there is an opportunity to make a more friendly environment for innovation.

Third, sharing and collaboration with other utilities and industry groups are critical ways to gain new knowledge and expertise. Interview responses were filled with examples of industry knowledge sharing. "We're all about sharing the information and for the most part, the industry is about sharing with each other." This occurred through international and national conferences and events, as well as participation within industry groups. Through these channels, utilities frequently share best practices with each-other. The industry is a strong network of knowledge sharing and collaboration. Since this strategy has been proven to be very beneficial and important to the industry, utilities should look for more ways to collaborate and share knowledge.

Fourth, with a few exceptions, R&D and innovation structures are still in early stages, with groups and processes being mainly informal and dispersed. Every individual interviewed recognized the immediate and critical need to transform the electric utility business model. There is a clear understanding that change is coming, but the reaction time is slow. "A lot of utilities are kind of waiting. They're just waiting. Many utilities are waiting to see what the other utilities are doing". Many utilities self-identified as slow moving and expressed that even when a decision is made to go in a certain direction, it can take years to do so. This translates into their innovation and R&D teams. With many utilities, they are still trying to explore and determine the best structure for their teams. Some utilities do not have distinct teams and rely on innovations coming through individual departments. Others are in early stages of trying new structures and frameworks. A few of the larger crown corporations are heavily organized with very distinct R&D and innovation activities. This works well for them but is not always possible with other provinces depending on the size of their utility and their regulatory scheme. Having an external subsidiary our group solely focused on R&D and innovation seemed to be one of the most effective ways to organize innovation teams. This often led to longer term thinking and transition foresight.

Overall, a shift to a more reliable, sustainable, and efficient energy system is underway around the world, and Canada is no exception. The changes occurring within utilities seems to differ by utility, there is not a uniform sense of change in how they are structuring.

> It's not like other industries, where there's innovation in an innovation group, and they've got an office. What we see in power utilities is that it is diversified to a number of groups. I think the utilities are still getting used to these concepts and practices. We're seeing a lot of variation across the utilities. Some innovation groups are in supplier relations, some are in customer solutions, some are in traditional R&D groups.

There is a distinctive need for business model innovation in electric power utilities. This is critical to be able to adapt to this transformation and make operations conducive to the changing system. One utility manager stated:

> One of the dangers of innovation is that it becomes too focused on the technology, and often the technology is not the problem. There are so many experts out there from vendors, from faculty, from different sources where we can draw on expertise around technology. The real nut to crack around a lot of technology in our industry is business models, rate design, and advocacy.

To that end, utilities should closely look into re-organizing and re-thinking their R&D and innovation business models in order to meet the need of the future energy system in Canada, perhaps in a collaborative approach with other utilities in their region or at a national level, e.g., a working group on new utility business models. Adopting models such as business model canvas and design driven innovation will help utilities broaden the way the think about their industry. Business model canvas provides a clear structure to outline opportunities in a way not thought of in the past. Design driven innovation will push utilities towards an overall shift in thinking of what the industry and the energy system could look like in the future. Re-imagining how consumers will use energy and thinking of a change in meaning of energy usage as a whole will help utilities break away from the traditional models and structures that are making innovation so difficult. Overall, Canadian electric power utilities share a common interest in transforming and modernizing the current energy system. Re-organizing their business models to strengthen industry collaboration and to rethink their R&D and innovation practices will lead to faster and more efficient adoption of innovative technologies. This will greatly improve their ability to meet the energy needs of the future in Canada and will allow them to transition to a more reliant, modern, and sustainable energy system.

Future Research

Future research should be conducted to provide a deeper analysis into R&D and innovation in the Canadian electric power system. This should include studies involving a larger sample size, allowing for more significant data collection. Further, given that this paper is a broad overview covering several business models, more in-depth research should be completed on each individual business model. For example, it could explore the large amount of lead user innovation that is occurring between utilities and suppliers, or analyze the impact of embedded researchers in the utilities sector. Future research should also investigate business model innovation. This might include studies of how vendors working within utilities conduct lead user innovation to enhance their innovation process, as well as develop new utility business models to adopt new hardware and software. Further, there are gaps in both the research literature and public policy on regulatory impacts on innovation, including what new regulatory models will support innovation and the development of new relationships between utilities and external organizations, such as start-up companies.

