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Understanding The Influence Of Complementary Innovations On Niche Formation In Large Energy Technology Systems The Case Of Distributed Electricity Storage In Ontario's Electricity System

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UNDERSTANDING THE INFLUENCE OF COMPLEMENTARY INNOVATIONS ON NICHE FORMATION IN LARGE ENERGY TECHNOLOGY SYSTEMS

THE CASE OF DISTRIBUTED ELECTRICITY STORAGE IN ONTARIO'S ELECTRICITY SYSTEM

by

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AUTHOR'S DECLARATION FOR ELECTRONIC SUBMISSION OF A THESIS

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Abstract

This exploratory case study finds evidence that the development of a storage technology niche in Ontario is being strategically managed through different stages by stakeholders within the system. It suggests that the complementary relationship between storage innovations and smart grid transitions supports the strategic management of a storage niche. It also suggests that the development of this niche supports the electricity system transition to smart grid. The study employs the Technology Innovation System (TIS) and Strategic Niche Management (SNM) analysis frameworks predominantly used by authors to study systems in Europe. By presenting empirical data from a jurisdiction outside of Europe, this research contributes to the growing theory on the formation of niches and the influence of complementarity on innovations in large technical systems. It also offers insights to practitioners within this sector, including the new entrants, incumbents and policy makers. Further research is recommended to determine the generalizability of these findings.

Acknowledgements

I'd like to formally acknowledge the help and support of all of the participants who agreed to be part of this study: Ravi Seethapathy, Hydro One, eCAMION, Opus Solutions, and all of the other participants who took part in this study. You took time from your demanding schedules and opened your door to a student to help her understand your reality. Above and beyond your commitment to your profession, I believe I witnessed a commitment to improving the lives of everyone in this global village through more sustainable management of our precious and shared resources and future. Please accept this thesis as an initial contribution to supporting this ambition, and the beginning of a career spent repaying that service.

The process of developing this thesis represents countless hours of contemplation, reflection and intellectual and personal discovery – the latter of which I'm sure gave my supervisors no end of headache and frustration as I tried to determine what I wanted and could do with this opportunity. I'd like to acknowledge and appreciate the constant kindness, patience and support from my supervisors throughout this journey. Dr. Philip Walsh and Dr. Charles Davis, you've inspired me, challenged me, and helped me find my way. Thank you.

Dedication

I'd like to dedicate this thesis to my father, Mel Hiscock. Growing up as witness to your excitement for technology, your personal dedication to understanding and improving the lives of others laid a foundation that I draw on every day. Daring me to dream of a future yet unknown and to stand for what I believe in lit a fire in my belly that won't go out.

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Introduction

Problem Statement

Ontario's Smart Grid Forum Report (2011) outlines the environment that it is working within given the challenges of aging infrastructure and the costs associated with maintaining and increasing the capacity of reliable and efficient electricity services to ratepayers. Added to the technical challenges of redesigning old and inefficient distribution systems, Ontario's electricity sector is undergoing an accelerated pace of change under the *Green Energy and Green Economy Act* of 2009 (Province of Ontario, 2009). Under the feed-in tariff *(FIT* and *micro-FIT)* programs managed by the Ontario Power Authority (OPA, 2010) to incentivise distributed renewable energy generation throughout Ontario, the Independent Electricity System Operator (IESO) now has to manage intermittent generation from the most installed wind capacity in the country and the largest photovoltaic facility in the world (Ontario Smart Grid Forum, 2011). Beyond environmental legislation and government incentives, increasing fossil fuel prices and other resource pressures compel the companies involved in generating, transmitting and distributing electricity to identify means of making the whole system more efficient and sustainable. Coupled with the technical challenges, Ontario's electricity system is also going through significant institutional change. As the grid moves toward a more decentralized model, the traditional roles of generators, distributers and consumers are shifting to support a more intelligent system that can accommodate an actor in parallel roles of consumer *and* generator *and* distributor. This would be made possible through advanced communication and controls technology, and through more complicated relationships between the organizations and networks that have traditionally held the roles of consumers, distributers, generators and other market participants.

Unsurprisingly this has spawned a level of ambiguity, experimentation and fierce negotiation amongst the various stakeholders as they endeavour to retain or increase the value of their shareholder value (Ontario Smart Grid Forum, 2011). Government policy makers, local distribution companies, power generators, regulators and operators alike are struggling to determine a strategic path forward. The FIT and micro-FIT incentive programs have been accused of being too expensive and unsustainable (Canadian Press, 2011). Legislated change can be accused of being bad for business and the economy as consumer electricity bills rise. The previously indirect participation of the consumer (outside of large industry) now faces the challenge of becoming a more direct participant in the creation of markets, encumbered by technical and institutional knowledge gaps and lack of bargaining power (California ISO, 2008). Each of these stakeholders stands to benefit from increased insight into the patterns of change within the electricity system. Leveraging the current dynamics that support innovation in this environment could produce a more sustainable momentum than would compliance with legislated minimum requirements, and use of expensive incentive programs.

Among the solutions being considered to accommodate the integration of intermittent generation (from renewable) and load patterns both now and in the future (such as electric vehicle charging), are storage technologies. Hailed as the "holy grail" within the industry (Ontario Smart Grid Forum, 2011), storage technologies are recognized as a key component of a system that would make better use of the current distribution grid infrastructure, defer expensive upgrades, prevent market losses from surplus generation during low demand periods, and facilitate increased flexibility, power quality, predictability and reliability to stakeholders (Brandon, 2008; J. Eyer, 2009). All of these benefits, unfortunately, at high capital costs ($500,000/MWh - $10,000,000/MWh depending on the technology) (ESA, 2010). Research and development continues with planned demonstrations and pilots in the coming years, all with the hope to bring the costs down, increase technology performance and create competitive business models (Ontario Smart Grid Forum, 2011).

The development of storage technologies is conducted in large part by researchers and entrepreneurs in small and medium sized enterprises (SMEs) who see opportunities for innovation and business growth. These SMEs find themselves in an under-supported space in Canada according to the Expert Panel on Business Innovation in Canada (Nicholson, 2009) and the more recent review of the Federal Support to Research and Development (2011). Aside from the complicated experience of navigating through the various government programs and other gaps in the system, these reports find that SMEs and their support networks within Canada lack commercialization capacity. They draw the connection between this capacity gap and contributions to limited growth of local economies and a persistent lag in the adoption of new technologies and systems.

For a business student then, the initial question of how to commercialize storage technologies in Ontario's distribution systems requires bigger picture frameworks than traditional business strategy models focusing on competitive forces and market dynamics offer.

Research Objective

Regarded in the early phases of development, electricity storage technologies for distribution systems and the niche environment they are developing within is a subject commonly explored by engineering and economics disciplines, feeding into policy and business finance disciplines. My underlying research objective is to understand the industry dynamics around the development of electricity storage in Ontario's distribution systems. In light of the challenges outlined in the problem statement, I look to frameworks developed from a cross-disciplinary understanding of technology systems change. Researchers studying change in electricity and other large infrastructure technology systems have called this evolutionary process *innovation journeys* (Schot & Geels, 2008; Van de Ven, 1999), *transitions* and *transition pathways* (Elzen, Geels, & Hofman, 2002; F. W. Geels, 2005; Kemp, 1994; Rotmans, Kemp, & van Asselt, 2001; Utterback, 1996; G. Verbong & Geels, 2007) and *innovation systems* (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008; Edquist, 2005; Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007; Lundvall, 2010; Malerba, 2004; Malerba, 2005; Markard & Truffer, 2008a). Recognizing the effectiveness of a cross-disciplinary approach to understanding systems, they draw from the disciplines of economics and management studies, sociology (especially of science and technology studies), political science and cultural studies (F. W. Geels, Hekkert, & Jacobsson, 2008).

Much of the empirical research conducted in these fields is conducted ex post. My research is looking at an on-going change that is still in the early stages. Thus the frameworks that I use are appropriate for understanding the formative phases of a system change with enough detail to find patterns or themes. This level of system change is referred to as the development of niches and the formative phases of innovation system development (F. W. Geels et al., 2008). Speaking to this field of study, Geels et al. (2008, p. 531) remarked:

> *"In the context of climate change policy, there is a particular need to understand better how the process from the initial 'niche' to a large scale transformation can be accelerated. To understand this take-off dynamic, we need to learn more about positive feed-backs between endogenous processes and the influences of external contexts. This is not just a theoretical endeavour, but also a challenge for empirical work and case studies, particularly when regularities, patterns or robust findings can be derived."*

The frameworks they discuss for analyzing these processes are called Strategic Niche Management (SNM) (Schot & Geels, 2008) and Technology Innovation Systems (TIS) (Bergek, Jacobsson, & Sandén, 2008) respectively. These authors lead me to the following exploratory research question:

How is the electricity storage niche developing for distribution systems in Ontario?

The frameworks of analysis I use were derived using case studies of existing technology systems, therefore my research will use a case study methodology (Bergek & Jacobsson, 2003; F. W. Geels, 2002; Hekkert et al., 2007; Hekkert & Negro, 2009; Jacobsson & Bergek, 2004; Kemp, 1994; Markard & Truffer, 2008a; Negro, Suurs, & Hekkert, 2008; Suurs, Hekkert, Kieboom, & Smits, 2010; G. Verbong & Geels, 2007). Key concepts from the literature on SNM are found in the multi-level perspective of transitions which identify: niche-innovations where new and radical innovations are developed by actors and networks; existing regimes that include incumbent infrastructure, technologies, actors and networks, as well as institutional structures such as regulation; and landscape factors that cannot be controlled by any regime player including the price of inputs, policy from other jurisdictions, public interest and so on (F. W. Geels, 2002; Rip & Kemp, 1998). Figure 2 illustrates these relationships visually. My research qualitatively explores the understanding of electricity storage niche development by niche and regime actors and networks.

Theoretically, the electricity storage niche is an interesting case to explore because, as I will argue in the literature review, unlike most other niches studied, storage technologies can be considered more complementary to the system than disruptive. As such, my research explores the influence of complementary technologies on systemic change by analyzing cases of actor, network and institutional treatment of electricity storage at the regime, niche and landscape level of distribution systems in the Ontario electricity sector. From there the following more theoretical research question arises:

> *How do complementary innovations influence the niche formation?*

which I answer only in part, with the empirical case of distributed storage in Ontario. Together these questions can be combined to:

> *What are the effects of complementarity on niche development and regime influence in the case of distributed storage technologies in Ontario?*

Literature on the diffusion of complementary technologies posits that they can be treated differently than disruptive technologies (Boyer, 2005; Carlaw & Lipsey, 2002; Delgado, Porter, & Stern, 2010; Gatignon, Tushman, Smith, & Anderson, 2002; Hall & Martin, 2005; Kemp & Volpi, 2008; P. R. Walsh, 2011). Collectively these authors suggest that complementary innovations can be more attractive and adopted or integrated more readily into existing systems (Gans & Stern, 2003; Teece, 1986; Veugelers & Cassiman, 1999). Considering the literature on industry and product lifecycles, complementary technologies have the potential to serve as bridging mechanisms from incremental to radical change in a regime (J. Eyer & Corey, 2010; Jacobsson & Bergek, 2004). However, as is stressed in the literature on sectoral transition and innovation systems, change or transition is a co-evolution of iterative dynamic events as opposed to a linear model (T. Foxon & Pearson, 2008; F. W. Geels, 2005; Jacobsson & Johnson, 2000). Therefore, certain innovations may not be recognized as complementary throughout the various stages of development. Thus whether niche and regime actors treat electricity storage technologies as complementary at all will be investigated in the case research as a means of exploring complementarity and checking research bias.

Within the proposed framework, complementary innovations are expected to contribute to the mobilization of resources, and the formation of positive externalities (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2005). Foxon and Pearson (2008) treat positive externalities as virtuous cycles that support the transition of niche-innovations from a formative phase to a growth phase. Accordingly, I use indicators and diagnostic questions regarding the mobilization of resources and the development of positive externalities or virtuous cycles (Bergek et al., 2005). These questions and indicators are captured in Appendix 1 – Case Study Protocol.

Knowledge Gap

There is abundant literature describing the characteristics and dynamics of developing technologies that is relevant to the development of the distributed storage technology industry. The literature speaks to the fields of policy, innovation and business management. My literature review has identified gaps in the frameworks and studies for each of these fields and they are summarized here. For much of the business and innovation research their application to my research question is limited because of one or more of the following knowledge gaps:

- the frameworks or studies rely on the dynamics of free markets
- the frameworks or studies assume the perspective of established firms with the associated vision, mission and strategic elements
- the frameworks or studies are for radical innovations which have a value-destroying effect (Schumpeter, 2006) on the existing system
- the frameworks or studies assume the presence of a technology push from incumbents
- the frameworks or studies assume some sort of existing customer demand (as a niche) within the targeted market
- the frameworks or studies don't consider institutional barriers to technology deployment beyond a customer's absorptive capacity and those institutional structures within the firm
- the frameworks or studies simplify the dynamics of change creating expectations of a somewhat linear pathway

For the new entrants and small firms developing distributed storage technologies within Ontario's regulated electricity sector, each of these gaps has the ability to render the insight and recommendations that are produced from them inappropriate, if they are taken in isolation. These gaps, found primarily when drawing from the fields of business management and marketing literature and technology innovation management literature are described below.

Part of the difficulty with understanding the dynamics surrounding the development of innovations like storage technologies for distribution systems is that there are several levels or perspectives to approach it from. The disciplines of economics, policy making, marketing, engineering and design, and management, for example, all have approaches to understanding and working within this field.

Looking first to the management literature, the evolution of new products or services and the dynamics that influence that process is studied under the headings of *new product development*, and the *fuzzy front end (Alam, 2006; Backman, Börjesson, & Setterberg, 2007; Kim & Wilemon, 2002; Reid & De Brentani, 2004; P. G. Smith & Reinertsen, 1991)*. Authors who primarily represent the marketing and management disciplines recognize that the period between the initial idea and the concept development is a messy stage called the 'fuzzy front end' and that if managed well can propel firms to the front of the innovation race (Kim & Wilemon, 2002). Experimentation and consultations with stakeholders is considered, but primarily this evolutionary phase focuses on changes to a specific product within an established firm that already has a clear vision and identified core competencies, operating in a free market environment. Cohen and Levinthal (1991) were among the first to connect these internal processes to a larger systems change concept, which was further explored by Reid & Brentani (2004). Looking at discontinuous innovations they attempted to bridge the fields of *new product development* and *technology and innovation management*. Theoretically these authors explored the interplay between organizational dynamics and the influences of the immediate external environment. This is what I attempt to do empirically. In other words, I attempt to produce information from my research that will help individuals in firms through the fuzzy front end, by giving them relevant information within the context of an environment which does not enjoy the free market dynamics that are often assumed in the literature. This theoretical link between Reid & Brentani's work and my own is outlined more fully in the Methodology section in a discussion of relating the findings.

Shifting to a systems level perspective, the challenge is to determine how to stimulate or facilitate niche development and systems change. This challenge exposes a gap within the policy and management literature:

> *"In the context of climate change policy, there is a particular need to understand better how the process from the initial 'niche' to a large scale transformation can be accelerated. To understand this take-off dynamic, we need to learn more about positive feed-backs between endogenous*

processes and the influences of external contexts. This is not just a theoretical endeavour, but also a challenge for empirical work and case studies, particularly when regularities, patterns or robust findings can be derived." (Geels, Hekkert & Jacobbson, 2008 p. 531)

Underlying this gap in empirical studies, another gap exposed is that of the idea of niches. Raven, van den Bosch & Weterings (2010, p. 61) illustrated this variance with a collection of definitions or uses:

1. "a 'space' or 'location' that is protected from the dominant regime, which enables actors to develop and apply an innovation without immediate or direct pressure from existing regimes
2. the micro-level of technological and social change
3. a new and relatively instable set of rules and institutions for innovative practices
4. (a series of) experimental projects such as demonstration projects and pilot plants
5. a constellation of structures, culture and practices that deviates in the way social needs are fulfilled
6. the variation environment for radical innovations."

These definitions or uses are still within the language of transition management. To compare it to the organizational management or marketing literature, they identify a key difference between what they describe as "sustainable innovations" (socio-technical innovations) and product innovations, is that niches must be created for sustainable innovations. They aren't pre-existing demand environments waiting to be satisfied. To borrow from management literature, Walsh's framework (2011) finds these sustainable innovations in a market situation that can be described as "Innovation Wasteland" where firms find themselves in an extremely vulnerable situation. For systems change in a regulated environment such as an electricity sector, niches are selection environments which involve more than the presence of an emerging customer market and they can be created (Bergek, Jacobsson, & Sandén, 2008; F. W. Geels et al., 2008). In the process of answering my research question, I will try to identify and describe these niches for distributed storage technologies in Ontario.

Commercialization strategies for technology developers in the business management literature has limitations when dealing with new technologies in regulated industries dominated by a few large incumbents. For free market systems there is abundant information, popularly from the likes of Schumpeter (2008), Porter (1985) and Christensen (2003) who study the tipping points or sequence of events that either incrementally or disruptively lead a new product or firm to market dominance. For the case of distributed storage technologies, their application is designed to be value enhancing to the existing infrastructure (the distribution systems) and value enhancing to innovations that are destroying the value of the existing system infrastructure (variable generation such as wind and solar and variable loads such as electric vehicles).

Complementary innovations differ from complementary assets which are regarded as core competencies or resources of a firm that increase the value of goods and services (Gans & Stern, 2003; Teece, 1986). In the context of innovation systems, complementary innovations are supportive to existing regimes either through network effects or other mechanisms that increase the existing value of products and services (Boyer, 2005; Carlaw & Lipsey, 2002; Kemp & Volpi, 2008). Much of the innovation systems research considers disruptive or radical niche-innovations leading to transitions with little attention to complementary innovations (Kemp & Volpi, 2008; G. P. J. Verbong & Geels, 2010). In more recent literature on the formation of phase of technology innovation systems, Bergek et al. (2008b) highlight the development of positive externalities as complementary innovations. My research acts upon the call in the literature for more empirical research on the influence of complementary innovations on existing regimes and niches. In doing so, it also addresses the call for more empirical research with respect to change in technological innovation systems from a multi-level perspective.

Looking to specific technology research, such as that of batteries in electricity systems, does not seem to fully address this gap empirically with a study of actor and network behaviour. In a representative study analyzing battery storage technologies, Divya and Ostergaard (2008) investigated the status of battery technology and methods of assessing theoretically their economic viability and impact on power systems operation. They recognize a gap in the research concerning how to choose the optimal size and capacity of battery storage and how to quantify benefits in power system planning. The empirical investigation of battery technologies as a complementary innovation within the system is left to observations of penetration rates within the Danish electricity system and projected technical demand from other systems around the world. In addition to their work, much of the research focus regarding batteries in electricity systems is on a cost-benefit analysis given the state of the technology and the price of inputs and electricity, despite there being other recognized benefits (J. Eyer & Corey, 2010; J. Eyer, 2009; Schoenung & Eyer, 2008).

Scope

The Ontario electricity sector provides an appropriate context within which to conduct case studies exploring the endogenous elements of change in a sector, and the influence of complementary innovations. This is because the sector is: (1) in a process of transition in response to government pressure most notably through the Green Energy and Green Economy Act and FIT program (Province of Ontario, 2009; OPA, 2010); and (2) it has active actors, networks and institutions in the niche and complementary innovation fields. More specifically relevant, the Energy Storage Working Group was formed in the fall of 2010, and is made up of participants from Ontario, largely in the eastern Ontario and Toronto region. This working group has the goal of "enabling the rapid deployment of distributed sustainable generation in Toronto and throughout the rest of the province of Ontario" (O'Malley, 2010, p.5). Thus, this study will take advantage of more concentrated information sources, in the Toronto region of Ontario.

Other technologies for electricity storage exist or are in development such as pumped hydro, compressed air and fuel cells (Chen et al., 2009; Divya & Østergaard, 2009; J. Eyer & Corey, 2010; Peterson, Whitacre, & Apt, 2010). Following the recommendations of Bergek et al. (2008) this research will focus on a single technology application as a means of defining the innovation system, and due to the recommended scope of a master's thesis. Distributed storage technologies have been chosen because of access to companies developing and marketing these in Ontario. For example, Ryerson University (2010) and the University of Toronto (2011) are conducting research on the implementation of modular Li-ion storage units of 340kWh capacity and 250kWh capacity respectively to be scaled to MWh capacity in partnership with companies in Ontario. Each of those projects are funded by various government and regime actors making the actors and networks easier to identify and more accessible to me as a student and as an employee of a federal funder for these projects.

The theoretical contribution may only be geographically relevant, at this point, for example, battery technologies for urban energy storage are emerging as an integrated part of electricity system evolution for those such as Japan and Denmark (Divya & Østergaard, 2009; ESA, n.d.; Ribeiro, Johnson, Crow, Arsoy, & Liu, 2001), but are used much less in North American systems such as Ontario's (Moore & Douglas, 2006).

This research is intended to be a contribution to the Centre for Urban Energy research program at Ryerson University and has received some initial funding for a study of the market formation. Additional funding was provided by the Ted Rogers School of Management Masters of Management Science program. This research was conducted over the period of August 2011 to August 2012.

Theoretical Contribution

The main contribution of my research is increased understanding of the formative phases of niche development and systems change, and further development of the SNM and TIS approaches through empirical research. The authors and proponents of these frameworks as single and combined approaches (e.g. (Bergek et al., 2005; F. W. Geels, 2005; Kemp & Volpi, 2008) acknowledge that the development of these frameworks (individually and integrated into a single approach) is thus far based on incomplete knowledge. More generally, the empirical findings contribute to the growing theory on innovation in technical systems the formation and influence of complementary innovations on niche development and innovation pathways. This study is conducted during the early stages of demonstration deployment for distributed storage technologies, as such is it conducted concurrently with the development of the system, as opposed to ex-post. This study could be compared to future studies conducted during later stages of the sector evolution as part of a longitudinal study of the development of distributed storage technologies and the influence of complementary on innovation pathways.

From my literature review the SNM and TIS, frameworks have not been used to analyze the electricity system in Ontario. Therefore, this research contributes to the literature by offering insight into the application of the SNM and TIS frameworks to jurisdictions outside of the European electricity context.

Practical Contribution

The practical applications of this research are in providing insight into the endogenous dynamics of change within Ontario's electricity sector for the actors throughout the value chain for storage technologies. A series of policy areas to explore are suggested, requiring further research to formulate specific recommendations. Still, policy makers struggling to determine the best form of government intervention can benefit from understanding current dynamics that could be leveraged in future policy. Start-ups and other stakeholders engaged in developing niche innovations for smart grid, as well as stakeholders managing the assets of the current electricity system can also find insight into the dynamics of innovating within smart grid in Ontario. Developers and supporters of complementary innovations such as urban electricity storage in particular can benefit from the added insight into the endogenous dynamics explored in this case study.

Thesis Outline

The Literature Review explores the relevant fields of literature to studying change within a technical sector at a systems level. It identifies two frameworks, the Technology Innovation Systems (TIS) and the Strategic Niche Management (SNM) analysis frameworks, that are being employed in current literature to understand these dynamics of change. It also reviews proposed ways of employing those frameworks in the study of change within a system, and proposes a methodology for using both in the study of a change that is currently underway.