Bibliography

Aguero, J. R., Takayesu, E., Novosel, D., & Masiello, R. (2017). Modernizing the grid: Challenges and opportunities for a sustainable future. *IEEE Power and Energy Magazine*, *15*(3), 74-83.

Alexander O., Yves P., Alan S., & Frederic E. (2020). The Invincible Company: How to Constantly Reinvent Your Organization with Inspiration From the World's Best Business Models. Wiley.

Bagheri, M., Guevara, Z., Alikarami, M., Kennedy, C. A., & Doluweera, G. (2018). Green growth planning: A multi-factor energy input-output analysis of the Canadian economy. *Energy Economics*, *74*, 708–720. https://doi org.proxy.hil.unb.ca/10.1016/j.eneco.2018.07.015

Bogers, M., Chesbrough, H., & Moedas, C. (2018). Open innovation: Research, practices, and policies. *California management review*, *60*(2), 5-16.

Carlson, R., Nciri, A. (2020). Enter the Sandbox: *Developing Innovation Sandboxes for the energy Sector.* Quality Urban Energy Systems of Tomorrow and Pollution Probe Foundation.https://questcanada.org/wpcontent/uploads/2020/07/Innovation-Sandboxes-Report-1-EN.pdf

Cheetham, M., Wiseman, A., Khazaeli, B., Gibson, E., Gray, P., Van der Graaf, P., & Rushmer, R. (2018). Embedded research: a promising way to create evidence-informed impact in public health?. *Journal of Public Health*, *40*(suppl_1), i64-i70.

Chesbrough, H. (2012). Open innovation: Where we've been and where we're going. *Research-Technology Management*, *55*(4), 20-27.

Chesbrough, H., Lettl, C., & Ritter, T. (2018). Value creation and value capture in open innovation. *Journal of Product Innovation Management*, *35*(6), 930-938.

Chesbrough, H. W., & Appleyard, M. M. (2007). Open innovation and strategy. *California management review*, *50*(1), 57-76.

Cooper, R. G. (1990). Stage-gate systems: A new tool for managing new products. Business Horizons, 33(3), 44–54. https://doiorg.proxy.hil.unb.ca /10.1016/0007-6813(90)90040-I

Cooper, R. G. (2008). Perspective: The Stage-Gate® Idea-to-Launch Process—Update, What's New, and NexGen Systems. Journal of Product Innovation Management, 25(3), 213–232. https://doi-org.proxy.hil.unb.ca/10.1111/j.1540-5885.2008.00296.x

Cooper, R. G., & Kleinschmidt, E. J. (1993). Stage Gate Systems for New Product Success. Marketing Management, 1(4), 20–29.

Costa-Campi, M. T., Duch-Brown, N., & García-Quevedo, J. (2014). R&D drivers and obstacles to innovation in the energy industry. Energy Economics, 46, 20–30. https://doi-org.proxy.hil.unb.ca/10.1016/j.eneco.2014.09.003

Costello, K. W. (2016). R&D and public utilities. *The Electricity Journal*, *29*(5), 19–26. doi: 10.1016/j.tej.2016.06.001

Dedrick, J., Venkatesh, M., Stanton, J. M., Zheng, Y., & Ramnarine-Rieks, A. (2015). Adoption of smart grid technologies by electric utilities: factors influencing organizational innovation in a regulated environment. *Electronic Markets*, *25*(1), 17-29.

De Goey, H., Hilletofth, P., & Eriksson, L. (2017). Design-driven innovation: Making meaning for whom?. The Design Journal, 20(sup1), S479-S491.

De Goey, H., Hilletofth, P., & Eriksson, L. (2019). Design-driven innovation: a systematic literature review. European Business Review.

Eisenberg, I. (2011). Lead-User Research for Breakthrough Innovation. Research Technology Management, 54(1), 50–58. https://doiorg.proxy.hil.unb.ca/10.1080 /08956308.2 011.11657673

Energy Information Administration (2000). The Changing Structure of the Electric Power Industry 2000: An Update. Retrieved from http://www.eia.gov/electricity/.

Enkel, E., Gassmann, O., & Chesbrough, H. (2009). Open R&D and open innovation: exploring the phenomenon. *R&d Management*, *39*(4), 311-316.

Enos, J.L. (1962) Petroleum Progress and Profits: A History of Process Innovation, MIT Press, Cambridge, MA.

Filippi, A., & van Oorschot, R. (2017, September). The Design-Driven Innovation Process in Start-Ups: The Role of Incubators. In 12th European Conference on Innovation and Entrepreneurship ECIE 2017 (p. 225).

Flaherty, T. (2017). Investing in Innovation: Utilities Scaling-Up. *Fortnightly*. https://www.fortnightly.com/fortnightly/2017/03/investing-innovation

Foord, D. J., & Kyberd, P. (2020). Embedded research in rehabilitation engineering. Prometheus, 36(3), 217-234.

Gambardella, A., Raasch, C., & von Hippel, E. (2017). The User Innovation Paradigm:

Impacts on Markets and Welfare. *Management Science*, *63*(5), 1450–1468. https://doi-org.proxy.hil.unb.ca/10.1287/mnsc.2015.2393

Gasparin, M., Green, W., & Schinckus, C. (2020). Slow design-driven innovation: A response to our future in the Anthropocene epoch. Creativity and Innovation Management, 29(4), 551-565.

Gaus, O., & Raith, M. (2013). The business model of the entrepreneurial university. Proceedings of the European Conference on Innovation & Entrepreneurship, 2013, P268.

Government of Canada. (2019). *Global Energy Market Research: Canada*, 1–36.

Grönlund, J., Sjödin, D. R., & Frishammar, J. (2010). Open Innovation and the Stage-Gate Process: A REVISED MODEL FOR NEW PRODUCT DEVELOPMENT. California Management Review, 52(3), 106–131. https://doi-org.proxy.hil.unb.ca/10.1525/cmr.2010.52.3.106

Gsodam, P., Rauter, R., & Baumgartner, R. J. (2015). The renewable energy debate: how Austrian electric utilities are changing their business models. *Energy, Sustainability and Society*, *5*(1), 1-12.

Hadlock, C. A., & McDonald, J. K. (2014). Design-Driven Innovation as Seen in a Worldwide Values-Based Curriculum. Educational Technology, 15-22.

Haley, B. (2018). Integrating structural tensions into technological innovation systems analysis: Application to the case of transmission interconnections and renewable electricity in Nova Scotia, Canada. *Research Policy*, 47(6), 1147–1160. https://doi-org.proxy.hil.unb.ca/10.1016/j.respol.2018.04.004

Hassan, S. S. (2008). Bringing Lead-User Innovations to the Market: Research and Management Implications. SAM Advanced Management Journal (07497075), 73(4), 51–58.

Hippel, E. V. (2005). Ideas ON THE Edge. *CIO Insight*, *54*, 54–60.

Högman, U., & Johannesson, H. (2013). Applying stage-gate processes to technology development—Experience from six hardware-oriented companies. Journal of Engineering & Technology Management, 30(3), 264–287. https://doi-org.proxy.hil. unb.ca/10.1016/j.jengtecman.2013.05.002

International Energy Agency (IEA), 2015. Key trends in IEA public energy technology research, development and demonstration (RD&D) budgets [Online]. Available from: http://wds.iea.org/WDS/tableviewer/document.aspx?FileId=1531 (accessed 21.07.16).

Januska, Martin & Spicar, R. (2016). Lead user innovation and paid innovation: The case of grinding gear games. 185. 476-485.