The Methodology section identifies an appropriate method for employing these analysis frameworks to study the development of a storage technology niche in Ontario. It discusses the approach along with the underlying ontological and epistemological assumptions of the researcher that are appropriate for employing these frameworks. In particular it highlights how these TIS and SNM frameworks are not predictive models of behaviour. Rather they permit a researcher to develop a theory regarding the endogenous dynamics of change within a particular system. The case study methodology is explained and sources are identified within the Ontario electricity system and electricity storage field in Ontario.

The Data Analysis section presents the evidence used to answer the two research questions regarding the nature of the development of a storage niche in Ontario, and the effects of complementarity on that development.

The Discussion and Conclusions section proposes a model for the current storage niche development in Ontario, and the effects of complementarity on that development. This model is compared to a business innovation model currently in the innovation policy environment for Canada as a means of highlighting how these dynamics are proposed to differ from business innovation dynamics in other sectors. Reflections on the methodology and the use of the TIS and SNM frameworks offer a basis for future research to test this approach to employing these analysis frameworks in an integrated way. The implications on the policy related to developing this storage niche in Ontario suggest areas for future policy development. The limitations of this research are outlined, and the next steps for future research are proposed to further test the validity of this model for the storage niche in Ontario, and to test generalizability of the findings to other innovations and other jurisdictions.

Literature Review

The process of change in a sector such as electricity has been differentiated from the study of change in other technology sectors by recognizing the implications of: the large physical infrastructure and sunk costs in technology; the competitive nature of the market given significant government policy intervention; the dynamics of active resistance to change by what are usually a few very large incumbents (F. W. Geels, 2004; Jacobsson & Bergek, 2004; Kemp & Volpi, 2008). To capture the dynamics of change in these large technical systems within societies, (F. W. Geels, 2004)authors have drawn from the fields of sociology (the sociology of technology in particular) and institutional theory and incorporated analytical tools from evolutionary economics, and the study of innovation diffusion (Carlsson & Stankiewicz, 1991; Elzen, Geels et al., 2002; F. W. Geels, 2002; Kemp & Rotmans, 2005; Malerba, 2005; Markard & Truffer, 2008b; Rip & Kemp, 1998; P. R. Walsh, 2011). To specify a unit of analysis they have adopted actor-network theory, with the general consensus that these systems can be analyzed by their actor, network and institutional behaviours and perspectives at various system levels (F. W. Geels, 2002; Jacobsson & Bergek, 2004; Malerba, 2004). This makes for a very complex model, in order for this to be accessible to researchers and practitioners of change in these systems various analytical approaches have been devised, and are explored in this section.

The literature dedicated to understanding and working with systemic change in large technical systems can itself be divided into two focuses. The first could be classified as understanding the overall process of change from the beginning to the end. These studies are done ex post by highlighting the key events that stimulated other activities in virtuous cycles of change (Bergek, Jacobsson, Carlsson et al., 2008; Hekkert et al., 2007; Hekkert & Negro, 2009; G. Verbong & Geels, 2007; G. P. J. Verbong & Geels, 2010)}}. These studies yield high-level insight and recommendations for planning. The second could be classified as those studying the formative phases of current systemic changes underway. Geels, Hekkert and Jacobbson (2008) in a review of transition studies, or innovation journeys, applied to sectors currently undergoing change recognize that transitions guided by sustainability goals face challenges that other systems and markets don't. The trouble with changes in these systems is that entering these markets is hard and the benefits of sustainability innovations are diluted across the system (F. W. Geels et al., 2008). Thus niches don't emerge under existing market dynamics. They lack the technology push from incumbents who are deeply entrenched within the system, and lack a technology pull from a market that has been similarly institutionalized from forces including regulation and generations of reinforced thinking around energy consumption.

Two approaches have emerged for studying the formative phases of current transitions, these are referred to as the (technology) innovation systems (TIS) approach (Bergek, Jacobsson, Carlsson et al., 2008; Carlsson & Stankiewicz, 1991; Malerba, 2005), and the Strategic Niche Management (SNM) approach (Schot & Geels, 2008), which is contextualized within the multi-level perspective (MLP) transition approach (F. W. Geels, 2002; Kemp & Rotmans, 2005; Rip & Kemp, 1998; G. P. J. Verbong & Geels, 2010). These approaches all study change at a systems level with attention to the endogenous dynamics within them.

My methodology will be drawn from elements of both of the SNM and TIS approaches to provide a detailed and systematic analysis of the endogenous dynamics of the formation of change within the sector (Hekkert et al., 2007; Hekkert & Negro, 2009; Kemp & Volpi, 2008; Van der Laak, Raven, & Verbong, 2007).

To appropriately apply the framework and methodology for my research, a literature review has been conducted of:

- institutional theory when combined with economic, technical and innovation theories;
- frameworks for analyzing change in large technical systems;
- the concept of complementarity in innovation diffusion;
- case study methodology for exploring the functionality of an innovation system.
- the link between analyzing change in large technical systems and interpreting them to a practitioner's perspective;

The review begins by establishing a holistic base of understanding the structure and dynamics of change in technical sectors with heavy infrastructure such as an electricity sector. It then moves to review how the theoretical components of that base fit into a framework of analysis. Finally it focuses on the concept of complementarity within the dynamics of change during the formative phases, and positions that within the framework of analysis. The methodology section then follows, outlining the mechanics of data collection and analysis appropriate for the research question and data analysis, and discusses the challenge with relating the findings with practitioners within the system.

Institutional theory with economic, technical and innovation theories

Institutional theory describes the social structures formed and reinforced by rules, norms, beliefs and routines within a population (Scott, 2008; Zucker, 1987). The social behaviour of individual and organizational actors and networks within the institution are influenced by these structures in a way that tends to encourage conformity and promote homogeneity. Although institutions tend toward stability, institutional theory can also be used as a basis to explain endogenous and exogenous dynamics of change (F. W. Geels, 2002; Oliver, 1990; Oliver, 1997).

In order to facilitate a more applied analysis of the dynamics of actual institutions, researchers have combined other theories with institutional theory. Relevant concepts from these theories are summarized in Table 1. In their seminal work with institutional theory, Baum and Oliver found that integrating other fields of study (such as the resource-based view and population ecology) provided a more detailed explanation of the aggregate behaviour of organizations within an institution, and the behavioural dynamics of managers within the organizations (Baum & Oliver, 1992; Baum & Oliver, 1996; Oliver, 1997). TIS, SNM and MLP approaches have arrived at a theoretical approach in a similar fashion, wherein the factors influencing behaviour at various levels of the system, and the system as a whole, can be explained in a co-evolutionary process of institutional change with economic and social factors (Bergek, Jacobsson, Carlsson et al., 2008; Carlsson & Stankiewicz, 1991; F. W. Geels, 2002; Kemp, 1994; Kemp & Rotmans, 2005; Malerba, 2005; Rip & Kemp, 1998). Despite academic knowledge of change as an iterative co-evolution of factors, Foxon et al. (2010) note that the problem with current modelling approaches to policy making is that they assume a highly economically rational behaviour from the actors and networks. It is for this reason that researchers continue to focus on the endogenous dynamics of change in order to advance the theoretical understanding of these change processes, but also practically to better enable stakeholders within the system to make informed decisions (T. J. Foxon, Hammond, & Pearson, 2010; Suurs et al., 2010; G. P. J. Verbong & Geels, 2010).

The inclusion of economic theory employs the rational decision making elements such as those presented in the resource-based view (Barney, 2001; Oliver, 1997) as a sort of counterbalance to the social decision making elements recognized in institutional theory. Economic theory also allows for the issues of price and market risk to be included within the analysis, which are two prominent issues in the discussion of new technologies or technology systems (Delucchi & Jacobson, 2011; EPRI, 2010; J. Eyer & Corey, 2010; Peterson et al., 2010; Schoenung & Eyer, 2008). It also recognizes the influence of an organization's competencies (Henderson, 2006; Prahalad & Hamel, 1990) and complementary assets (Gans & Stern, 2003; Teece, 1986; P. Walsh & Walters, 2009) in deciding on alternatives. Concepts within network externalities (Katz & Shapiro, 1986) such as lock-in and path dependence, often used to describe demand patterns, have also been used to describe the patterns and behaviours of firms within an industry (Baum & Oliver, 1991; Baum & Oliver, 1996).These economic factors are often part of the literature on technology development and adoption as well.

Table 1: Relevant concepts to institutional change processes in large technical systems.

	Relevant Concepts	Authors
Institutional Theory	Rules, norms, routines, beliefs Regulative, normative, cognitive rules Emergence, conformity, conflict, change Legitimacy Organizational embeddedness	(Zucker, 1987) (Oliver, 1990) (Baum & Oliver, 1992) (Scott, 2008)
Economic Theory	Resource-based views Population ecology, population density (Core) Competence Complementary assets Price; cost/benefit Market risk Network externalities; lock-in, path dependence Clustering()	(Barney, 1991; Barney, 2001; Oliver, 1997) (Baum & Oliver, 1996) (Prahalad & Hamel, 1990) (Teece, 1986) (Schoenung & Eyer, 2008) (Katz & Shapiro, 1986) (Delgado et al., 2010)
Technology Theory and Innovation Theory	Technology cycles; design competition, incremental change Dominant design Technological discontinuity Absorptive capacity Commercialization strategy Diffusion; technology push / pull strategy Business & Process innovation / Technology & Product innovation Disruptive innovation	(Anderson & Tushman, 1991) (Abernathy & Utterback, 1978) (Utterback, 1996) (Cohen & Levinthal, 1990) (Teece, 1986) (Gans & Stern, 2003; Roberts & Liu, 2001) (P. R. Walsh, 2011) (Rogers, 1995) (Markides, 2006) (Christensen, 2003; Christensen, 2006) (Edquist, 2005)
Actor-network Theory and Evolutionary Theory	Actors, networks Social order Sociology of Technology Co-evolution of technology and society Techno-economic networks Non-linearity	(Latour, 2000) (Callon, 1991) (F. W. Geels, 2004; F. W. Geels, 2005)

The inclusion of technology theories, and often in close relation innovation theories, brings in cyclical processes of learning (Cohen & Levinthal, 1990) and innovation (Anderson & Tushman, 1991) to the processes of institutional change. This allows researchers to consider the life cycles that industries and products go through in their search for a dominant design (Abernathy & Utterback, 1978) and the efficient exploitation of it through various commercialization and process strategies (Abernathy & Utterback, 1978; Gans & Stern, 2003; Roberts & Liu, 2001; Siegel, Hansen, & Pellas, 1995; Teece, 1986; Utterback, 1996; P. R. Walsh, 2011; Zahra & Nielsen, 2002). Included as a "pull" force on the technology development and diffusion, are phases of technology adoption from market demand (Rogers, 1995; P. R. Walsh, 2011). "Push" forces on technology development and diffusion tend to come from policy or research and development (R&D) strategy (Brown, Berry Rajeev, & Linda, 1991; Carayannis, Alexander, & Ioannidis, 2000; Carley, Lawrence, Brown, Nourafshan, & Benami, 2010; Kemp & Volpi, 2008; Markides, 2006).

Innovation theory has become a richly explored field often associated with technology (Carlsson & Stankiewicz, 1991; Christensen, 1997; T. Foxon & Pearson, 2008; Jacobsson & Johnson, 2000; Kemp & Volpi, 2008; Lundvall, 2010).But Christensen—one of the principal authors on the subject—has also explored innovation within public services such as education and health care (Christensen & Raynor, 2003; Christensen, Aaron, & Clark, 2003). In looking at public services, Christensen recognizes the difference in the barriers and incentives to change that exist within a heavily regulated public institution as compared to the free, competitive market context which much of the innovation diffusion theory adopts (Assink, 2006; Dodgson, Gann, & Salter, 2006; Hall & Martin, 2005; Henard & Szymanski, 2001; Rogers, 1995; Utterback, 1996). These considerations are taken into account in both the SNM and TIS approaches. The concept of disruptive innovation is of particular interest to the innovation systems and transition approaches because it captures the general process of something new substituting something old through a means of better defining or reshaping demand (Bergek, Jacobsson, Carlsson et al., 2008; Bower & Christensen, 1995; Carlsson & Stankiewicz, 1991; Christensen, 2006; F. W. Geels, 2004; Malerba, 2004).

Underlying the study of technology cycles, industry cycles and institutional change, is the inclusion of actor-network theory which brings together the social and technical parts of a heterogeneous network where each part is equally important to the social order (Callon, 1991; Latour, 2000). In this way Geels (2004) has described the transition approach as a socio-technical approach which recognizes the co-evolution of both technology and society. While actor-network theory was originally to analyze the individual, these concepts are extended to organizations through the recent literature on technology adoption models (Bagozzi, 2007) and innovation systems where change is brought about through an individual and collective act (Carlsson & Stankiewicz, 1991; Jacobsson & Bergek, 2004).

A functional framework of analysis

The concepts summarized in Table 1 are brought together in both the technology innovation systems (TIS) approach, and strategic niche management (SNM) transition approach to analyzing sectoral change. The TIS and SNM approaches are described separately below, but as will become evident, many of the concepts are shared between them and are applied to their respective frameworks in a similar fashion. Thus it is possible to integrate the two, as has been reviewed in the integrated TIS and SNM approach sub-section.

The technology innovation systems (TIS) approach

Summarizing the work of Carlsson & Stenkiewicz (1991), Edquist (2005) and Malerba (2005), an innovation system is defined as "...composed of networks of actors and institutions that develop, diffuse and use innovations" (Markard & Truffer, 2008a, p.597). The innovation system approach recognizes change in a sector or system in its ability to function as an innovation system. Using a case study methodology the concepts in Table 1 are applied in a framework for structural and functional analysis. The structural components include actors, networks (formal and informal) and institutions as in Figure 1 (Bergek, Jacobsson, Carlsson et al., 2008). A system function captures the contribution toward a system's performance by a component or set of components (Bergek, Jacobsson, & Sandén, 2008; Bergek, Jacobsson, Carlsson et al., 2008; Hekkert & Negro, 2009). Performance is implicitly left to mean technology diffusion but as will be addressed in the section on integrating the TIS and SNM transition approaches this may not be a strict case of deployment.

The functional approach to studying innovation systems can be used to assess the innovation system and compare it to others (Bergek, Jacobsson, & Sandén, 2008; Bergek, Jacobsson, Carlsson et al., 2008; Markard & Truffer, 2008b). Recent literature focusing on the formative phases of innovation systems (Bergek, Jacobsson, & Sandén, 2008)(Bergek, Jacobsson, & Sandén, 2008; Bergek, Jacobsson, Carlsson et al., 2008; Hekkert et al., 2007; Hekkert & Negro, 2009) has synthesized the literature on innovation systems to produce eight functions for analysis. While the total number of functions is somewhat arbitrary, they found that these eight work well with the key processes in the dynamics of any TIS. These functions interact with each other resulting in what Hekkert and Negro (2009) describe as virtuous or vicious cycles that transform a system. The interactions of these functions are noted below where the stronger links have been suggested by Hekkert and Negro (2009), but are not considered prescriptive or exhaustive in their application to each function. In a case study analysis similar to the case studies that I will conduct, Hekkert and Negro (2009) described the TIS functions more fully, but they are described in Box 1 as I will use them in my data assessment.

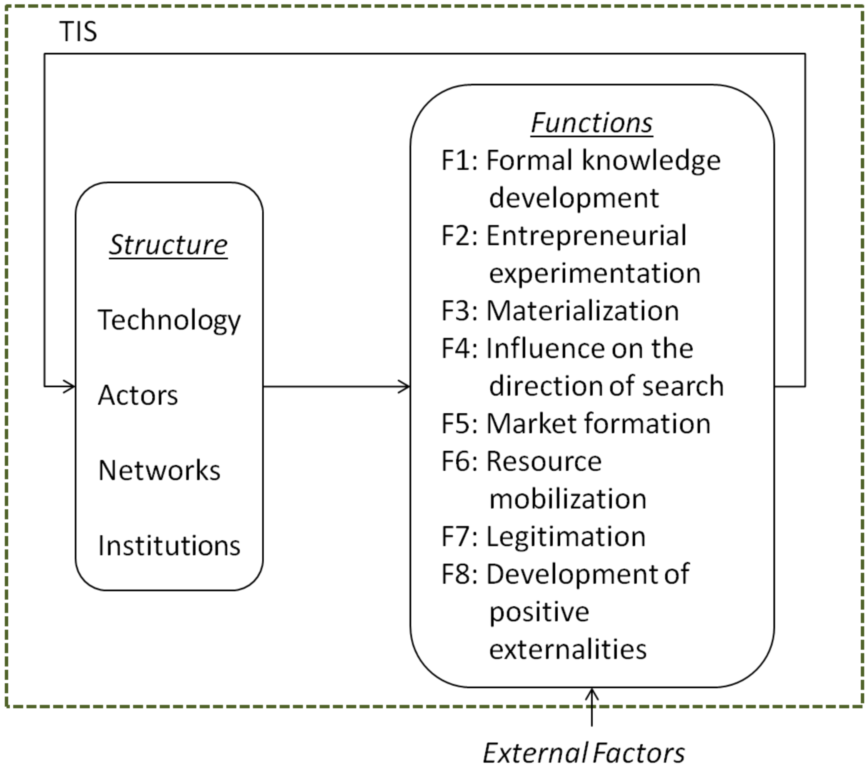

Figure 1: Relations between external influences, structural elements and functions in a Technology Innovation System (Bergek, Jacobsson & Sandén, 2008, p. 579)

These functions will assist in creating a detailed explanation of the endogenous dynamics of the system, but as acknowledged by Hekkert and Negro (2009) they will offer limited observations on the interaction between events internal to the system and external to the system. Consideration of relevant events external to the system within the analysis will help to present a fuller explanation of an innovation system. Thus, as proposed by Markard and Truffer (2008a) the transition approach adds value by delineating a multi-level perspective to frame the analysis.

Box 1: The 8 functional assessments of an innovation system as described in (Bergek, Jacobsson & Sandén, 2008, p. 578)

Function 1: Development of formal knowledge The breadth and depth of the formal, research-

Function 2: Entrepreneurial experimentation Knowledge development of a more tacit, explorative, applied and varied nature – conducting technical experiments, delving into uncertain applications and markets and discovering/creating opportunities, etc.

Function 3: Materialisation The development of (and investment in) artefacts such as products, production plants and physical infrastructure.

Function 4: Influence on the direction of search The extent to which supply-side actors are induced to enter the TIS, or put more subtly, direct their search and investments towards the TIS.

Function 5: Market formation Articulation of demand and more 'hard' market development in terms of demonstration projects, 'nursing markets' (or niche markets), bridging markets and, eventually, mass markets (large-scale diffusion).

Function 6: Resource mobilisation The extent to which the TIS is able to mobilize human capital, financial capital and complementary assets from other sources than suppliers and users and the character of this mobilisation.

Function 7: Legitimation The socio-political process of legitimacy formation through actions by various organisations and individuals. Central features are the formation of expectations and visions as well as regulative alignment, including issues such as market regulations, tax policies or the direction of science and technology policy.

Function 8: Development of positive externalities ('free utilities') It reflects the strength of the collective dimension of the innovation and diffusion process. It also indicates the dynamics of the system since externalities magnify the strength of the other functions.

These functions interact with each other in cyclical ways, where, in a virtuous cycle for example, knowledge can be developed and shared (Function 1) through entrepreneurial activities (Function 2) in addition to the more academic forms of R&D. Entrepreneurial experimentation can be supported by the combination of new knowledge (Function 1), efforts of networks or associations (Function 7) and new markets (Function 5). Entrepreneurial experimentation (Function 2) can lead to the materialisation of new products, services or processes (Function 3) which leads to increased legitimacy (Function 7) for the emerging new technologies and the associated system changes. The influence on the direction of the search (Function 4) can itself indicate a degree of legitimacy (Function 7) and stimulate the mobilisation of resources (Function 6). Increased functionality of market formation (Function 5) can encourage entrepreneurial experimentation (Function 2) and in establishing the legitimacy of an alternative technology for the existing system (Function 7). The presence of resources (Function 6) can support knowledge development (Function 1) and entrepreneurial activity (Function 2). The legitimacy (Function 7) afforded by stakeholders can have an influence on the resource availability (Function 6), market formation (Function 5) and the development of policies and programs to support the development and diffusion of a technology (Function 4). Finally, positive externalities (Function 8) such as the emergence of other innovation systems and related markets can afford further resources (Function 6), legitimacy (Function 7) and influence on the direction of the search (Function 4).

The eighth function is of particular interest because it studies the effects of complementarity between niches as will be discussed further when integrating the approaches of TIS and SNM.

The transition approach

The transition approach uses 3 general levels or perspectives (the multi-level perspective, or MLP) within a system or sector to explain the endogenous and exogenous dynamics of transition: landscape, regime and niche (F. W. Geels, 2002). What is in each level depends on the unit of analysis, which for this approach is what I choose as the regime. The regime level is the most tangible and identifiable level of the system, which includes the incumbent actors and networks, physical and institutional infrastructure, including regulation, and technology. The niche level includes radical or disruptive innovations to the regime, pioneered by actors and networks often characterized as entrepreneurs and small business acting within protected spaces. The landscape level describes pressures on both the regime and niche levels of a sector and is outside of their direct control or influence, such as international legislation, public opinion, the price of inputs and so on. The mechanics of change on the regime are brought about by the combination of actions and pressures from the niche and landscape levels. These levels are described graphically in Figure 2.

While it is possible to map these 3 levels onto actual system components, authors working with this framework stress that it is important to remember that this is an analysis framework only, and thus the 3 levels are only analytical, not ontological (F. W. Geels, 2005; F. W. Geels et al., 2008; Raven, Van den Bosch, & Weterings, 2010; G. Verbong & Geels, 2007). As Raven et al. (2010) put it, the categorization of elements observed into these levels is useful for better understanding socio-technical change, as opposed to discovering real entities in the system.

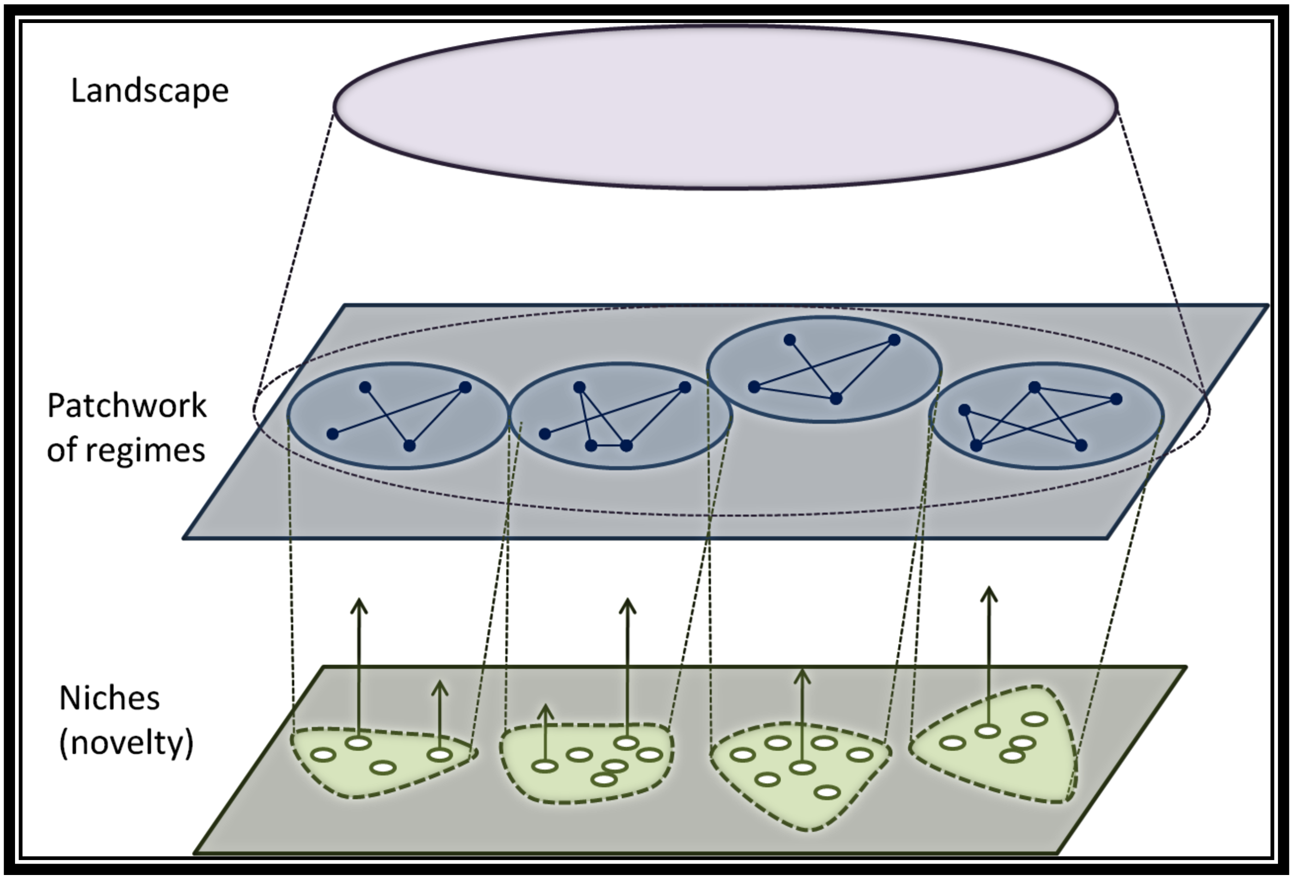

Figure 2: Multiple levels as a nested hierarchy from the multi-level perspective of sectoral transition (Geels, 2002; 2010)

It's important to recognize that despite the graphical illustration in Figure 2, the transition pathway that is a product of the socio-technical evolution that is being observed is quite dynamic and iterative. Raven et al. (2010) describe this process with 4 activity clusters (p.59):

1. structuring the problem in question and establishing and organising a multi-actor network
2. developing a sustainability vision, transition agenda and deriving the necessary transition paths
3. mobilising actors and establishing and executing transition experiments
4. monitoring, evaluating and learning

What is particularly relevant to my research question is the development of the distributed storage niche and the innovation pathway that emerges for it and related niches to influence the regime. For understanding this process, Geels and his colleagues have developed the strategic niche management (SNM) analysis approach (F. Geels & Raven, 2006; F. W. Geels et al., 2008; Schot & Geels, 2008), contextualized within the multi-level perspective. Under the SNM approach Schot and Geels (2008) present a more dynamic illustration of the influence that niches have and the path that they follow to influence regimes, shown in Figure 3.

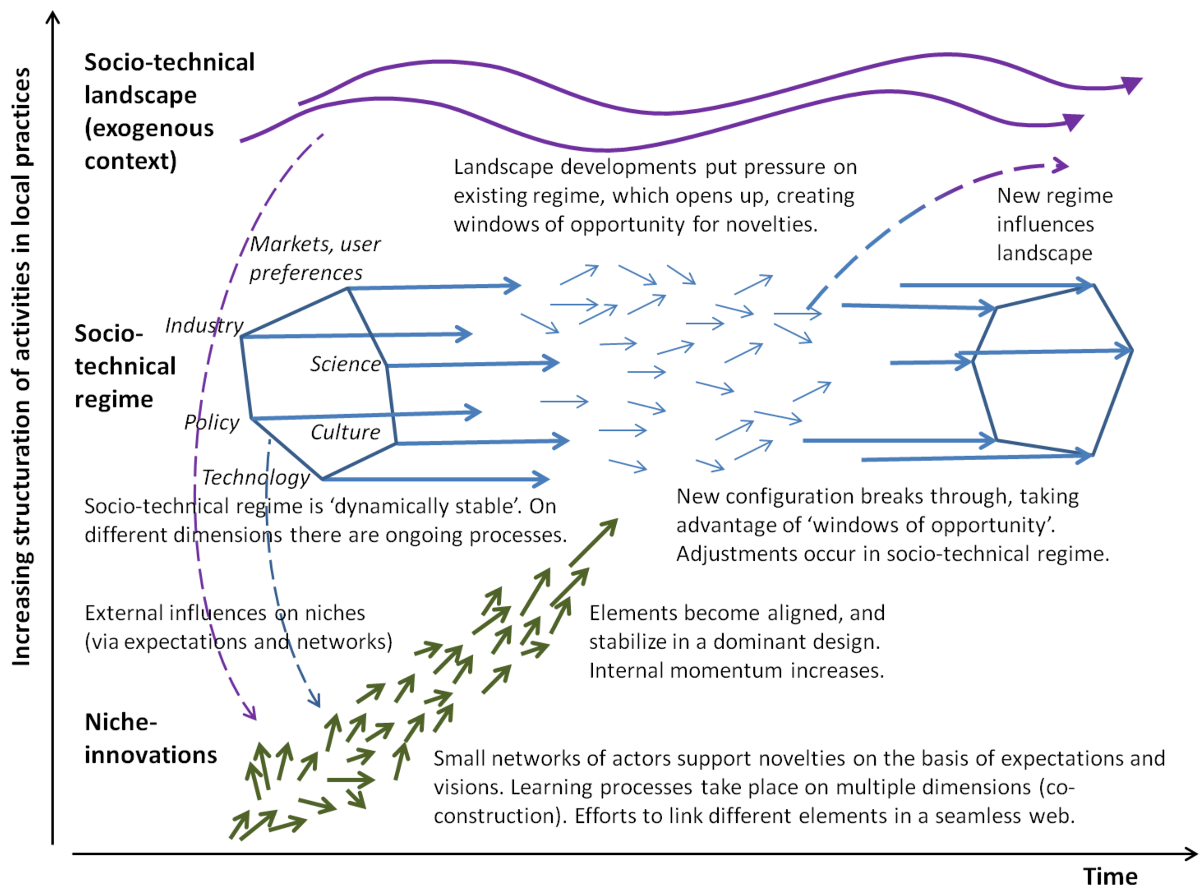

Figure 3: Multi-level perspective on transitions (adapted from Geels 2002, p. 1263)

A key feature that sets apart sustainable innovations, that is those that aim to solve some fundamental societal need by influencing change within the whole system, is that these niches must be created; they are not pre-existing pockets of demand waiting to be satisfied (Raven et al., 2010). As can be seen from the illustration in Figure 3, this pathway is also a product of the influences of the regime and niche. The development process that these niche innovations follow in their *efforts to link different elements in a seamless web* leading to their eventual alignment resulting in a dominant design, while difficult to predict, is quite methodical. As identified in the 4 activity clusters listed above, the process of experimentation within activity cluster 3 has a defining effect on the overall technological trajectory.

In exploring this phase, the 3 key internal processes of SNM were found (Schot & Geels, 2008):

1. The **articulation of expectations** and visions. Expectations are considered crucial for niche development because they provide direction to learning processes, attract attention, and legitimate (continuing) protection and nurturing.

2. The **building of social networks**. This process is important to create a constituency behind the new technology, facilitate interactions between relevant stakeholders, and provide the necessary resources (money, people, expertise).

3. **Learning processes** at multiple dimensions:
    a. technical aspects and design specifications
    b. market and user preferences
    c. cultural and symbolic meaning
    d. infrastructure and maintenance networks
    e. industry and production networks
    f. regulations and government policy
    g. societal and environmental effects

Graphically this process has been depicted as in Figure 4.

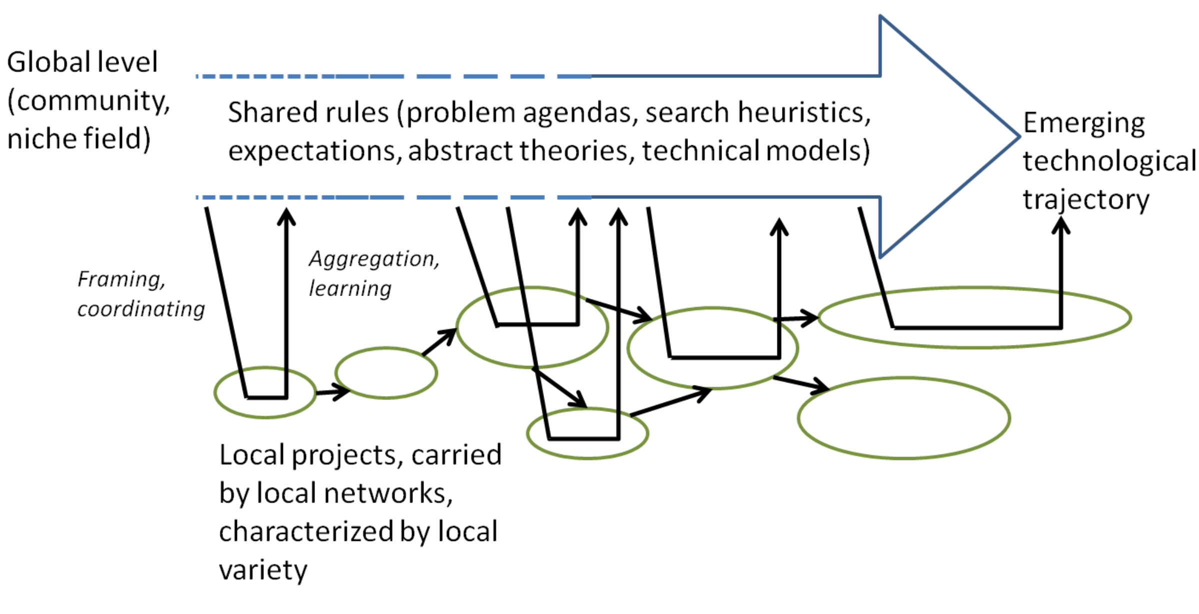

Figure 4: Emerging technical trajectory carried by local projects (Geels & Raven, 2006, p. 379)

Through this progression SNM looks at the phase between R&D and market introduction, commonly referred to as the "valley of death" where technologies often fail to become commercialized. This process is what I intend to explore for distributed storage technologies in Ontario's electricity sector by looking for the 3 internal niche processes listed above. My research questions could then be mapped onto this process along the niche development path as in Figure 5.

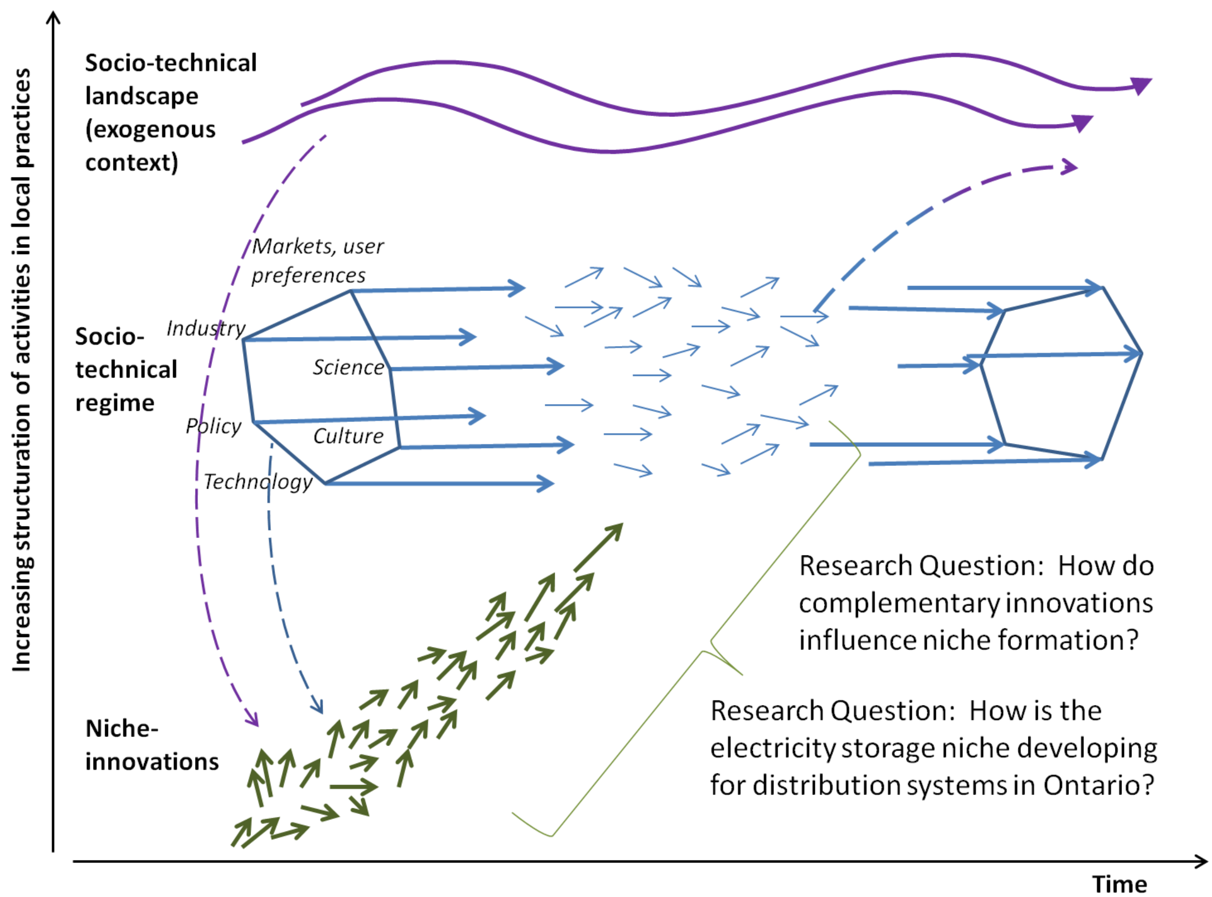

Figure 5: My research questions mapped onto the niche development process (illustration adapted from Geels 2002, p. 1263).

Using the SNM approach frames my research question in a way that will yield insight into the interactions between regime and niche, between niche innovations, or experiments, and into the influence of the landscape on this process. But to explore this and share the findings in a way that can thoroughly explore the nature of the interactions, requires the use of the TIS framework to link the systems perspective with an entrepreneurial perspective.

The integrated TIS and SNM approach

Writing on the relationship between the TIS and SNM, Geels, Hekkert and Jacobsson (2008) note the different disciplinary backgrounds of the two approaches that have lent the TIS approach a more economics and entrepreneurial flavour, while the SNM approach has more of a socio-cognitive one.

Despite this, they can work in concert and a number of authors have in fact done this (T. Foxon & Pearson, 2008; T. J. Foxon et al., 2010; F. W. Geels et al., 2008; Markard & Truffer, 2008b). Most opinions settle around TIS spanning the niche development to regime influence.

Graphically then the integrated use of the two approaches could appear as in Figure 6.

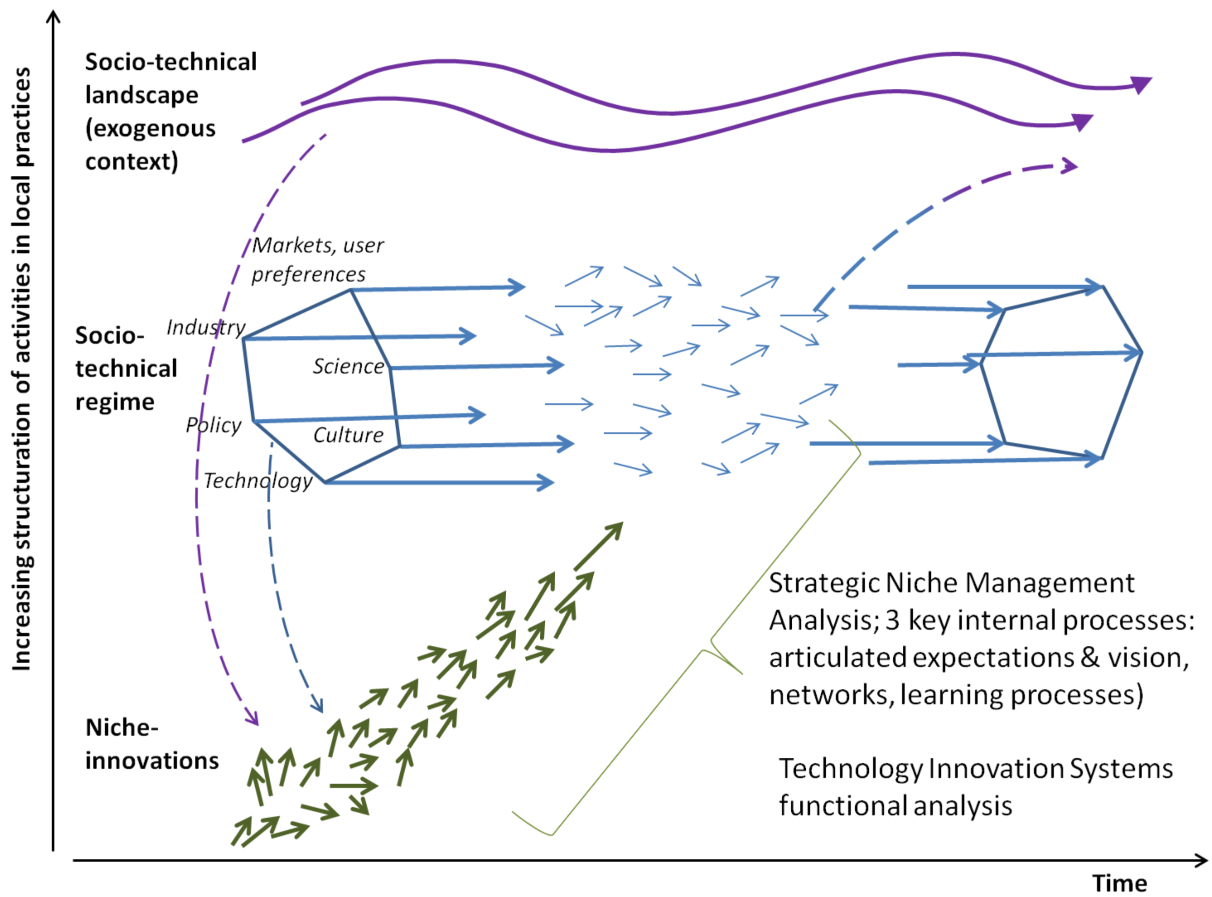

Figure 6: Analyzing niche development with strategic niche management (SNM) and technology innovation systems (TIS) (adapted from Geels, 2002, p. 1263)

The TIS approach provides specific lines of questioning which have been incorporated into my interview protocol in Appendix 1 – Case Study Protocol. The SNM approach offers themes at a higher level for me to compare with those that emerge from the qualitative analysis of the interview responses. In tandem it is not hard to indentify links between the 3 key internal processes of SNM and the 8 functions of TIS. For example, shaping expectations across a built network can be identified through the fourth and seventh functions of influence on the direction of the search and legitimacy. Learning processes can be identified in entrepreneurial experimentation, the development of knowledge and influence on the direction of the search, the first, second and fourth functions.

The authors of the frameworks have made a number of observations about policy in sustainability transitions (F. W. Geels et al., 2008). They are summarized below:

1. Early market formation is critical. Core to both SNM and TIS.
2. Consistent and stable policy frameworks are required to facilitate cost/benefit calculations.
3. Social embedding of technology and socio-political legitimacy to foster market formation and back commercialization processes. (Too much focus on R&D in early stages and not the other dimensions required for commercialization and scaled deployment.)
4. Innovation is a virtuous cycle influenced by multiple innovation journeys. Policies shouldn't set it up so that only one TIS wins in a "misguided notion of efficiency" because it cuts the niche-innovators' ability to form a broader advocacy coalition for change.
5. The incumbents-new entrants relationship is full of tension. It's a delicate issue for policy and different for every sector.
6. Policy makers need to be technologically and socially competent enough and have enough experience to recognize attempts to reframe arguments with hype.
7. Policies need to target all TIS functions, not be limited to R&D subsidies and changing relative prices (as economists and engineers are want to build into their models).

The application of these general findings to the development of the storage niche in Ontario is discussed as implications on policy.

Complementary Innovations

The remaining piece to be discussed in this literature review is the concept of complementarity, which is not always explicit in studies using the TIS and SNM frameworks. It is important for my study, however, because theoretically it differentiates storage technologies from other technologies concurrently being developed and changes being promoted within Ontario's electricity sector. The challenge remains to demonstrate that differentiation empirically, and to identify any significant implications of that differentiation.

Complementarity has been discussed throughout the innovation diffusion literature. In many cases it is studied in terms of complementary assets that aid in the dissemination of innovation, which often means commercialization capabilities, product support (Cassiman & Veugelers, 2006; Delgado et al., 2010; Gans & Stern, 2003; Teece, 1986; Veugelers & Cassiman, 1999), or business clusters (Carlsson & Stankiewicz, 1991; Delgado et al., 2010; Markman, Siegel, & Wright, 2008). This type of complementarity is usually in the form of business or process innovation as opposed to technology or product innovation (Markides, 2006). Relating back to the integrated TIS and SNM approach, these assets could facilitate the development or adoption of niche-innovations by the incumbent regimes and facilitate the eventual transition of the whole system, but there is another type of complementarity I intend to explore.

Complementarity is also considered in the literature as complementary technologies, products or innovations. These complementary innovations differ from the radical or disruptive innovations in that they are value enhancing as opposed to value destroying for existing technologies or systems (Boyer, 2005; Carlaw & Lipsey, 2002; Charitou & Markides, 2002; Markides, 2006; M. Smith, 2004). In this way, complementarity is considered as an alternative to competition in much of the innovation diffusion literature. Returning to the study of sectoral change, Kemp & Volpi (2008) conducted a review of the literature on the diffusion of clean technology innovations. They framed the dilemma that management faces around choosing between end-of-pipe or new solutions. The sunk costs and previously adapted technology, they argued, dictates a strong bias for the first of those two options. With my research, I want to explore the implications of a complementary technology on that choice.

Boyer (2005) goes into more detail on the types of complementarity that can be seen empirically. He divides them into categories of natural complementarity, technical complementarity, complementarity by design, ex post discovered complementarity, and functional complementarity.

Table 2: Categories of complementarity in capitalist economies as delineated by Boyer (2005).

Natural complementarity	**Value derived from the combination of naturally existing properties such as chemical properties.**
Technical complementarity	Man-made properties that combine in a coherent way to add value, such as car production and oil consumption and production.
Complementarity by design	Man-made properties strategically chosen to enhance value, such as assembly lines and equipment design.
Ex post discovered complementarity	An emerging co-evolution of technology and management models observed in retrospect as a system matures or goes into decline, such as ICT and profit optimization in the airline industry which took over a decade to realize the advantages or real-time price adjustments to online booking in order to manage demand and fill more seats.
Functional complementarity	The added value to systems due to the social roles that complement each other, such as supply and demand, or credit and debt repayment.