Jenkins, L. D., Maxwell, S. M., & Fisher, E. (2012). Increasing conservation impact and policy relevance of research through embedded experiences. *Conservation Biology*, *26*(4), 740- 742.

Jones, K. (2019). Electric utilities are now hotbeds of innovation. *Electrical Apparatus*, *72*(9), 16–16.

Joskow, P. L. (2010). Dumb Grids, Smart Grids, Our Grids. Retrieved from http://economics.mit.edu/files/5395.

Kind, P. (2013). Disruptive challenges: financial implications and strategic responses to a changing retail electric business.

Kitsios, F., & Kamariotou, M. (2020). Stage-Gate and Agile Manufacturing in New Product Development: A State-Of-The Art. Proceedings of the European Conference on Innovation & Entrepreneurship, 330–337. https://doi org.proxy.hil.unb.ca /10.34190/EIE.20.147

Koomans, M., & Hilders, C. (2016). Design-driven leadership for value innovation in healthcare. Design Management Journal, 11(1), 43-57.

Kossahl, J., Kranz, J., & Kolbe, L. (2012). A Perception-based Model for Smart Grid Adoption of Distribution System Operators - An Empirical Analysis. Proceedings of the 18th American Conference on Information Systems (AMCIS), Seattle, USA.

Kraaijenbrink. (2012). Three shortcomings of the Business Model Canvas. Kraaijenbrink Training & Advise. Retrieved October 18, 2013, from http://kraaijenbrink.com /2012/07/shortcomings-of-the-business-model-canvas/

Kyllikki Taipale-Erävala, Erno, S., & Lampela, H. (2021). Towards a new business model canvas for platform businesses in two-sided markets. Journal of Business Models, 8. INSERT-MISSING-URL

Leary, A., Kaulartz, S., (2019). Introducing the New Era of Lead User Innovation. *IPSOS Views*. https://www.ipsos.com/sites/default/files/ct/publication/documents/2019-01/lead-user-innovation-web.pdf

Loredo, E., Lopez-Mielgo, N., Pineiro-Villaverde, G., & García-Álvarez, M. T. (2019). Utilities: Innovation and sustainability. *Sustainability*, *11*(4), 1085.

Martiskainen, M., Schot, J., & Sovacool, B. K. (2021). User innovation, niche construction and regime destabilization in heat pump transitions. *Environmental Innovation and Societal Transitions*, *39*, 119-140.

Maurya, A. (2010). Why Lean Canvas vs Business Model Canvas? Practice Trumps Theory. Retrieved October 9, 2013, from http://practicetrumpstheory .com/2012/02/why-leancanvas/

McGahan, A. M., Bogers, M. L., Chesbrough, H., & Holgersson, M. (2021). Tackling Societal Challenges with Open Innovation. *California Management Review*, *63*(2), 49-61.

McGinity, R., & Salokangas, M. (2014). Introduction: 'embedded research' as an approach into academia for emerging researchers. *Management in Education*, *28*(1), 3-5.

Meadowcroft, J. (2009). What about the politics? Sustainable development, transition management, and long term energy transitions. *Policy Sciences*, *42*(4), 323–340. https://doi-org.proxy.hil.unb.ca/10.1007/s11077-009-9097-z

Osterwalder, A., Pigneur, Y., & Clark, T. (2010). Business model generation : a handbook for visionaries, game changers, and challengers (Ser. Strategyzer series).

Osterwalder, A., Pigneur, Y., Smith, A., & Etiemble, F. (2020). *The Invincible Company: How to Constantly Reinvent Your Organization with Inspiration From the World's Best Business Models* (Vol. 4). John Wiley & Sons.