By these differentiations, the case of distributed storage technologies would be considered technical complementarity because the ability to store electricity in a large variety of environments allows it to increase the value of the electricity service to the customer or generator. In the case of electricity generated by wind and solar technologies, the storage would increase the quality of the power generated by regulating the voltage, and the reliability of the power because it could be drawn from the battery regardless of the weather conditions. Thus the value of the electricity generated through niche technologies such as wind and solar could be enhanced. Considering electricity distribution and the progression toward a distributed energy *smart grid*, distributed storage technologies would be an appropriate technology for managing demand. Storage options could be drawn on during peak demand periods thereby reducing the need for extra generation during the day, and exploiting excess generation stored during the nights. Thus the value of existing assets and future assets in the electricity system could be enhanced.

To classify distributed storage technologies as complementary requires the acknowledgement of some debate about that. Markard & Truffer's (2008a) integrated framework indicates the presence of complementary innovation systems in their model, and leaves the empirical exploration of the implications of complementarity to future work. Their later work could provide a comparison to my research, which applies the framework in an actor-oriented analysis of stationary fuel cells (Markard & Truffer, 2008a)b. The technological interrelatedness of stationary fuel cells with electricity systems was acknowledged from the perspective that its diffusion is dependent on further infrastructure developments and coordinated efforts between supplier, manufacturers, utilities, installers and customers. In their study they classify fuel cells as radical innovations because their widespread adoption would facilitate a shift from a centralized power production, to a distributed power production electricity system. Their analysis then focused on the strategic intent by the actors developing fuel cells to address the barriers to the diffusion of a radical innovation. Fuel cells are generators of power and as such I think radical is an appropriate classification. Other storage technologies could serve a similar role in facilitating the shift to a decentralized power system, however, under the logic explained above I think their influence is more value enhancing for the regime and other niche innovations.

It is this type of complementarity that I propose to explore through the integrated TIS and SNM approach, using the case of distributed storage technologies. SNM relates to the concept of complementarity through the transition work by identifying relationships between niche innovations and regime systems as symbiotic (F. W. Geels & Schot, 2007). TIS has dealt with complementarity by looking at the influence of positive externalities on the formation of an innovation system. They identify the eighth function: Development of positive externalities, as a critical function, along with the seventh function of Legitimacy as critical to the formation of a TIS. The conventional view of the relationship between niche players is that they are all vying for the dominant design, or competing for the same R&D and commercialization resources, such as could be expected between renewable energy technologies such as small-hydro, wind, solar and biomass.

Bergek, Jacobsson & Sandén (2008) dispute that conventional view by pointing to empirical evidence that is showing that transitions of the formation of TIS occur instead when complementary relationships prevail over competitive ones: *"A diverging view is one where each emerging TIS centred on carbon neutral technologies, may contribute to destabilise the energy 'regime', by increasing both its own functionality and that of related TIS."* (p. 585) Where related niches, or emerging TIS, are those that share structural elements: actors/networks/technology/institutions shown graphically in Figure 1. This relatedness doesn't necessarily have to be physical; it could simply be a perception. For example, the Green Energy and Green Economy Act (2009) and Feed-In Tariff program in Ontario (OPA, 2010) can promote a modernization of grid capabilities beyond the integration of wind, solar and biomass electricity generation into the grid that the FIT program targets. Thus while wind, solar and biomass generation may share little in common technically with distributed energy storage, they can still be grouped together in people's minds as they consider policy instruments and other institutional changes that are required for the deployment of each of these technologies. My research will look for indications that the FIT program and other provincial policies, programs or regulation, while offering no specific incentives, is benefiting the distributed storage technology niche as well.

But the identification of positive externalities will extend past a search for passive spill-overs to a search for deliberate attempts to foster them. Bergek, Jacobsson & Sandén (2008) referencing studies of the emergence of TISs, state that to promote the emergence of a TIS managers need to align interests across TISs and policy makers need to not pit TIS against each other.

> *"For managers, it becomes essential to align the interests of advocates of several 'competing designs' and, in particular, to work across TIS by forming broader advocacy coalitions. Policy makers need to support such broader coalitions by selecting support schemes that do not pit various emerging TIS against each others in a misguided notion of efficiency that presupposes that the issue at stake is the selection of the most cost-efficient technology 'from the shelf'. Instead, they should favour regulatory frameworks that enable a number of TIS to go through a formative phase in parallel, drawing strength from structural and functional overlaps, thus 'filling the shelf' with a diverse set of technologies." (Bergek, Jacobsson, & Sandén, 2008)*

As my research will look at the effects of complementarity on niche development and regime influence with the case of distributed storage technologies in Ontario, this type of deliberate formation of positive externalities will be looked for in the responses of interview participants and in the language of policy.

Table 3: Transition pathway typologies as summarized by Verbong & Geels (2010).

Transformation This pathway is characterised by external pressure (from the landscape level or outsider social groups) and gradual adjustment and reorientation of existing regimes. Although external pressures create 'windows of opportunity' for wider change, niche innovations are insufficiently developed to take advantage of them. Change is therefore primarily enacted by regime actors, who reorient existing development trajectories. Outside criticism from social movements and public opinion is important, because it creates pressure on regime actors, especially when they spill over towards stricter environmental policies and changes in consumer preferences. Although regime actors respond to these pressures, the changes in their search heuristics, guiding principles and R&D investments are modest. The result is a gradual change of direction in regime trajectories. New regimes thus grow out of old regimes through cumulative adjustments and reorientations. Radical innovations remain restricted to niches.
Reconfiguration In this pathway, niche-innovations are more developed when regimes face problems and external landscape pressures. In response, the regime adopts certain niche-innovations into the system as add-ons or component substitutions, leading to a gradual reconfiguration of the basic architecture and changes in some guiding principles, beliefs and practices. In the reconfiguration pathway, the new regime also grows out of the old regime it differs from the transformation pathway in that the cumulative adoption of new components changes the basic architecture of the regime substantially. The main interaction is between regime actors and niche actors, who develop and supply the new components and technologies.
Technological substitution In this pathway, landscape pressures produce problems and tensions in regimes, which create 'windows of opportunity' for niche-innovations. Niche-innovations can use these windows, when they have stabilised and gathered momentum. Diffusion of these new technologies usually takes the form of 'niche-accumulation', with innovations entering increasingly bigger markets, eventually replacing the existing regime. In this pathway newcomers (niche actors) compete with incumbent regime actors.
De-alignment and re-alignment Major landscape changes lead to huge problems in the regime. The regime experiences major internal problems, collapses, erodes and de-aligns. Regime actors lose faith in the future of the system. The destabilisation of the regime creates uncertainty about dimensions on which to optimise innovation efforts. The sustained period of uncertainty is characterised by the coexistence of multiple niche-innovations and widespread experimentation. Eventually one option becomes dominant, leading to a major restructuring of the system (new actors, guiding principles, beliefs and practices).

The concept of complementarity between the niche innovation, other innovations and the existing regime is explored most in the Geels & Schot (2007) discussion of symbiotic relationships. According to their typology of the types of transition pathways that regimes and niches could follow, symbiotic relationships tend to lead to reconfiguration pathways. Four types of transition pathways are summarized by Verbong & Geels (2010) and shown in Table 3.

Geels & Schot (2007) explore the symbiotic relationship in their paper with the purpose of exploring the relationships between regime and niche in niche development and regime shift. They describe a process of symbiotic innovations being adopted into the regime as component innovations of a greater reconfiguration transition. In other words, the symbiotic innovations build on each other to support a larger transition, as opposed to being adopted into the current regime as would be observed in a transformation pathway. It is expected that storage technologies will be seen as having a symbiotic relationship to the existing electricity infrastructure based on the review of the literature and storage technology benefits. Therefore evidence will be sought to determine they types of transition pathways that storage may be supporting in the regime.

Methodology

This section describes the research approach, case selection, the data collection and analysis methods. I make the claim that a single case study with embedded units of analysis is appropriate for my research question and framework. I further claim that reliability and validity of my findings can be established by adopting similar methods to previous case studies around technologies in electricity systems in Europe. Recommendations are made for future work that could longitudinally build on current observations and test the generalizability of my findings.

Research Approach

My research is an applied study intended to build on the existing theory that is used to inform policy and program development. I make the assumption that societal problems can be solved with knowledge (Patton, 2002). This sounds like I could be adopting a positivist view, particularly when I'm making use of a framework that considers how a social system 'functions' as if in a mechanistic way. However, in the development of the functional approach of the TIS framework, Hekkert et al. (2007) take care to differentiate the notion of a system 'function' from the traditionally associated positivist view. In order to apply the functional approach to a restricted set of social phenomena at a micro-level of the technology innovation system (as opposed to forming abstract views of the macro-level systems) they stress the *heuristic view* of a function. In this way the functional analysis of the TIS is an applied research method that can be used by practitioners and participants within the system from an interpretivism research paradigm.

A heuristic framework poses a challenge for a researcher outside of the system (as in my case) so I refer to the greater field of phenomenological analysis of which heuristic inquiry is a part (Patton, 2002) in order to understand the subjective experience of the actors and networks within the system. In doing so, I maintain an interpretivism research paradigm. The interpretivism research paradigm fits with the ontological assumptions underlying theories drawn from sociology reviewed earlier in my proposal. Institutional theory relies on ontological assumptions that reject rational-actor models that assume society behaves in a mechanistic way (Zucker, 1987; Scott, 2008). The innovation systems approach adopts a complex and dynamic ontological view of the world, in which technology and elements of society change in a co-evolutionary way (Carlsson & Stankiewicz, 1991; Edquist, 2005; Lundvall, 2010; Malerba, 2005).

Case studies can be conducted in a number of ways for explanatory, exploratory, evaluative and predictive purposes (Yin, 2009). This case study could have been an explanatory case study were it testing a causal framework of the endogenous dynamics of change in a sector. The SNM transition approach does build a narrative that can identify causal relationships between niche, regime and landscape factors and overall sectoral transition (Elzen, Geels, Hofman, & Green, 2002). However, its primary purpose is to provide depth to insight for practitioners looking to understand a particular change process (F. W. Geels et al., 2008; Raven et al., 2010; Schot & Geels, 2008);(F. W. Geels et al., 2008; G. P. J. Verbong & Geels, 2010) G. P. J. Verbong & Geels, 2010). Likewise, the functional TIS approach has been used to suggest some "motors of change" (Hekkert et al., 2007; Negro et al., 2008) which sequence the functions that tend to lead to virtuous cycles advancing technological change and innovation. These cycles could be used as a causal framework if a cross-comparison with other cases produced generalizable results. Presumably this is the approach by Foxon et al. (2010) who propose to use these methods to build scenarios. But the primary intention for the TIS functional approach is to build a narrative that provides insight into a specific context and allow for more systematic analysis, not to predict causal relationships (Bergek, Jacobsson, Carlsson et al., 2008; Hekkert & Negro, 2009). Thus, the use of these frameworks is as guides to my data collection and analysis, rather than as models to be tested. While I don't test the existence of specific patterns or functions, I do gain insight into the dynamics that exist, and identify patterns that could be tested in future work.

Understanding the role of these frameworks, it is important to understand what assumptions and paradigms are invoked by using them. The development of the TIS functional and SNM transition approaches through case study analysis made use of epistemological assumptions that theories are shaped by context, and constructed from multiple perspectives in order to better understand a phenomenon. Thus in my case it is imperative that I source data from multiple perspectives. This is evident in my case design. In both approaches, the narrative produced from the case studies was used in an interpretivist exercise of building a theory for analysing the endogenous dynamics of a system (Bergek, Jacobsson, Carlsson et al., 2008; F. W. Geels, 2002; F. W. Geels, 2005; Jacobsson & Bergek, 2004; Johnson & Jacobsson, 2001; Schot & Geels, 2008; G. P. J. Verbong & Geels, 2010). My research will continue to explore the theory from an interpretivism research paradigm, which has implications on the data collection and content analysis that are explained in the Research Methods and Sources subsections.

Both the SNM and TIS frameworks have typically been applied in a top-down manner of fitting data into existing themes. Historical Event Analysis was used by Suurs et al. (2010), Hekkert and Negro (2009), Negro et al. (2008) in developing their case narratives as a quantitative support to the qualitative empirical study of innovation systems. But their studies are mainly conducted ex-post, which facilitates an easier chronological sequencing of events. In my case, I'm studying an emerging TIS where not many events have happened and full cycles are less likely to be able to be observed or identified by those I interview within the system. Thus I require a greater depth of information in order to discern any patterns, which may produce theory that doesn't fit neatly into the TIS functions and SNM internal processes. To allow for this, I will use these frameworks in a top-down way to choose the sources and create the interview protocol, but conduct the interview in a semi-structured way that allows the conversation to meander into greater depth. The analysis will be bottom-up, with a comparison to the functions and processes of the frameworks near the end of each analysis segment.

The analysis uses a grounded theory approach (Strauss & Corbin, 1998) to content analysis. Grounded theory is an appropriate approach for this case because it is exploratory in nature and because I'm not using an ontological model or causal framework that can be tested. I could use a more deductive approach that would plug data directly into the analysis frameworks, but due to the fuzziness of this emerging niche explained above and the threat of research bias, a grounded theory approach allows for other factors to emerge. In keeping with the interpretivism epistemological view, my research was subjected to scrutiny by the participants in my research in order to have the relevant findings endorsed by them and a level of construct validity achieved.

Research question and case selection

My primary research objective is to understand how a niche is developing and what the effects of complementarity are on that development and on a niche's regime influence. To do this I ask the following research question:

> *What are the effects of complementarity on niche development and regime influence in the case of distributed storage technologies in Ontario?*

My framework of analysis was derived using case studies of existing technology systems (Bergek & Jacobsson, 2003; F. W. Geels, 2002; Hekkert et al., 2007; Hekkert & Negro, 2009; Jacobsson & Bergek, 2004; Kemp, 1994; Markard & Truffer, 2008a; Negro et al., 2008; Suurs et al., 2010; G. Verbong & Geels, 2007), for comparative purposes it follows then that my research will also use a case study methodology. A case study is appropriate because this is an empirical and qualitative "how" question that distinguishes itself from needing other research methods along the following criteria summarized by Paré (2004). Comments on the relevancy to other research methods are indicated in Table 4 taken from Yin (2009).

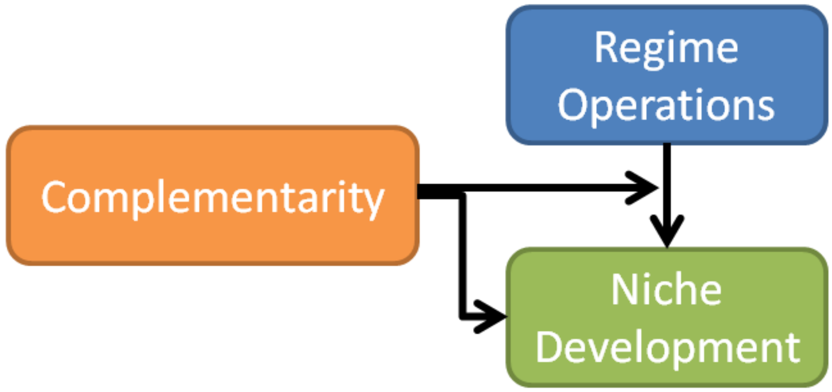

Figure 7: Visual representation of research question: how does complementarity affect a regime's influence on the development of a niche, and how does it affect the niche development perspective and behaviours?

As will be discussed in the Research Methods sub-section, the case is built using qualitative methods of data collection primarily from documentation and interviews, and supported by other primary and secondary sources. This generally follows in the footsteps of Suurs et al. (2010), Hekkert and Negro (2009), Markard and Truffer (2008b) and Geels and Raven (2006) in their recent case studies.

Table 4: Research criteria that benefit from case study methodology as opposed to other research methods.

Research question criteria for case methodology	Relevance to other possible research methods
Explores a contemporary phenomenon that is broad and complex	Insights beyond what a survey, historical or archival study could provide are required.
The existing body of knowledge is insufficient to permit the posing of causal questions	Experimentation is not possible as relationships are not well enough understood.
A holistic, in-depth investigation is needed	Some of the criteria of analysis will be emergent, this could not be leveraged as easily in survey data collection.
A phenomenon cannot be studied outside the context in which it occurs	Experimentation is not possible as behavioural variables are outside of the control of the researcher.

Yin (2009) states that a single case study methodology is justifiable if it is a revelatory case where previously inaccessible information becomes available due to recent events. Distributed storage technologies are considered a revelatory case to empirically explore the effects of complementary innovations. This is because the technologies and institutional mechanisms to support them in Ontario are in an early stage of development and demonstration (O'Malley, 2010), despite the science behind many of the technologies having been around for generations (J. Eyer & Corey, 2010). Evidence of this formative phase gaining some momentum is the Energy Storage Working Group which was formed in the fall of 2010 with the objective of “enabling the rapid deployment of distributed sustainable generation in Toronto and throughout the rest of the province of Ontario” (O’Malley, 2010, p.5). Consisting of representatives from local distribution companies, government bodies, electricity storage technology manufacturers, universities and colleges amongst other stakeholders, the Energy Storage Working Group provides a useful reference for identifying key actors and networks within the innovation system. It also provides useful data through its events and publications, and helps to articulate a compelling need for this research within Ontario.

The nature of the problem and the attributes of the frameworks lend themselves to an embedded case design that allows for multiple units of analysis (Yin, 2009). The embedded design features a single context, which for my research is the Ontario electricity sector. Following the recommendations of Bergek et al. (2008) this research focuses on a single technology category as a means of defining the innovation system: distributed storage technologies. The embedded units of analysis then follow the framework perspectives of regime, niche and landscape, shown visually in Figure 8. In addition to matching the framework perspectives, the embedded single case design also improves the sensitivity of the case study to emerging themes as the research is conducted. As was discussed in the sub-section on Research Approach, this exploratory case uses grounded theory for data analysis. Therefore the possibility of elements emerging during the course of research that require a modification to the research question is acknowledged throughout the course of research. Following Yin’s (2009) advice, selecting an embedded case study design can help to focus the case study inquiry by using subunits of analysis and avoid slippage in the nature of the study. These subunits are identified and explained later in the Analysis and Findings sections.

The Ontario electricity sector provides an appropriate context within which to conduct a case study exploring niche development, and the influence of complementary innovations. This is because the sector is: (1) in a process of transition in response to government pressure most notably through the Green Energy and Green Economy Act and FIT program (Province of Ontario, 2009; OPA, 2010); and (2) it has active actors, networks and institutions in the niche and complementary innovation fields (O’Malley, 2010). In order to have a common context for comparison, the case studies will all be within Ontario as opposed to using cases from outside the province.

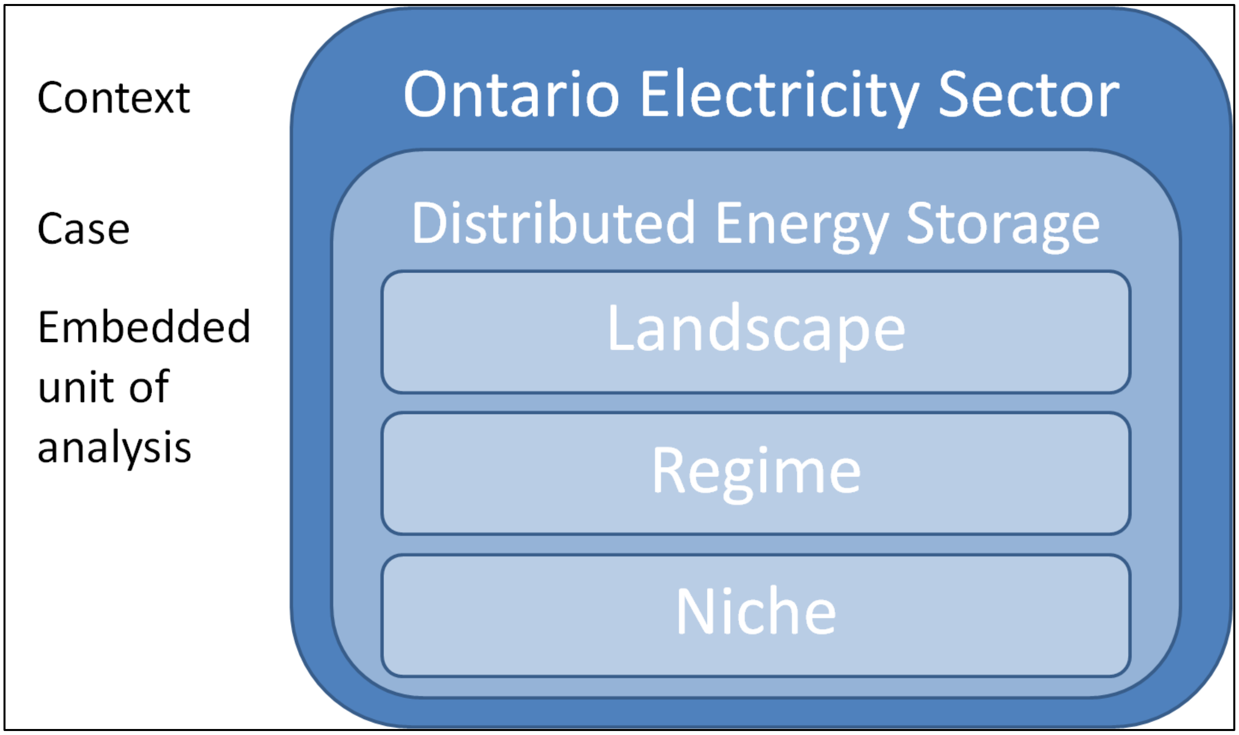

Figure 8: Embedded single case design (Yin, 2009) of the Li-ion battery storage technology innovation system in Ontario.

The particular distributed storage technologies studied in this case were selected subject to my ability to interview the technology developers. Many were recruited either through their affiliation with Ryerson's Centre for Urban Energy, or through my professional network of contacts.

Research Methods

The general process of constructing case studies begins by assembling the raw case data, constructing a case record of categorized information, then writing the final case study narrative (Patton, 2002). To maximize the contrast between regime and niche perspectives, I collected data from each perspective in 2 separate stages. I completed the regime collection and analysis first which informed the data collection and analysis of the niche perspective. I chose to start with the regime perspective in order to gain a broad and comprehensive understanding of the environment that the niche actors exist within. That way my collection and analysis of niche data could be more targeted along specific lines of enquiry related to niche realities, and not spent as much on learning about the structure of the market environment.

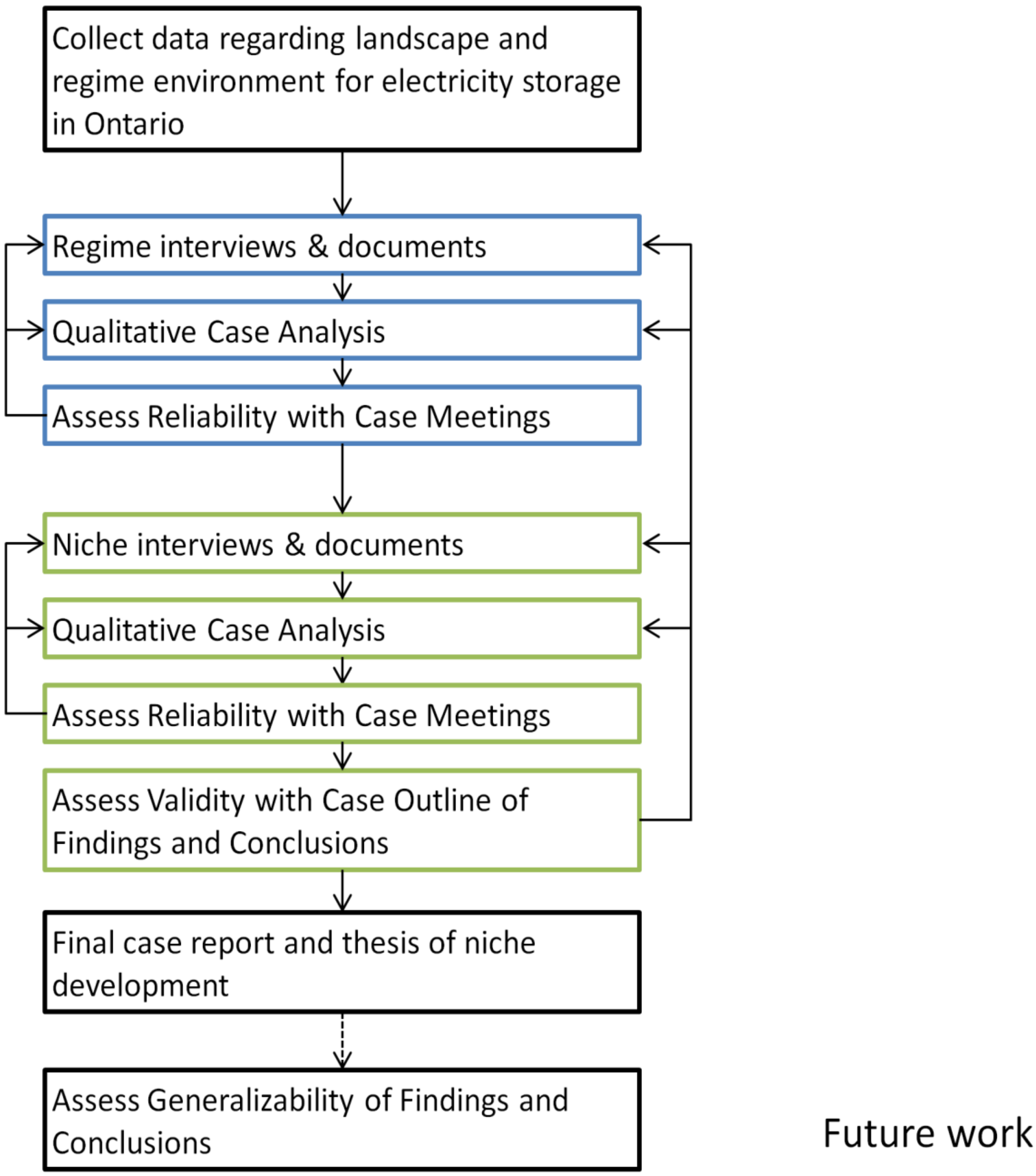

Figure 9: Case study research design

The iterative process illustrated above allowed me to compare and contrast the themes to the three key internal processes of SNM (articulation of a vision and expectations, building a network, and learning processes) and the more specific 8 functions of an emerging TIS – with particular attention to functions 7 and 8. Assessments for reliability looked for some conceptual or theoretical coherence to explain why some accounts of the regime and niche dynamics may dispute others and dispute observable facts or trends, such as whether outages are a problem in a particular distribution system or not.

Roy Suddaby (2008), in an editorial explaining what grounded theory is not, emphasized that grounded theory requires a constant interplay between induction and deduction. I adopted a grounded theory approach in effort to build a narrative which could develop a working theory about how actors are interpreting change and how they perceive causal relations between each other. The alternative would be a strict phenomenological approach which would summarize what was said. The approach is illustrated in the figure below. Theory-driven and data-driven nodes were assigned to the summaries of what was said in the interviews and found in documents in a similar manner to the hybrid inductive/deductive analysis outlined by Fereday & Muir-Cochrane (2006), O'Sullivan & O'Dwyer (2009) set-up in the manner that Miles & Huberman (1999) describe as the usual case method (p. 83). This produced a narrative that captures how actors understand current processes of change occurring in the electricity sector.

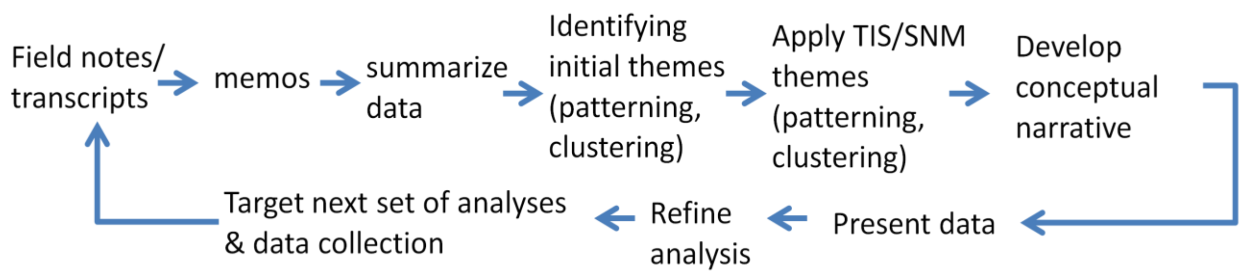

Figure 10: Iterative process of qualitative case analysis steps

Between the steps of identifying themes, patterns and developing the conceptual narrative, the grounded theory approach guided the number of iterations and depth of enquiry.

Grounded Theory Narrative:

1. Use thematic analysis as a preliminary step to understand what's going on
2. Follow with looking for meaning and interpretations of reality
3. Continue constant comparison of my findings to other data "what am I hearing?" until my data is saturated and I'm not hearing anything new
4. Build a narrative that explains these actor realities at a conceptual level (not just summarizing what's going on)

Yin (2009) describes tactics to ensuring the validity and reliability of case study findings during the various phases of the research. My measures to ensure validity and reliability are categorized under the 4 criteria that he recognizes.

- **Internal validity:**
  - Because this is an exploratory case study, the main concern was the accuracy of the inferences I made when trying to build a narrative through understanding relationships and the sequence of events. Care was taken to search for other possible explanations for relationships and sequences of events. Instances of non-confirming data were explored and the premises developed during analysis will be tested with them.
    - My supervisors assisted in this measure by reviewing a selection of transcripts and looking for other explanations of why actors behaved and thought in certain ways. This feedback was reviewed and inquired about more deeply in the next data collection and analysis phase.
  - The data was analyzed in segments designed to maximize the contrast in the narrative. That is, actors in the regime perspective were interviewed and analyzed first until, through exercises of contrast and comparison, I was hearing the same things repeated with no new information. Then, presuming the niche actors to have a contrasting view, interviews and analyses were conducted with specific themes from the regime perspective narrative used to probe the lines of SNM and TIS questioning to niche respondents.
  - The findings of my research were scrutinized by informants and other stakeholders within the system.
  - The data came from a variety of sources (documents, interviews, conferences, websites, etc.).
- **External validity:**
  - The findings of this research may not be generalizable beyond the case of electricity storage in distribution systems in Ontario. Ideally the findings would be compared to case explorations of electricity storage technologies in other jurisdictions. Or compared to other possible complementary innovations in Ontario. Following those exercises a deductive study testing the findings through a survey approach could test the generalizability of the findings, but that will be beyond the scope of this research.
  - Representativeness is limited in this research, but the selection of these sources within the categories of regime and niche was informed by experts, they were also somewhat random based on connections that I could make.

- **Reliability:**
  - I developed a case study protocol that covered the research objectives, field procedures, case study questions, and framed each analysis segment.
  - I developed a database using NVivo for the purposes of a systematic content analysis and to facilitate future replication.

Constructing the interview guide

The interview questions, terms of confidentiality along with an overview of the purpose, benefit to participant, procedures and confidentiality are included in the Case Study Protocol presented in Appendix 1. The interview questions are categorized under the 8 TIS functions. Using historical event analysis in their study of bioenergy innovation systems, Hekkert and Negro (2009) and Negro et al. (2008) coded events and interview content according to its positive contribution to virtuous cycles that would lead to a sectoral transition. The deductive themes for coding events in their research are summarized in Table **5**, where they used a slightly different set of 7 functions for a TIS. They are included here as a reference to the types of premises I could expect to form during the analysis phase that helped compose the questions in the interview guide and with the identification of virtuous or vicious cycles.

Table 5: Thematic coding of events to system function. Drawn from Hekkert and Negro (2009).

Function	Event category
Entrepreneurial activities	Project started Contractors provide turn-key technology
	Project stopped Lack of contractors
Knowledge development	Desktop assessments, feasibility studies, reports, R&D projects, patents
Knowledge diffusion	Conferences, workshops, platforms
Guidance of the search	Positive expectations of electricity storage technologies. Positive regulations by government on electricity storage technologies
	Negative expectations of electricity storage technologies. Negative regulation by government on electricity storage technologies.
Market formation	Tax regimes/feed-in rates, environmental/technical standards, consumer awareness/interest
	Expressed lack of tax regimes/feed-in rates, environmental/technical standards, consumer awareness/interest

Resource mobilisation	Subsidies, investments
	Expressed lack of subsidies, investments
Creation of legitimacy/ counteracting resistance to change	Lobby by actors/networks to improve technical, institutional and financial conditions for particular technology related to electricity storage
	Expressed lack of lobby by actors/networks
	Lobby for other technologies that compete with electricity storage technologies
	Resistance to change by actors/networks in regime or niche level

Connecting systems change theory to the practitioner's reality

My Case Study Protocol has been developed in large part out of the diagnostic questions and indicators provided in the manual by Bergek et al. (2005). It served as a tool for reliability in my research, which was revised as became necessary, due to the ongoing analysis throughout the data collection process. The Informed Consent Agreement also served as a mechanism to prepare my research subjects for the types of questions I was going to ask. Still, the concepts I'm exploring can be somewhat esoteric to a respondent. It became important to make a few connections between the language of systems change and the language of marketing and management.

Turning to the management theory and organizational theory more directly familiar to decision makers and proponents of change within a firm, I looked for links between common themes. On the subject of systems change, Raven, van den Bosch and Weterings (2010) have attempted this by developing guides and workshops for practitioners of transition experiments. Prompting their work was the recognition that SNM is not directly applicable or accessible by practitioners without innovation policy backgrounds; it's too abstract. To help make these concepts more accessible, links between their work, and the literature on the fuzzy front end (Alam, 2006; Kim & Wilemon, 2002; Reid & De Brentani, 2004) can be made along themes listed in the first column. Following each theme, the body of literature the term was commonly found within is indicated by its acronym in brackets.

Table 6: Connection between concepts in strategic niche management (SNM) framework and business innovation literature on new product develoment (NPD) and fuzzy front end (FFE)

Theme	Strategic Niche Management Applied (Raven et al., 2010)	Fuzzy Front End and New Product (or Service) Development
Innovation Pathways (within a sector) (SNM)	Socio-technical alignment; the co-evolution of social and technical characteristics which manifest themselves in various ways including goals, drivers and influences on each other.	Network effects; individual decisions made within the firm based on the decisions of competitors and related firms that appear to point to the emergence of a new dominant design (Reid & De Brentani, 2004).
Innovation Projects (NPD)	Transition experiments; guided by a broader social challenge with the intention to contribute to a transition in the sector or system. These facilitate multi-stakeholder learning on institutional and technical barriers to change.	Product testing; market tests, demonstrations and pilots which can contribute to multi-stakeholder learning but often focus on learning for a specific firm to develop a competitive edge with specific product attributes (Alam, 2006).
Discontinuous Innovation (NPD)	Regime Change; institutional constructs such as rules, regulation, policy, cultures and practices, as well as technology systems change to accept new technologies or radical innovations, potentially with new actors that create a new regime with new capabilities.	Disequilibrium in the market leading to a new dominant design; as opposed to incremental innovations which are product improvements as a result of new information or advances in existing technology. The disequilibrium in the market can also allow new entrants previously in emerging markets to access mainstream markets (Kim & Wilemon, 2002; Reid & De Brentani, 2004).
Champions (FFE/NPD)	Practitioners interested in transition experiments, they can include policy-makers, firms, consultants, and intermediary organizations.	Individuals within a firm that drive the process from idea generation to concept development (Reid & De Brentani, 2004).
Boundary-Spanners (FFE/NPD)	Also practitioners as described above.	Individuals with extensive links within and external to the firm. They serve the role of information exchange and also translating that information into firm relevant activities (Reid & De Brentani, 2004).
Strategic Alignment (FFE)	The co-evolution of technology design and capability with social behaviour and needs; a product of learning from transition experiments, this can often mean that new entrants adjust their strategies and business models, and that other actors remove institutional barriers	Product development is aligned with an established corporate strategy, vision or mission, and the firm's capabilities. The product development process is designed to leverage core competencies while meeting customer needs (Kim & Wilemon, 2002).

	to a desired systems change that is increasingly understood by a growing number of actors.	
Visioning & Expectation Setting (SNM)	The coordination of expectations and vision for a future system with new technological capabilities. This shared vision between stakeholders allows for greater shared learning by testing hypotheses and assumptions in transition experiments.	Primarily considered within the firm, not with stakeholders in what would be equated to niche or regime environments (Kim & Wilemon, 2002).
Building Stakeholder Networks (SNM)	Creating networks between regime and niche players to facilitate the development and dissemination of knowledge, gain access to necessary resources, and to create and exploit positive externalities.	Cooperation with external organizations; activities include joint ventures, consortia, partnerships, customer communication, and supplier networks that benefit the development phase of a product (Kim & Wilemon, 2002).
Learning Processes (SNM)	Experienced at multiple dimensions by the stakeholder network; dimensions include the technical and design aspects, market and user preferences, cultural and symbolic meaning, infrastructure and maintenance networks, industry and production networks, regulations and government policy and societal and environmental effects (Schot & Geels, 2008).	The learning from innovation projects is manifested in new products or services which in turn influence the overall trajectory of a technology in a sector. Learning requires 3 perspectives: environmental, individual, and organizational to be telescoped together. The overall technology development trajectory in a sector is thereby indirectly influenced by the interpretation of learning by individuals engaged in the fuzzy front end development of new products within a firm (Kim & Wilemon, 2002; Reid & De Brentani, 2004).

The two columns obviously stem from two different perspectives; the high-level systems perspective and the on-the-ground organizational perspective. Both can be used to describe the same types of phenomenon (at least in part). For my research purposes it is important to recognize language from the second column and be able to link it to the ideas from the first column.

Sources

When trying to understand a TIS and define my system boundary I had to apply a narrower and wider system boundary in parallel to figure out what level of detail is needed to understand the critical elements. In keeping with the literature, I used the existence of positive externalities to identify how wide the system boundary should be drawn. (Bergek, Jacobsson, Sandén, P. 586) My theoretical framework dictates a theory-based sampling approach which used a constant comparative method of analysis to refine the data collection process based on emerging concepts (Patton, 2002). Yin (2009) states that case studies require the researcher to have an inquiring mind *during* the data collection. He states that while the data collection does follow a plan, the specific types of information that may become available are not always predictable. Thus as the case progressed, I used additional sources as they became available to me in order to gain a deeper understanding of the various actor realities.

From the outset, there were a number of sources of data that I could predict would provide valuable information. In the literature on TIS, sectoral change is referred to as the formation of innovation systems with the overall goal of developing, diffusing and utilizing innovations (Bergek et al., 2005; Bergek, Jacobsson, Carlsson et al., 2008). In applying the TIS framework, they recommend that the scope of a study be drawn to include the actors, networks and institutions engaged in the functions presented in Box 1 with intents that affect the degree of technology development, diffusion and utilization. The parent literature to SNM on the Multi-Level Perspective (MLP) starts by identifying existing regimes and radical niche-innovations and the landscape of rules and social and resource pressures that they exist within (F. W. Geels, 2002; F. W. Geels, 2005; G. P. J. Verbong & Geels, 2010). In a similar way, the artefacts of landscape influences and the regime and niche level actors, networks and institutions can be identified and included in the appropriate units of analysis:

- The landscape pressures of national and international regulation and government incentives, along with increasing public pressure can be analyzed in their role as influencing investment decisions within the sector.
- The regime actors and networks could be identified as the provincial government and Ontario Power Authority (OPA), the regulator (Ontario Energy Board, OEB), utilities supplying most of the electricity generation in Ontario, the local distribution companies (LDCs), the not-for-profit market administrators such as the Independent Electricity System Operator (IESO), and the customers of electricity and energy technologies in Ontario. These regime actors all play a role in the current regime mode of operation or status quo.
- The niche-innovation actors and networks of primary focus could be identified as developers, retailers and proponents of distributed electricity storage. Here the actors and networks can be found in niche environments where storage technologies are being advanced and invested in from the private sector, universities and associations. Conveniently, they are all outlined in the

Energy Storage Working Group briefing paper for stakeholders (O'Malley, 2010) as entrepreneurs and suppliers. The niche market perspective also includes potential investors and consumers of electricity storage options.

Interviews and documentation were sought from selected stakeholders listed in the Energy Storage Working Group draft paper, through connections with the Centre for Urban Energy and through my professional network. According to the ethics protocol, interview data and non-publicly available documentation was collected with informed consent.

Mapping the Multi-Level Perspective to the Data

Throughout the beginning phases of data collection and preliminary analysis it became evident that I could distinguish sub-groupings of the regime and niche-level actors. Within these two levels it became useful to categorize the actors and the institutions to which they were found into groups of what I labelled "system" and "implementing" roles. These four quadrants of actors are illustrated in Table 7 and were used to compare and contrast the commonly held frameworks and dominant characteristics of regime and niche actors.

The characteristics of each quadrant of actors that were discovered in the analysis are described specifically in the following Analysis section. From types of organizations listed in these quadrants it was possible to recognize and anticipate some high-level characteristics. The first quadrant of regime-level system actors would be both authors of and reacting to policy drivers and sensitive to political trends in light of the social and economic contexts. The second quadrant of actors would generally be one step removed from authoring policy, but would be regularly informing or consulting on the activities of the first quadrant of actors. More importantly, these would also be the actors that were responsible for implementing activities and delivering results under the regime policy and programs. The end customer was also found in quadrant two, as an actor who was intended to be the ultimate beneficiary of the policies and programs. Quadrant three would contain actors that were more intimately involved with the storage technology developers, but who would also be required to speak to regime-level system actors regarding the policies and programs in place to support the development of niches. These actors had more "skin in the game" because the success of these organizations depended on the success of the activities of quadrant four actors. Quadrant four actors represent the primary unit of analysis for this case study. These actors are the core component of the storage niche that is being developed (or not) in Ontario because they are the developers of new storage technologies and the related business models and strategies intended to be integrated into the regime-level operations.

Table 7: Four quadrants of actor groups used for comparison and contrast between regime and niche actors

Regime	Government policy / program managers Regulators, system operators, system planners Electricity policy industry groups	Local distribution companies Building owners/managers Engineering consulting
Niche	Incubators Public funders outside of regime governance Angels/ Venture Capital (VC) Tech Transfer Offices Collaboration/Partner Brokers Niche association	Storage technology developers: Entrepreneurs / Innovating companies
	System	**Implementing**

Figure 11 maps the actors from these quadrants onto a stakeholder map of the electricity sector in Ontario, with potential points of application for distributed storage technologies indicated to give a sense of how actors may be implicated.

Addressing researcher bias

Each quadrant was analyzed separately in effort to maximize the potential contrast between the actor realities that were found in each. The regime actor data was collected and analyzed first as a method of starting with the broad environmental context that would house the more specific niche dynamics. The choice to begin with the regime level was supported by a few factors.

First, and as described earlier in the Research Methods subsection, my frameworks of analysis and interview protocol were designed from a systems perspective that could be somewhat abstract to implementing actors in the sector. Thus it made sense to start with a more strict reliance on the original wording of the questions in the interview protocol for the first quadrant actors, and to make adjustments to the wording and lines of enquiry as appropriate to each actor in the remaining quadrants. These adjustments are explained in detail in the Analysis section.

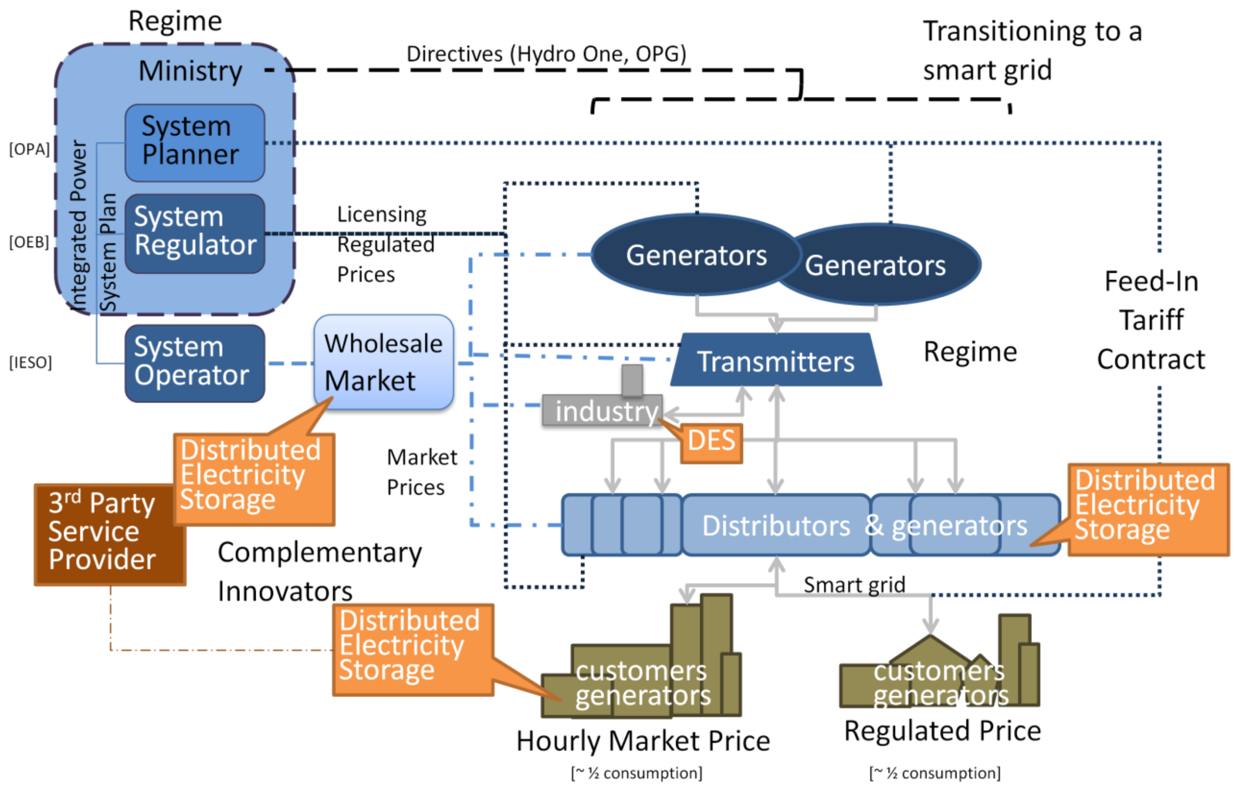

Figure 11: Electricity stakeholder map in Ontario and potential application points for distributed storage technologies

Second, and as a somewhat related point, given that studying change in an electricity sector wasn't an entirely new field of research for me I wanted to maximize the potential for new ideas to contrast against my previous understanding of electricity sector dynamics. There was a likelihood that I had a personal "system perspective" bias from my previous work for Natural Resources Canada. In effort to expose and challenge any potential biases I began the data collection and analysis with what I anticipated to be more confirming data to my pre-existing understanding. The niche-level actors could then be interviewed and data analyzed by questioning the realities that I understood from the regime perspective. The TIS and SNM frameworks of analysis provided a systematic way of identifying the regime realities and biases that I may have had, and provided discussion points with the supervisors of this research.