Osterwalder A, Pigneur Y, Tucci C (2005) Clarifying business models: origins, present and future of the concept. Working Paper. CAIS: Communications of the Association for Information Systems

Piñeiro Fabio Da Silva, Oliveira, J. M. de, Cruz, A. C. da, & Patias, T. Z. (2017). Business models on startups: a multicase study. Revista De Administração Da Ufsm, 10(5), 792–807. https://doi.org/10.5902/1983465929161

Richter, M. (2013). Business model innovation for sustainable energy: German utilities and renewable energy. *Energy Policy*, *62*, 1226-1237.

Richter, M. (2013). German utilities and distributed PV: How to overcome barriers to business model innovation. *Renewable Energy*, *55*, 456-466.

Rosenbloom, D., Meadowcroft, J., Sheppard, S., Burch, S., & Williams, S. (2018). Transition Experiments: Opening Up Low-Carbon Transition Pathways for Canada through Innovation and Learning. *Canadian Public Policy*, *44*(4), 368–383. https://doi-org.proxy.hil.unb.ca/10.3138/cpp.2018-020

Rosenthal, Patrice and Peccei, Riccardo (2007). 'The work you want, the help you need': Constructing the customer in Job centre Plus. ORGANIZATION. 14, 2, p. 201 - 223

Schot, J., Kanger, L., Verbong, G., 2016. The roles of users in shaping transitions to new energy systems. Nat. Energy 1 (May).

Schweisfurth, T. G., & Raasch, C. (2015). Embedded lead users—The benefits of employing users for corporate innovation. *Research Policy*, *44*(1), 168–180. https://doi-org.proxy.hil.unb.ca/10.1016/j.respol.2014.09.007

Schweisfurth, T. G. (2017). Comparing internal and external lead users as sources of innovation. *Research Policy*, *46*(1), 238–248. https://doi-org.proxy.hil.unb.ca/10.1016/j.respol.2016.11.002

Smolnik, T., & Bergmann, T. (2020). Structuring and managing the new product development process - review on the evolution of the Stage-Gate® process. Journal of Business Chemistry, 2, 41–57. https://doi-org.proxy.hil.unb.ca/10.17879/22139478907

Spanz, G. (2012). Startup best practice: Business Model Canvas. Venture works Blog. Retrieved October 22, 2013, from http://blog.ventureworks.ch/post/18727255435/startup-best-practice-business-modelcanvas

Tayal, D. (2016). Disruptive forces on the electricity industry: A changing landscape for utilities. *The Electricity Journal*, *29*(7), 13-17.

Tayal, D. (2017). Leveraging innovation for electricity utilities. *The Electricity Journal*, *30*(3), 23-29.

Timmons, J. A., Spinelli, S., & Tan, Y. (2004*). New venture creation: Entrepreneurship for the 21st century* (Vol. 6). New York: McGraw-Hill/Irwin.

Tucci, C. L., Chesbrough, H., Piller, F., & West, J. (2016). When do firms undertake open, collaborative activities? Introduction to the special section on open innovation and open business models. *Industrial and Corporate Change*, *25*(2), 283-288.

Verganti, R. (2008). Design, meanings, and radical innovation: A metamodel and a research agenda. Journal of product innovation management, 25(5), 436-456.

Verganti, R. (2009). Design driven innovation: changing the rules of competition by radically innovating what things mean. Harvard Business Press.

Vindrola-Padros, C., Pape, T., Utley, M., & Fulop, N. J. (2017). The role of embedded research in quality improvement: a narrative review. *BMJ quality & safety*, *26*(1), 70-80.

von Hippel, E. (1988) The Sources of Innovation, Oxford University Press, London and New York.

Wu, C., de Jong, J. P. J., Raasch, C., & Poldervaart, S. (2020). Work process-related lead userness as an antecedent of innovative behavior and user innovation in organizations *Research Policy*, *49*(6), N.PAG. https://doiorg.proxy.hil. unb.ca/10.1016/j.respol.2020. 103986

Zhu, K., Kraemer, K. L., Xu, S., & Dedrick, J. (2004). Information technology payoff in e-business environments: an international perspective on value creation of e-business in the financial services industry. Journal of Management Information Systems, 21(1), 17– 54.

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