Third, and linked to the second factor of my previous work, professional connections with the regime-level system actors made it easier to schedule interviews with these actors first. Some of the other regime and niche participants whom I didn't have connections with in this study were referred to me by participants during their interviews or through follow-up correspondence.

In effort to counter my researcher bias I adopted an approach to the interview that was intended to make the respondent comfortable as quickly as possible in the interview by giving them some freedom over the direction and flow of the conversation. The hope was that once the respondent was comfortable, they would be more able to explore some of the less certain aspects of systems change and niche development that they were experiencing (or not). I gave the respondents the option of either opening the interview with a description of their reality to give me a context for the questions, or we could launch straight into the questions. Should they choose to begin with questions, they were offered the opportunity to direct the conversation to other issues should they be relevant to understanding their reality in relation to storage technology development and integration into Ontario's electricity sector.

Data Collection

In total 32 interviews were conducted of regime and niche actors from 30 different organizations. There were 8 regime system interviews, 14 regime implementing, 5 niche system and 5 niche implementing interviews. Most interviews were with individuals in person, recorded and transcribed for analysis. Of the 32 interviews, 3 were with 2 individuals, making a total of 35 people interviewed to provide data for this study. Of the 32 interviews, 3 were over the phone and notes were taken, and 2 were in person and notes were taken because the participant requested not to be recorded.

Data Analysis

The purpose of this section is to present the evidence used to answer my research question and create a model that is presented in the Discussion section that could be tested with future research. This section is prefaced by a description of the evolution of the enquiry as the case study was being conducted and analyzed in order to answer my research question. It then presents a high-level view of events in Ontario's electricity sector using the TIS framework to recognize functions of the innovation system and cycles of innovation. This provides the reader with a reference to actual events when exploring the more abstract SNM discussions of articulation of a vision and managing expectations, building social networks and engaging in learning processes. It then adopts a firm-centric view of niche development by comparing storage entrepreneur development pathways to expectations of storage niche development by other niche and regime actors. The related business models and regime actor decision making frameworks are also presented in relation to those storage entrepreneur development pathways. The TIS and SNM models are both used in the analysis section, illustrating where they proved useful in understanding the dynamics of the system. In their use here, the process of an emerging storage innovation system is roughly equivalent to the process of the development of the storage niche and the related regime shift. The findings are based primarily on qualitative evidence, supported by some quantitative evidence relevant to the findings.

Evolution of the enquiry

In order to answer my primary research question, I chose first to establish an understanding of the context of the regime structure and relevant points of influence. As described earlier in my Methodology section, early into the analysis of the regime, it became evident that there were different roles within the regime and niche that I could label as "system" and "implementing." These roles are illustrated in Table 7 of the previous section. In my initial interviews with regime system actors, I recognized a pattern of speaking about smart grid in order to create the context for a discussion about storage technologies. Therefore, in an effort to understand storage niche development in Ontario, it became evident that I needed to first understand the regime shift toward smart grid. The result was an evolution in the analysis questions, and the language of the niche interviews which followed the analysis of the regime interviews. This sub-set of questions was posed while still asking questions under the headings of the 8 TIS functions. Figure 12 illustrates the evolution of this line of enquiry:

	ENQUIRY	ANALYSIS	NARRATIVE
Regime Systems	8 TIS functions Transition pathway	SNM patterns Roles Actor frameworks Treatment of complementarity Context + pathway scenarios	How is the regime shifting toward smart grid?
Regime Implementing	8 TIS functions Decision making factors Transition pathway	SNM patterns Roles Actor frameworks Treatment of complementarity Compare context + pathway scenarios	
Niche Systems	8 TIS functions Decision making factors Niche development pathway Business strategy, model, case	SNM patterns Roles Actor frameworks Treatment of complementarity Compare context + pathway scenarios	How is the niche developing for storage?
Niche Implementing	8 TIS functions Niche development pathway Business strategy, model, case	SNM patterns Roles Actor frameworks Treatment of complementarity Compare context + pathway scenarios	

Figure 12: Evolution of the line of enquiry to storage niche development in Ontario

Once the analysis of each quadrant's contributions to the niche development activities was achieved, follow-on questions regarding who is managing the development of this niche and whether it is being strategically managed are addressed. Other questions were used to understand the link between niche development and the storage developer's business development pathways, and the overall niche development pathways that were expected. These questions (shown in Figure 13) were used to produce a more comprehensive narrative and to answer the ultimate research question about the influence of complementarity on the development of the distributed storage niche in Ontario.

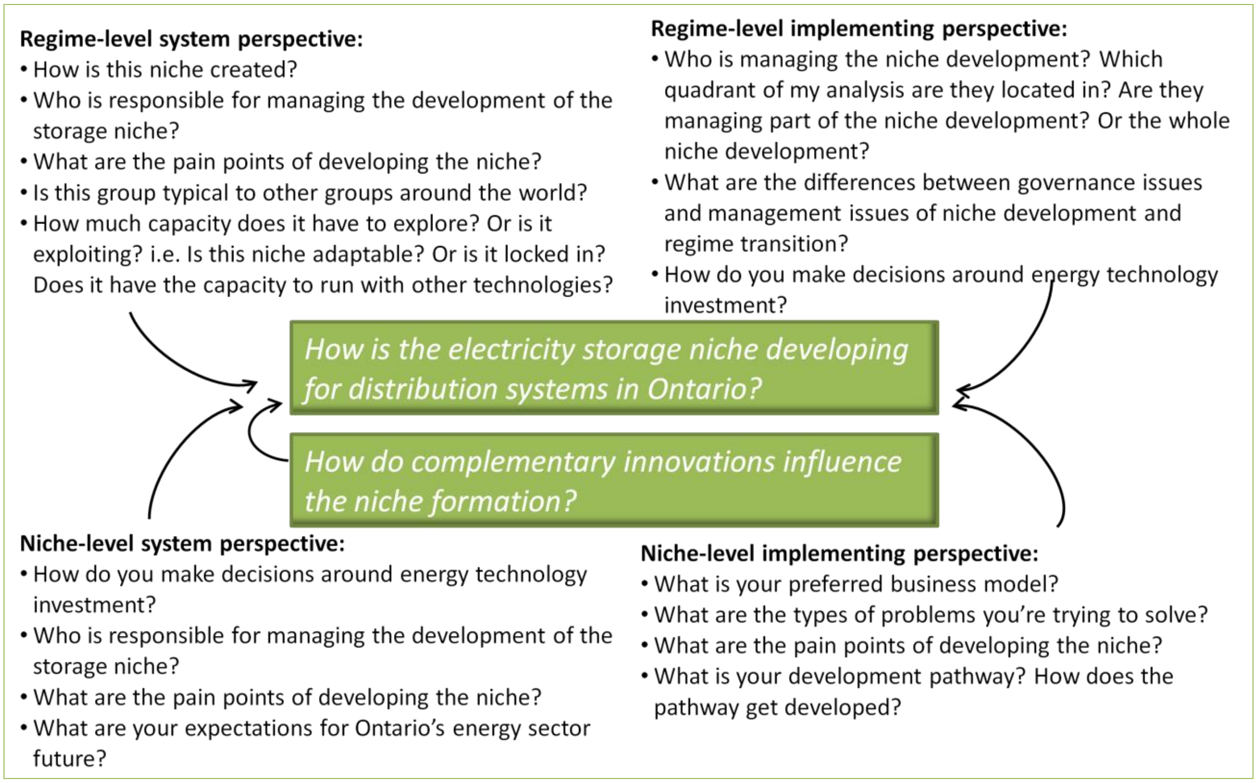

Figure 13: Sub-set of questions that emerged during data collection and analysis

These questions could not be answered by all respondents and the data from publicly available resources was not always conclusive. They represent the types of questions that respondents were able to explore regarding regime transition and niche development in their response to the questions in the Interview Protocol in Appendix 1.

Using SNM and TIS frameworks to understand storage niche development in Ontario

The Strategic Niche Management (SNM) framework guided the analysis to answer the primary research question about how the storage niche is developing in Ontario. The contribution from each of the quadrants of actors to the three clusters of niche development activities: articulating a vision and setting expectations, building social networks and learning processes are explored in this sub-section. The description of their contributions uses functions from the Technology Innovation Systems (TIS) model to illustrate the types of activities that contribute to those SNM processes, and provide more of a sense of associated roles or strategies adopted by the actors. The relationship between the use of the TIS functions and SNM processes as they are used in this research is illustrated for niche development in Figure 14.

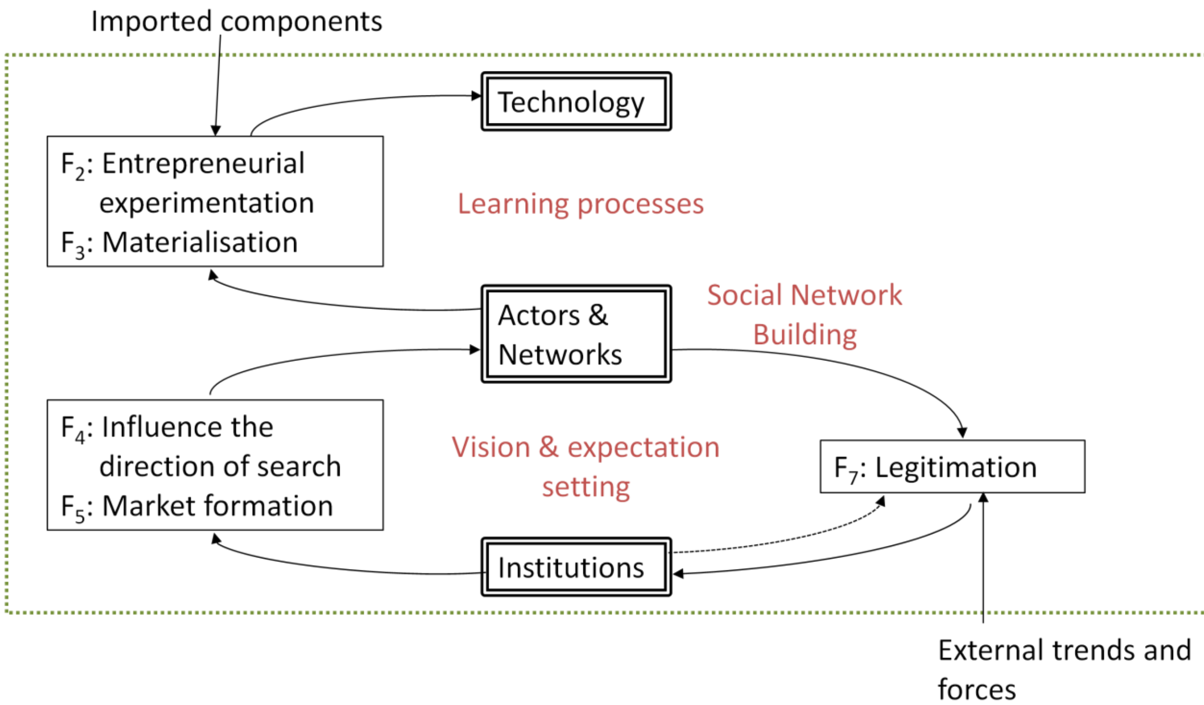

Figure 14: The formation of a TIS presented in Bergek et al. (2008, p.580) with clusters of SNM activities (Schot & Geels, 2008) indicated in relation to the cycles as used in this analysis.

Several themes that were not merely synonyms for the 8 TIS functions or SNM processes were used by interview respondents. They are described in Appendix 2 – Respondent terms and their relation to TIS and SNM processes as they related to innovation system functions and strategic niche management processes. Under the landscape forces and each quadrant of actors, Figure 15 maps the contributions to the storage niche development in Ontario to functions of the innovation system. These events and actor behaviours were included in Figure 15 based on the responses of interview participants and the relatedness of events occurring during the course of the study to storage technology development in Ontario. The following sub-sections describe the evidence observed for each of the functions in Figure 15, with a more detailed exploration of the role of the Smart Grid Forum in supporting TIS functions and SNM processes.

Legitimacy of Ontario's Storage Niche

Legitimation was a major focus during interviews with all actors, as was expected given previous work by Bergek et al. (2008). At the niche-level, the entrance of new innovating firms developing storage technologies and business cases in Ontario provides some requisite evidence of a niche developing. However, according to many respondents, the legitimacy of storage as an expected niche to be developed and integrated into Ontario's electricity system had more to do with regime-level activities.

Landscape	**Legitimation** (Global smart grid development, white papers on storage) **Knowledge Development & Dissemination** (EPRI, SANDIA, IEA reports) **Market Formation** (Public pressure to phase out fossil fuels, Climate Change movements, early customers)	
Regime	**Policy/Regulation** ***Legitimation*** *(GEA (2009), Clean Energy Task Force (2012), Clean Energy Institute (2012))* ***Market Formation*** *(system demand created through FIT and TOU, market certainty unclear with current regulation and market/energy contract rules)* ***Guidance of the Search*** *(Long term Energy Plan (2010) with direction to explore storage, Directive to OEB on smart grid (2010) with Smart grid principles and objectives, including the ability to integrate storage in one of the objectives. Smart Grid Forum developing framework for storage, and providing Smart Home Roadmap)*	**Production/Delivery/Consumption** ***Legitimation*** *(LDCs produce smart grid plans, and participate in Smart Grid Forum)* ***Guidance of the Search*** *(LDC Smart Grid Plans, partnership in demos)* ***Resource Mobilization*** *(partnership in demos, strategic advice, future investment limited by regulation on rate recovery for storage)* ***Market Formation*** *(Early customers participate in demos, LDCs recognize business case for storage)*
Niche	**Incubators/Investors** ***Resource Mobilization*** *(MaRS and other incubators support storage start-ups and technology commercialization with business strategy support and partnership networks, OCE, NRCan, SDTC fund demos , Universities partner in technology development)* ***Knowledge Development & Dissemination*** *(through system and implementing networks, supporting and sharing new IP through partnerships)*	**Storage technology innovators** ***Legitimation*** *(Temporal Power, Hydrostor and eCAMION enter market to join approx. 20 others[1] in this space as Ontario entrepreneurs or suppliers.)* ***Entrepreneurial Experimentation*** *(Storage solutions in early commercialization stages)* ***Knowledge Development & Dissemination*** *(new IP through partnerships)* ***Market Formation*** *(Demonstrations and pilots increase market confidence and provide reference customer, Energy Storage Working Group of Smart Grid Forum makes recommendations for regulatory change)*
	Systems	**Implementing**

Figure 15: Current functions of distributed storage innovation system

[1] This number was estimated based off of the entrepreneurs and suppliers listed in the Storage Group Working

Legitimacy was a subject explained in the most detail and comprehensive manner by the regime and niche system quadrants of actors. All actors in the system indicated a need to see a locally recognized problem, and a strategic intent to develop solutions locally. Although it was not expected that all solutions would be developed locally, there had to be some demonstrated interest in attempting to develop solutions locally. Key government instruments, including the Green Energy Act (2009) and the Long Term Energy Plan (2010) and the programs that followed, including the Feed-In Tariff (FIT) for renewable generation, were attributed with affording legitimacy to the creation of a storage niche, or cluster. This was by virtue of creating a technical need or demand in the system, and by setting expectations for the strategic intent of the regime actors. This guidance of the search doesn't necessarily have to appear deliberate or explicit, but must be recognized as an overall strategic intent. As this respondent explained it:

> ***NS-4:*** *"I think there is an emerging storage cluster and there is an emerging Smart Grid cluster coming. And I think it's being driven by some of the work that was creating the Green Energy Act. And there will be -- I think the number is about 2,000 megawatts of energy coming on stream over the next couple of years ...And moving that energy around properly is going to create a little industry and expertise that can be marketable in other parts of the world. And that basically defines a cluster the way we've had a telecom cluster and so on. So I think the answer is, yes. And I think it was an unexpected collateral. I think it will be an unexpected collateral benefit of the Green Energy Act."*

Regime system activities that provide a direction or guidance of the search also provide legitimacy to the development of the storage niche. The direction provided to the firms, can also indicate an active interest by regime system actors to support the adoption of niche innovations into the regime. As this actor from the niche system quadrant explained:

> ***NS-4: "*** *But there is a lot of uncertainty about them because anything to do with energy you figure there are regulatory things surrounding it, so a lot of times we wonder, okay, what are the approvals for this type of thing? Unless it's something that plugs into the wall and its CSA and end user project then that's one thing.*
>
> *But anything that sort of behind the plug and requires approval, then all of a sudden that's an immediate question there because there's all sorts of approvals and bureaucracies and so on that companies would have to go through"*

Addressing this barrier, the Ontario Minister of Energy issued a directive to the OEB in 2011 that provided smart grid principles and objectives that the OEB should follow when creating and enforcing regulation for Ontario electricity sector participants. The principles and objectives are included in

Appendix 3. Under the focus of creating and maintaining adaptive infrastructure, the directive issues an objective of flexibility with specific note of storage technologies:

> *"Provide flexibility within smart grid implementation to support future innovative applications, such as electric vehicles and energy storage."*

With a supporting objective to encourage innovation:

> *"Nest within smart grid infrastructure planning and development the ability to adapt to and actively encourage innovation in technologies, energy services and investment/business models."*

This directive is supported by work done by Ontario's Smart Grid Forum, convened in 2008. Chaired by the IESO, this network provides a less formal environment for major stakeholders in Ontario's smart grid future the opportunity to develop a vision for smart grid in the province. In addition to a number of other functions, the Smart Grid Forum provides guidance in the search for storage technology business models, cases and technologies that will successfully capture markets.

Relevance to storage niche development:
Actors in the system indicated a need to see legitimacy of the development of a storage niche in Ontario at the niche-level and the regime-level. At the niche-level actors in the system need to see new entrants developing technologies with local business cases based on the technical needs of the system. At the regime-level, actors in the system needed to see a local problem with some direction and indication of intent to both adopt and develop these technologies locally. In this way, legitimacy is tied to the coordination of vision and expectations of all actors involved, and also a participation in learning processes. This creation and coordination of vision and expectations is explored in more detail in a later sub-section. The relationship between the regime shift to smart grid and local storage solution development is introduced with the function of legitimacy and will be explored further through other functions and the SNM processes.

Ontario Smart Grid Forum: creating a vision, setting expectations and building a network of support for storage technologies in Ontario

The Ontario Smart Grid Forum serves primarily to coordinate the development of a vision and expectations for smart grid in Ontario. This vision includes storage as a component. In its 2009 and 2011 reports, the Smart Grid Forum submitted recommendations to the government and administrative and regulatory bodies under the vision created by its members. The Forum membership from the 2011 report is included in Appendix 4. Forum members include actors primarily from the regime implementing quadrant, and also the regime system and niche systems quadrants. By the publishing of the second report, the Forum included a Corporate Partners Committee. This committee draws together experts from the regime and niche-level firms (actors from the regime and niche implementing quadrants) that would contribute to a regime transition and the development of a range of smart grid technology niches. Under this committee, an Energy Storage Working Group[2] was formed. In April 2012 it presented three major recommendations to the Forum for integrating storage technologies into the Ontario grid. This Energy Storage Working Group is led and driven by a handful of storage and demand response technology developers, indicating a level of coordination and legitimacy to the development of the niche.

Both 2009 and 2011 Forum reports include specific discussion and recommendations regarding storage. The 2011 report called for the IESO, OPA and OEB to collaborate on creating a framework to promote the integration of storage with the grid. This recommendation would in effect create the market rules regulation required for the formation of a storage market in Ontario that would permit LDCs and other actors to participate in Ontario's energy markets and recover costs for investments in storage technologies. The recommendations made by the Energy Storage Working Group informed the design of this framework for storage with the following three recommendations:

- Modify market rules to recognize the inherent differences and benefits of Energy Storage applications.
- Change structure of IESO ancillary service contracts so that Energy Storage assets are eligible where it makes economic sense.
- Establish a consistent, transparent mechanism to value the defused benefits to the ratepayer.

Each of these recommendations deals with market formation through activities by regime systems actors. It is delivered in a way that influences the direction or guidance of the search by further articulating a vision to be shared by the other regime and niche-level actors. The regime systems actors have lent legitimacy and engaged in an expectation setting exercise with their release of a Discussion Paper (2012) authored by the Smart Grid Forum Working Group and released in April 2012. This Discussion Paper is the deliverable from the action item that the Working Group received in order to address the storage recommendation in the May 2011 Smart Grid Forum Report. In addition to a review of the technology development status, the Working Group began to link beneficiaries and market

[2] Energy Storage Working Group members include: Enbala Power Network, Temporal Power, Hydrogenics, Hydrostor, and S&C Electric.

incentives to storage technology benefits. Figure 16 is taken from the Discussion Paper, and shows how LDCs and other regime implementing and niche implementing actors are expected to participate in integrating storage technologies into the regime according to the benefits they could claim.

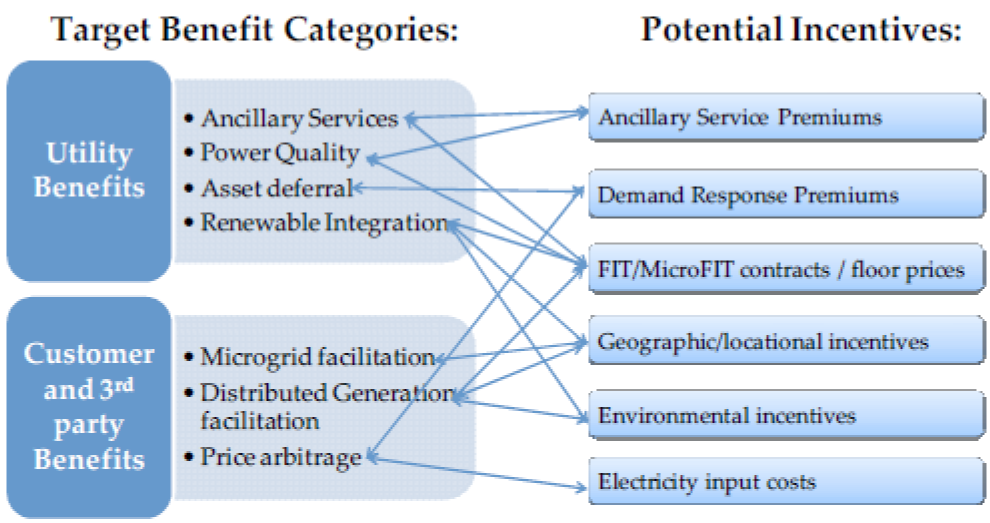

Figure 16: Linking benefits to incentives. Image taken from (Ontario Smart Grid Forum Working Group, 2012)

The Discussion Paper then identifies which regime system actors and regime implementing actors would be responsible for creating the incentives and linking them to the benefits. It goes another step further by anticipating the problems that will need to be addressed in creating those incentives. It links them to storage benefits by presenting a problem tree around developing a framework for the integration of energy storage where it is cost effective.

The Discussion Paper then identifies organizations that would need to be involved in solving each of the problems in Figure 17. It also provides guidance for the problem solving goals with statements that answer "Why solving it is important to the development of the storage integration framework." It closes with recommendations on determining an order of priorities of problems to solve and an effort to manage expectations in the problem solving effort by regime and niche-level actors shown here in Figure 18.

The Smart Grid Forum's work appears to serve a critical role in the SNM processes of creating a coordinated vision, setting expectations, at least at a high-level. It also builds a social network that storage developers have been able to join. Many of the members of the Forum are those who in their formal roles within the electricity system would be required to support the transition to smart grid, and influence niche development. Thus it is possible that the current dynamics of regime transition and niche development could be observed without the Forum's activities. However, according to many actors interviewed, this less formal organizational environment appears to provide a supportive environment for the co-evolution of technology and society that Geels and his peers in transition management refer to in their literature (F. W. Geels & Schot, 2007; Kemp & Rotmans, 2005; Loorbach, 2007; Raven et al., 2010; G. P. J. Verbong & Geels, 2010).

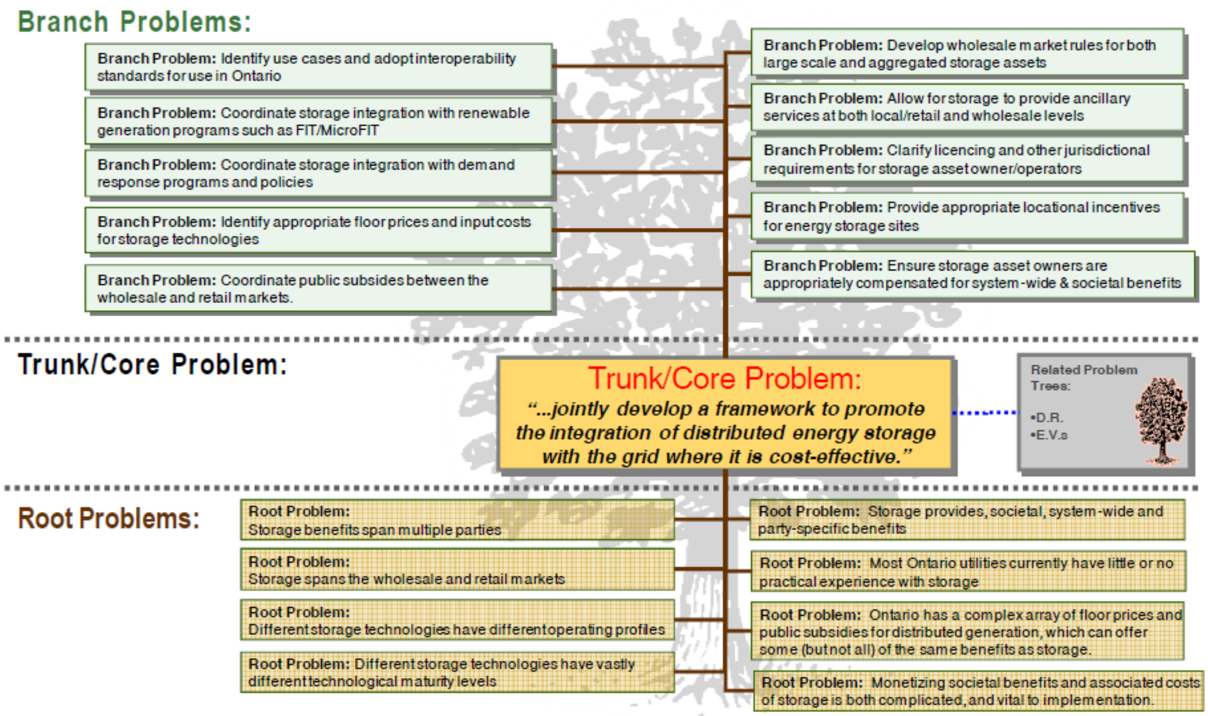

Figure 17: Emerging problem tree for the development of Ontario's Energy Storage Framework. Image taken from (Ontario Smart Grid Forum Working Group, 2012)**.**

The Forum is chaired by a regime system actor, the IESO, which appears to afford the Forum the legitimacy it needed to engage other actors, and to maintain momentum on solving the issues raised. When compared to the niche-lead Ontario Energy Storage Working Group, for example, that group has not remained active following the writing of the Storage Working Group Briefing Paper (O'Malley, 2010). It can be noted, however that a number of the same niche and regime implementing actor organizations that were active in the niche-lead group are now active in the Smart Grid Forum.

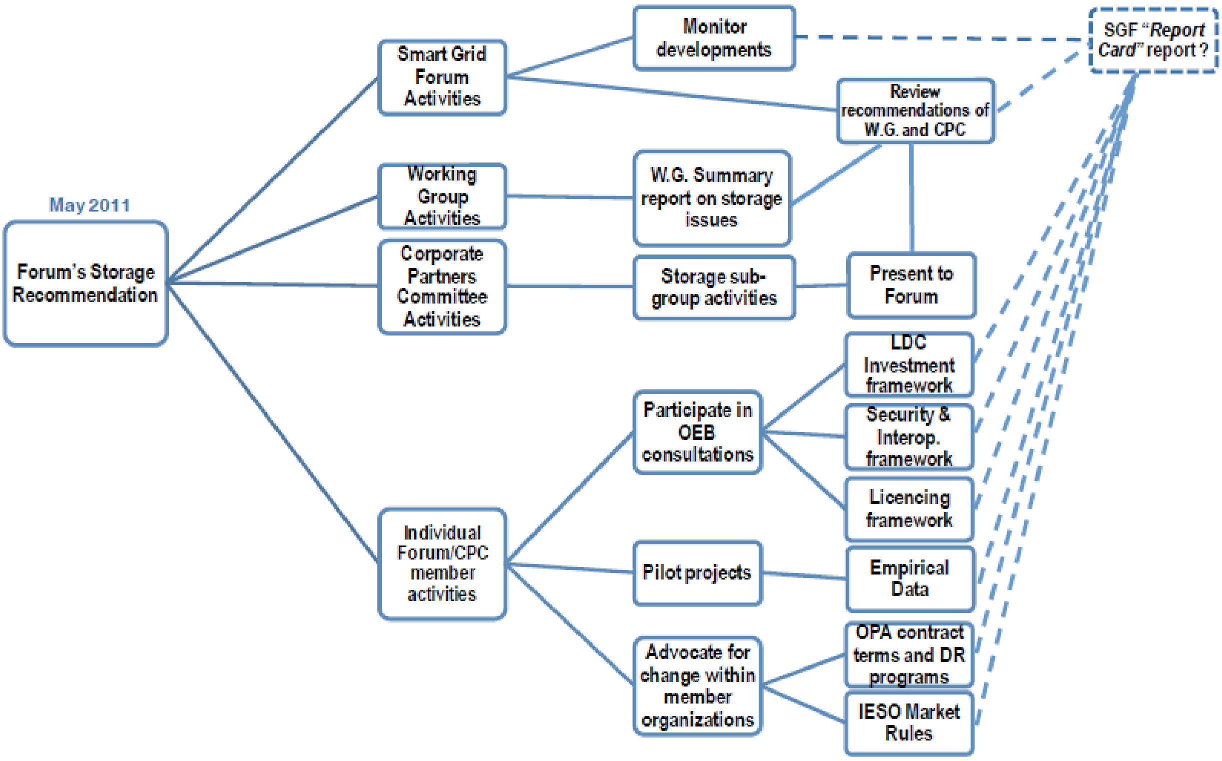

Figure 18: Potential problem solving activity pathway for developing an Energy Storage Framework in Ontario. Image taken from (Ontario Smart Grid Forum Working Group, 2012)**.**

Relevance to storage niche development:

The Smart Grid Forum activities, with participation from the Energy Storage Working Group, house some key TIS functions and facilitate SNM processes. The TIS functions of market formation, guidance of the search and legitimacy, in particular, are supported through the Forum reports, recommendations and tasks to working groups. The incorporation of storage into the overall vision for smart grid also provides an indication of how the development of positive externalities to storage, namely the development of other smart grid technologies, is supporting the development of a storage technology industry. The coordination of a vision and expectations for smart grid through a less formal, more flexible network appears to support the shift of the regime to smart grid, and the development of a local storage niche. The development of that vision requires the building of social networks within the forum that can then be seen to facilitate the participation of actors in learning processes. This is illustrated by the publicly funded demonstrations described in a later sub-section.

Market formation for Ontario storage technologies

Regime systems, implementing and niche implementing actors indicated a responsibility for market formation that extended beyond participation. This is evident in the language of the Smart Grid Forum materials, and from interviews with regime-level actors. The regime systems actors indicated a strong mandate to support the stability of the existing regime, while still promoting niche development to satisfy to the Ministry of Energy policy objectives for smart grid.

For the regime systems actors, the responsibility was described primarily around removing barriers to market entry and by maintaining a market that would be "fair." As one regime systems player put it:

> ***RS-5****: "I want to make sure whatever framework we have at the end of the day has a realistic encapsulation of what are the operating characteristics of these facilities, regardless of what you call it. Are we actually capturing the right characteristics? Are we choosing an appropriate economic model to treat this on an equal footing or the correct footing, if you will, in comparison with public subsidies that we're giving to distributed generation for example and that sort of thing, and make sure we have an even playing field? Are we giving a particular bias to one technology or another and if so, is that intentional or is that by accident? We've got to be really careful here.*
>
> *Here in Ontario, we have a sort of mix in public subsidies for certain types of assets and then we also have an open electricity market.*
>
> *So if we're going to have some additional contracts or subsidies for one technology, we've got to be really careful here that we're not unintentionally building a bias for one over the other. If we are going to do that, then we have to make sure there's a good public reason why we're using public money to promote one of the expense of another or over another, if you will."*

This attention to fairness can also be seen in the language of the Smart Grid Forum Working Group (2012) Discussion Paper on creating an energy storage framework for Ontario. The Discussion Paper presents a table (p.10) that identifies actors who need to be involved in solving problems to creating a storage framework. This table uses language that revolves around principles of fairness in the market under the column on motivations for solving the problem.

A critical contribution to market formation for storage technologies is the increased generation in Ontario from variable sources of electricity, particularly wind. This lead several actors to recognize the Feed-In Tariff (FIT) for renewable generation in Ontario as a key policy supporting smart grid and storage technologies by creating an operational need for it. These regime-level actors observed:

RI-1: *"If the micro-FIT/FIT was not here, I'll tell you right now, we wouldn't be doing storage. Because a big value chain is that variable generation. We would not be doing storage in the way we are attempting to do it."*

RS-3: *"So they sort of, so they drove FIT...and certainly if you have a lot renewables, you need some solution to the intermittency of the renewables for your system to operate."*

For the implementing actors at the niche level, market formation activities and responsibilities were related to supporting the creation or modification of market rules, and in engaging potential customers. This engagement was primarily evident in the niche implementing actors' ability to secure demonstration partners for projects in Ontario. For most storage developers, the initial focus was on LDCs as customers, but other potential customers were identified for medium and longer-term markets. Market formation efforts were also evident in the business models designed to provide customers with a package solution to a particular problem, as opposed to just supplying a technology or component of the solution. Publicly funded demonstrations are also effective mechanisms of informing future market rules and policy in order to remove barriers to market development. A range of methods of engaging customers and using the results to support the modification of market rules are illustrated by the niche development pathways outlined in the next sub-section.

Potential early stage customers from the commercial and industrial sectors were interviewed as respondents from the regime-implementing quadrant. These customers ranged in their level of interest for storage technologies, and in their levels of awareness. The most conservative responses focused on payback periods, while the most risk tolerant responses discussed multiple value propositions, life cycle analyses, and corporate sustainability strategies. One of the more risk tolerant potential customers was a property manager who described:

RI-13*: "First of all, simple payback is not how we work. When we recommend any measure or anything in regards to either greening the building or energy conservation, simple payback is the very first and the most simplistic approach that you could take to generally explain this is what you are going to put in and this is when it's going to go out.*

However, if you are having a situation where, let's say, two simple things. You are having ECM, Energy Conservation Measure, to finely tune the boilers. And you are having, again, ECM number two to retrofit exit lights from incandescent bulbs to something more practical like LEDs.

These two projects might be carrying the same price tag. However, they are substantially different. Simple payback as a method cannot distinguish between them. It would be the same thing.

> *However, that is why we are requiring, and actually that's part of our standards, we are requiring some kind of a lifecycle metrics, some of the methods being ROI, return on investment or net present value or whatever, there are four of five methods, to understand the difference between the two, under the umbrella of lifecycle metrics."*

Early stage customers who were more risk-tolerant and more sophisticated in their management of energy projects, discussed demonstration opportunities and recognized the value of participating in demonstrations as a means of gaining a competitive advantage. These customers exhibited a valuable capacity to inform niche technology and business development. This valuable input was also observed from the LDCs working with niche entrepreneurs as future customers. The less risk tolerant potential customers asserted that the development of storage technologies would be the responsibility of LDCs and regime system players.

Relevance to storage niche development:

Market formation is an activity that both niche and regime-level actors are participating in and appears to be regarded as a responsibility for both niche and regime actors. This participation by both regime and niche actors further demonstrates a relationship between the regime shift to smart grid and storage niche development. Niche implementing actors have a responsibility to lead in customer engagement (largely through demonstration projects in the early stages) and to contribute to the modification of market rules and removal of other market development barriers. Regime system actors have a responsibility to remove market barriers to niche development while maintaining the fairness of the market. Some potential customers recognized themselves as having a responsibility to helping to define the solution to their problems through their participation in demonstration projects. The strategic intent of the regime actors in market formation is further explored as evidence of the relationship between the regime shift to smart grid and the local development of storage innovations in a later sub-section on the learning processes observed in this niche development.

Storage innovation inputs: knowledge, talent and funding

The remaining functions identified in Figure 15, resource mobilization, knowledge development and dissemination, and entrepreneurial experimentation are discussed here as the direct inputs to the immediate environment that storage entrepreneurs are working within. In the formative stages of firm and technology development for storage, most resources were made available through or by the niche system actors. Universities, incubators, public demonstration funds are all playing very influential roles in attracting and supporting new firms according to the niche implementing start-ups interviewed.

NI-4: "*I actually think we have very good innovation ecosystem here. There are a few points where [we] came close to no longer being in existence as a result of lack of being able to access funds that would help us move along at a very early stage, before we received seed money..*

I suspect many great ideas got lost at this stage.

But I think once the ball got rolling, we have been well supported -- we have been fortunate that we have been supported by the Ontario government, the Federal Government Hydro One, OCE, and Toronto Hydro. I feel like now we have started getting to get to the point where we are seeing success from early stage companies. Yes, we want new technologies; we want innovation, we want them to be successful; we want the best technologies in the world. I think we are seeing that happening."

Before the Ontario government's actions to provide guidance and legitimacy to storage technologies through smart grid in Ontario, these niche system actors were contributing to the public knowledge and awareness of storage technologies. For example, respondents highlighted a storage workshop organized by the OCE in 2008. Others referred to many conference presentations on the benefits of storage, trends and technology attributes. These were conducted locally and internationally by the regime implementing and niche system actors in particular. It appears that support for storage entrepreneurs had been gaining momentum before resources for business development became more available.

The older, more established storage firms interviewed also recognized the importance of these niche system actors in developing new technologies and business lines. According to one firm, these niche system actors were quite influential in the early stages. However, at this point their interaction is mainly limited to demonstration funding and partners, and supports to R&D like the Scientific Research & Experimental Development (SR&ED) tax credits. This interaction seems to reflect the maturity of the firm as opposed to a deviance in the pattern of responses, and gives an indication of what might be expected from niche-system and regime implementing actors as the niche develops as a whole.

Moving from the initial stages of technology development into business development and technology demonstration, niche-level actors discussed the mechanisms of securing investment. As the niche system quadrant of actors explained, investment support for electricity storage technology development relies on the legitimacy and guidance of the search afforded by the regime system actors. One incubator recognized this with financing renewable energy projects in Ontario:

***NS-2**: "What is really important is that the financial community not blink. Because it's taken 2 years for the big 5 Canadian Banks to suddenly decide, 'I'm going to build up enough internal capacity, in terms of people's abilities and departments and whatever, that I'm going to be able to lend money for big renewable project finance.' And that's finally happening. And if we blink and show that the political risk is real they'll be like 'Well, why did I invest all of that time and* *money? I told you!!' Because banks are the most conservative people in the world. And it's banks that decide what equipment gets installed. Not utilities. Not CEOs, not governments, it's banks."*

Looking forward to investing in storage technologies, an angel investor similarly remarked:

> ***NS-4****: "Yeah, I think Angels have gotten to the point where they realized there are many macroeconomic determinants of success, in the sense of historically Angels would have said, look at the micro-determinants of success. How good is my business plan? Do I have a good management team? How good is the product and so on, right? And they would have said I can't bother with any of the macro-determinants. I can't do anything about them, so I'm not going to worry about them, like how strong is our dollar, what's our currency risk. I can't do anything about those.*
>
> *But all these things play a role, right? And what incentives are there for -- we're doing something in electricity here, what incentives are there to encourage engineering talent to come out, what are the research grants --*
>
> *... because I don't think there is a jurisdiction in the world now that isn't encouraging, trying to encourage innovation in some way through some sort of policy mechanisms, whether it'd be tax, whether it'd be whatever, because it's no longer a laissez-faire world. You just need too many -- there's too many people trying to make things happen and the economy has been suffering for years, right?"*

The combined view of various actor roles is depicted in Figure 19, where regime actors are in blue and niche actors in green. The identified needs of niche development, and enabling the related shift of the regime, are listed below the actors who require resources in order to develop the niche. The arrows indicate the identified providers of these resources. No single organization was identified as one that could provide resources to satisfy all of the niche development needs. The providers of the resources necessary to enable the early customers or business partners are represented in dashed lines because there was some debate about who is responsible for engaging customers. Some advocated for scenarios where the government would engage in power purchase agreements, something like the feed-in tariff or other procurement mechanisms of supporting local innovation. Others suggested that the business case existed without feed-in tariffs, but that customers required access to affordable financing.

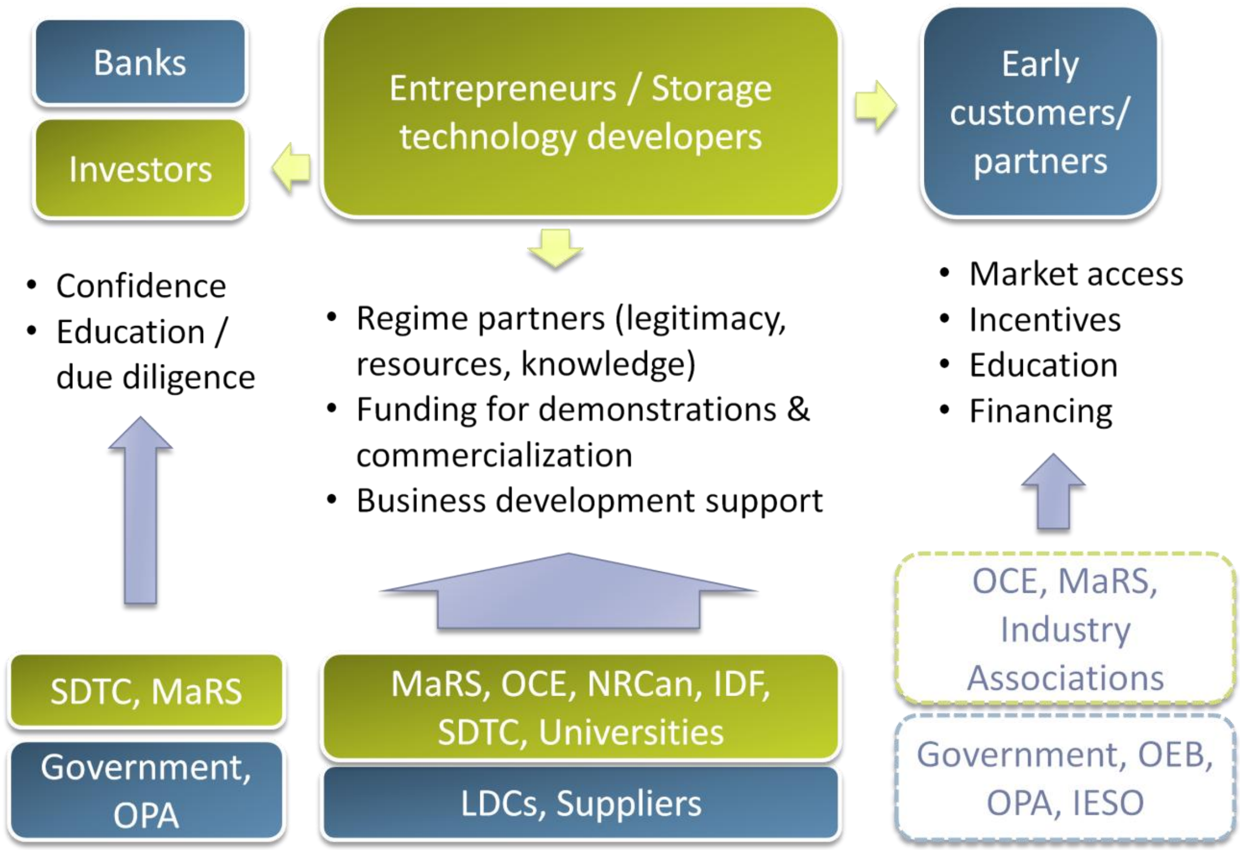

Figure 19: Current storage niche development environment and roles as described by niche-level actors

Niche-system actors identified regulatory and market uncertainty as major barriers to investment. The confidence that those actors need to invest in electricity sector technologies in Ontario requires a government policy or other instrument such as a feed-in tariff that indicates a strong level of regulatory and market certainty. Investors also require an understanding of the industry in order to make strategic decisions about investment. Organizations such as Sustainable Development Technology Canada (SDTC), who have a project screening and due diligence process made public and accessible through their website, play a role in educating and coaching investors and entrepreneurs as applicants. Further investor confidence is enabled through SDTC's client monitoring program to study firm performance and follow-on funding in the years following SDTC investment. Investors can choose from the portfolio of SDTC clients with some confidence in the due diligence that the firms have already progressed through.

> **NI-4:** *"...an organization like SDTC is hugely important. They have a rigorous process to access funding which is respected by venture capital groups and companies around the world and that provides innovative companies with a great access point to these important players.*

So by the time you have secured an SDTC project, you have a well respected organization, having done a technical and business due diligence of your idea, and said, yeah, if you can bring an industry partner and the rest of the funds, you are providing environmental benefit, money is there for you. And that alone makes you do all your business case work, all the things that you should be doing as a company in terms of planning out, and it puts a big stake on the ground for other people to look at and say, the due diligence is done, it's a little bit more palatable because one third of the cost is committed. So I think that's been a huge accelerator for the business."

Satisfying the storage entrepreneur's need for funding, partnerships and business development support was attributed to the public funding programs and partners from the regime implementing quadrant. LDCs use long-term plans and smart grid strategies to help inform the business development strategies of the storage entrepreneurs. One entrepreneur relayed the story of their company's early visioning and planning from an LDC's perspective of the role that the LDC can play in business model and strategy development:

NI-1: *"but it's like [this LDC] became sort of like the VCs. [With the LDC perspective that as an LDC]...'we access a lot of technologies, we do due diligence a lot of technologies, we inform and guide a lot of technologies, not as a board member but as a utility, but we are open, because we are a public entity, so a regulated entity.'*

'... So [the entrepreneurs] are willing to work with us...we like that they are coming with an empty slate but they have the capabilities of [developing a technology]. We are just going to inform them.' And that's how the conversation first started."

As this entrepreneur saw it, before their company was even at the demonstration phase, it was critical that the storage company consult with LDCs on their overall technology and business development strategy. Similarly, technology suppliers for storage entrepreneurs were recognized as increasing the perceived credibility of the project and provide the entrepreneurs with valuable input.

Finally, there were also several models for educating and engaging customers that are illustrated in the sub-section on Storage Niche Development Pathways. The early stage customers, who could also be demonstration partners, were identified as needing market incentives and financing support, in addition to the basic access described in the previous sub-section on market formation. Market incentives also included savings and arbitrage opportunities, aside from other forms of rebates and tariffs. However, before these incentives would have any effect, a level of electricity system and storage technology literacy was discussed as a barrier to overcome. Early customers and demonstration partners would be able to become engaged in projects or invest in technologies the more electricity and technology literate they were. The more risk tolerant of the potential storage customers from the regime implementing quadrant indicated that this literacy was not always a formal undertaking. As one potential customer explained:

> ***RI-8:*** *"I am looking it globally, like I mean, I think we are very much interested in Scandinavia, in certain parts of the world and I keep in touch with people that have similar, sort of similar interests like one of my very good friends is ...with TSSA, and [he] is one of these visionaries that believes that we're destroying the planet, but there is so many great opportunities, there are people like doing different things in different parts of the world and we are stupid for not assuming or not following their lead.*
>
> *... there are some very visionary people out there, and you will meet them and NRCan has some very visionary people. So again I think that over the years, I sort of maintained contact with people that I even go to advice, 'what do you think of the Stirling engine?' or something of that nature and 'do you see application?'*
>
> *So again I think maintaining those contacts is very important. So maybe they have perception, they learn something, they may think, oh, here is a good idea for you to consider. So that's how it works."*

Champions of niche development

All quadrants of respondents were asked if they recognized any champions for the development of a storage niche in Ontario. The subject of a champion allowed actors to explore different aspects of the SNM processes by identifying coordination points for vision and expectations, building a network and learning. None of the respondents could identify an individual or individual organization that they would consider the formal champion for the storage niche development in Ontario. They did, however, identify activities by regime and niche actors to champion storage technology development in Ontario. In the words of one niche implementer:

> **NI-4**: *"I think we are at the very start of having a real dialogue and a real look at the use of energy storage in Ontario. You start to see this with energy storage being mentioned by the Premier and ministers; the Minister of Economic Development and the Minister of Energy.*
>
> *I think at the Future of Energy Summit at MaRS, there was a major energy storage theme. There are champions within the industry. There are people who want to develop energy storage projects. Ontario has what I think is a cluster of storage technologies, including Temporal Power, including Hydrostor, including Electrovaya, including Hydrogenics, there are some great companies here."*

Many actors either recognized the IESO, or expected the IESO to be a champion for storage niche development through its work in market formation through the Smart Grid Forum.

***RS-7**: "I think the only champion that I'm aware of and I look at -- I'm not the best person in the world to talk to this, but I would say the IESO, Paul Murphy, has been -- you know they've been -- they're a champion of storage."*

***NS-5**: "Again I think there would have to be some kind of push from the electricity system operator and there will be a demand for it then. And then it will happen. I think you need that. You need it to be required for system stability. And until it's really required, nobody will ... it'll just be research in universities and stuff... it won't be something applied. It'll just be 'ya that's good to know, but we don't need it.' You have to need it."*

Along with the IESO, others recognized the OPA and OEB as part of a trio of champions required for new technologies to be integrated. The OPA acts as a champion for new technologies through their planning role with the electricity system in Ontario, and the OEB as the regulator enabling new entrants and LDC investment can indirectly champion niche development.

***RI-2**: "So I mean, currently the IPSP, the power system plan, is a bit of a joint document between OEB and OPA, but it is an OPA document. So you've got to get agreement or some aligned goals with OPA and OEB and in fact IESO (the operator) on the valued benefit of storage and how to put that capacity in place. And really, without those... without an OPA working on this file I don't think it's going anywhere."*

One LDC identified themselves as a champion for new technologies:

***RI-1:** "Because we in some way will lead the path. I think we have an obligation to lead the path, subject to regulatory [approvals]...and the risk you can take. You see, you can take a larger risk when you're a larger company. You can't take a risk when you're a smaller company. So in very many ways that's where it fits. We've got the capacity, the engineering capacity, when most utilities that are small don't have any engineering capacity. So you can afford to throw some good resources behind this. I would think that in Ontario, yes, we would be expected to lead, subject to regulatory approvals."*

And similarly some of the storage developers recognized utilities as champions of new technologies for the grid.

NI-4: *"If you're going to develop grid scale technologies, you need a utility who is willing to work with you and willing to allow you to look at data, willing to allow you to connect the grid and try out the solutions.*

It is something that is a necessity for energy storage if it's going to be a grid scale. We are very fortunate that local utilities in the Province that have been supportive of us, but it's a potential barrier if you can't get support of the utility. Utilities traditionally are quite conservative. They *are in the business of making sure everything works just fine. So a new technology can be a scary proposition.*

This will be a challenge for any energy storage company looking to prove itself on the grid level."

Still, many actors reported a lack of any clear champion for storage in Ontario that was coordinating efforts and maintaining momentum. For the most part this was attributed to the challenge of having the benefits of storage spread across the system, with no single actor standing to gain the most value from its deployment.

RS-8: *"No, it used to be Ontario Hydro then Hydro One was a bit involved in it and then there's this technology arm that been used to do pilots and technology things, but now they only do it when someone pays them to. So I don't think it's not organized like that. There's not a key body."*

NS-3*: "I mean the other problem with storage which makes it a very interesting academic case is that the business case is very complex because there are a lot of free riders... I mean this idea of multiple values has been-- there's lots of papers out of the U.S. on that and so --but it's a real situation because you end up with -- it's not economic for an industry to invest in storage because most large amounts of values accrue to the distribution utility or to the whole system"*

The storage entrepreneurs themselves were identified by niche system actors as champions for storage development:

NS-2: *"No it's local. I mean aside from the technical reports from Sandia, no it's local. It's Hydrostor CEO having a conversation with Toronto Hydro and GE about "Wow do we build this thing? What it is it for? How big should it be?" I mean it's happening on a very entrepreneurial level."*

NS-5: *"To me that's one of the reasons why Ontario is somewhat falling behind some other jurisdictions because we have like 80 distribution companies in Ontario. Hydro Quebec has Hydro Quebec, that's it. Of course Hydro Quebec is putting out charging stations and is doing the research. You know, it's just one company and they have all the incentive in the world, they have the whole chain. Right? They're the distributor, they're the generator. And so whatever gets sold, it's just directly profits for just them. And so for them there's such a good case. Plus their emissions are very low on electricity. It's all hydro. So it makes so much sense for them. But in Ontario you have this very fragmented system where you have, you know. A number of generating companies, one transmitter (so there's one bit of monopoly), but then you have all these distribution companies. So you don't have anybody who's naturally going to take the lead on this. Like OPG's not really doing work on storage. And so you sort of think "Who is?" then "Who will?" A small start-up is the only ones who are really going to do it."*

The maturity of the storage industry was also identified as a contributing factor to a lack of champions for storage:

> ***NS-4:*** *"I think it's hard. I think it's a new industry. I look at like parallels to telecom where you had champions come out like Terry Matthews out of Mitel, who has become like a super Angel. He's invested in dozens of companies afterwards and where you had an industry like Nortel in the 90s, and out of that company you would have had several hundred middle managers come of out of there with $2 million or $3 million in the 90s and a bunch of them would have become Angels or started up in companies on their own.*
>
> *You don't have that for storage. Like we don't have it or there aren't any RIMs yet...we don't have 200 storage guys with $2 million in their pockets to start new companies because they've had 15 years careers in storage and some expertise and understanding of the marketplace that they're going to start it.*
>
> *We've got young engineers who've been maybe with the utility or somewhere else and see this as a need and they're going out there but, they don't have that first stake to bootstrap something unless they have from their -- it's a different dynamic. There's the ready comparison compared to computer industry or the telecom industry and you look at what Nortel and Mitel did in Ottawa and then what RIM did in the Waterloo area and all the companies that have started up, we just don't have that for energy storage."*

Championing of storage development in Ontario, through the coordination of activities, vision and expectations seemed to be served most by the Smart Grid Forum, or the Forum's membership. As evidenced by the membership list provided in Appendix 4 – Ontario Smart Grid Forum Members, the Forum's members represented most of the champions discussed in the interviews. This collection of champions is roughly identified in Figure 19. Analyzing the activities of this collection of champions allowed for insight into the degree to which the storage niche in Ontario is being strategically managed.

Relevance to storage niche development:

The storage innovation inputs that characterize the immediate environment for storage entrepreneurs are provided by niche and regime-level actors. A single individual or organization is not unanimously regarded as a champion for storage technology and business development in Ontario. However both regime-level and niche-level actors are recognized as championing its development through knowledge development, resource mobilization and in leading or supporting entrepreneurial experimentation. This immediate environment existed in many respects before a coordinated vision and expectation setting for regime shift to smart grid started to appear through the Smart Grid Forum, Ministry Directive and other influential regime events noted earlier. This indicates that the development of a storage niche and a regime shift to smart grid are not tied in a causal relationship. However the regime shift to smart grid appears to foster an environment that is even more supportive to local storage development, mainly through the mobilization of resources.

Storage Niche Development Pathways

To tie the abstract concepts of innovation system functions, transitions and niche management processes to a firm's realities, niche-level actors were asked to describe their experience with and expectations of storage development pathways. Regime-level actors were asked to describe their experience and expectations with how new technologies, such as storage would be integrated into the system. Beginning with the niche implementing quadrant of actors, respondents described their firm's business development pathway. The development pathways described did not always start and end at the same periods. They are presented here in Figure 20, Figure 21, Figure 22 and Figure 23 as they were provided during the interviews. In effort to protect the identity of the respondents, and to facilitate comparison, these development pathways are identified here under the names "Start-up X" and "Public Company X."

Figure 20 shows the business development pathways that the storage entrepreneurs described during their interviews. Start-up 1 had more of a local focus to their business development pathway, while Start-up 3 had a pathway that relied on international customers in the near term to grow the company and deliver investors a return. Start-up 2 also looked to global trends and global customers for business growth. What all three start-ups had in common was that their business development relied on having an LDC as a reference customer through current demonstrations that would support their efforts to access other markets. These start-ups expected the Ontario market to take longer to develop in terms of regulatory and market changes than it would take to develop the technologies and business models. Their biggest pain points are currently around timing. Their strategy is to support their existence through short-term market opportunities, and time the building of their firm's capacity in order to ramp-up production and capture Ontario market opportunities once they become available.

The established firms were public companies with other core business lines. Their business development pathway also included international customers as reference customers in demonstrations. The Ontario market is of interest by offering potentially higher margins by virtue of proximity, but they also expected this market to take longer to develop than the technology. Public company 1 had the benefit of having lived through hype cycles before, which gave it confidence that the current market trends were sustainable. They referred to "shrewd customers" such as Walmart and Enbridge behind the emerging demand storage technologies which inspired a lot of supplier confidence.

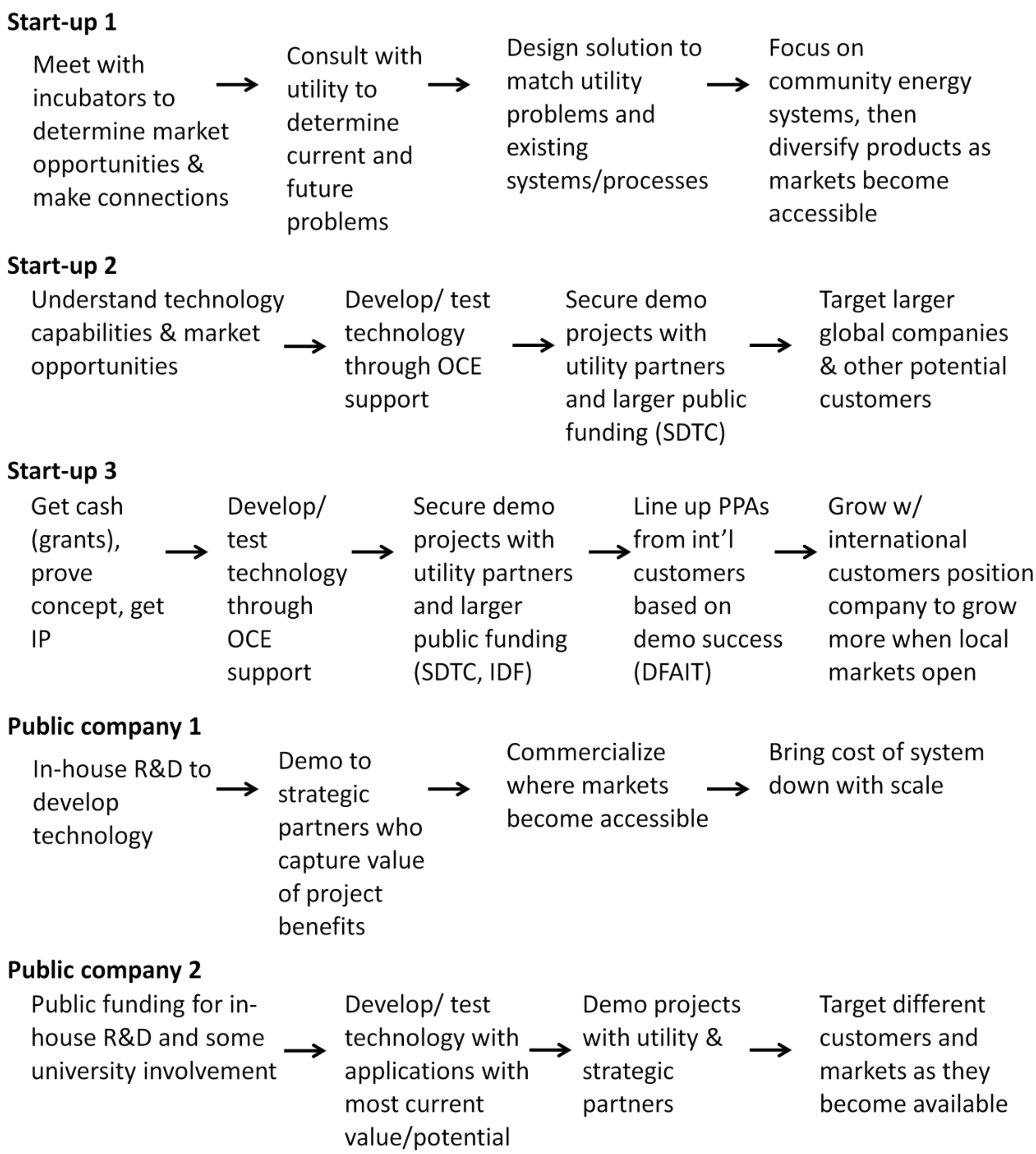

Figure 20: Storage entrepreneur experience and expectations of storage business development pathway in Ontario

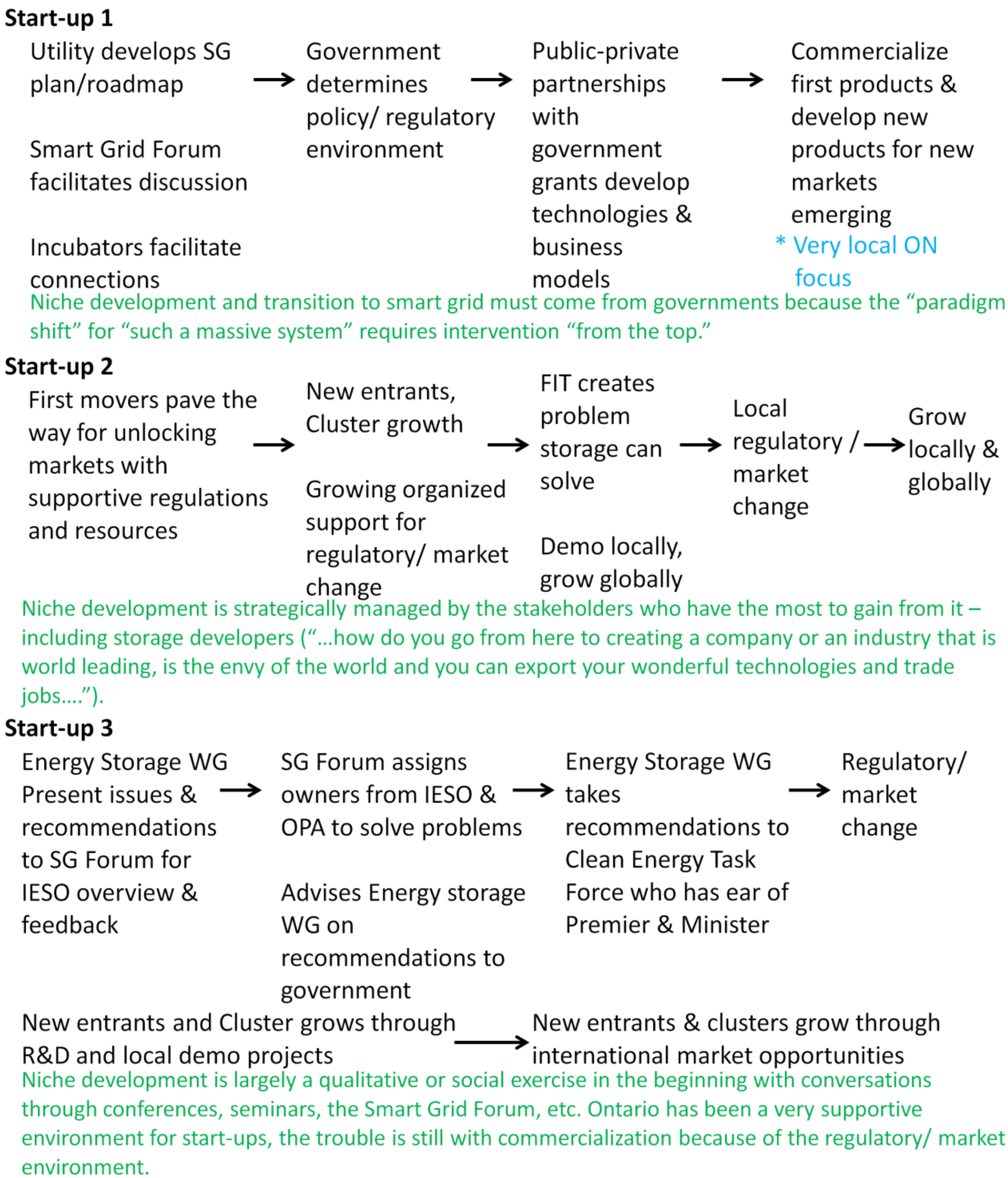

Figure 21: Storage start-up firms' expectations for the development of a storage niche in Ontario

Speaking more broadly of a storage niche or cluster in Ontario, Figure 21 and Figure 22 show niche implementing actor expectations for niche development and regime transition, each as part of their expectations for a development pathway. Start-up 1 gave a detailed expectation for local pathway development, while Start-up 2 and particularly 3 described niche development pathways which included international customers and partners as a necessary part of firm growth. All three start-ups expected that the niche would be strategically managed by regime system and implementing quadrant actors, as indicated in their development pathways. Start-up 2 and 3 also saw specific roles for themselves and other storage entrepreneurs in regime shift and market development. This was enabled by virtue of their participation in the Energy Storage Working Group which advises through the Corporate Partners Committee to the Smart Grid Forum.

These expectations for niche development were not too dissimilar to those of one of the public companies shown in Figure 22. However this public company regarded the development pathway to be primarily one of maturation; as more of an organic evolution as opposed to one that is so strategically managed. Still, action from the regime system and implementing quadrant of actors was expected during the process of regime shift and niche development. This company also saw themselves as having a role in regime shift and niche development through their efforts in market development. This company saw market development as supported through their work with codes and standards development. They also recognized the Energy Storage Working Group and Smart Grid Forum as enablers for regulatory change and market development.

These development pathways may not be entirely accurate in representing the niche entrepreneur strategies as they were not taken from strategic firm documents, and were simply what was described during the interviews. What can be taken from what is presented here is the variety of expectations for business development pathways that exist within the storage niche. This indicates a pattern of searching and adjusting of expectations for niche development and a persistent level of uncertainty about future market opportunities. Despite the apparent uncoordinated expectations, these pathways appear to present a consistent strategy of securing a local reference customer.

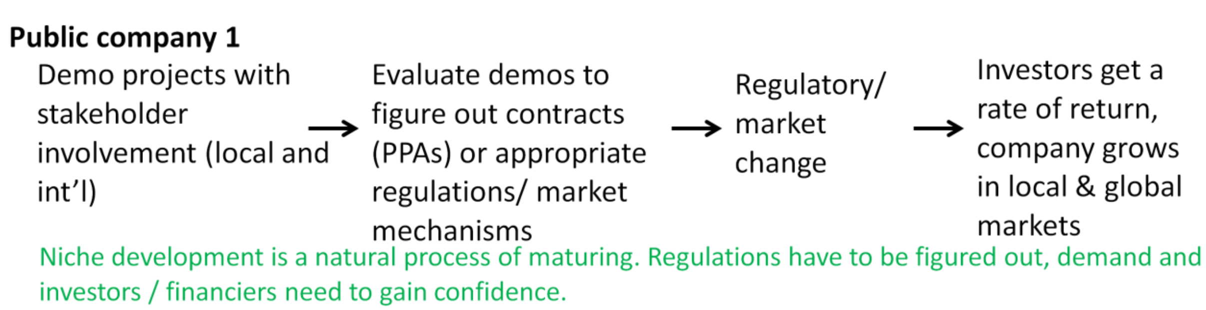

Figure 22: Established firm's expectations for the development of a storage niche in Ontario

These development pathways can be compared to those expected by the niche system quadrant of actors shown in Figure 23. Again, in an effort to mask the identity of respondents and to facilitate comparison, the respondents have been labelled as “Funders,” “Incubator,” “Angel Investor” and “Niche Association.” These actors generally spoke about development pathways for individual firms and broader niches in relation to their involvement. In some cases, such as with Funder 2, this meant that they spoke almost entirely in terms of regime shift pathways. The Angel Investor described a pathway that was more like a cycle of cluster development following individuals through the development of the niche. In comparison to the niche implementing quadrant responses which were firm-centric with regime change as part of the process, these development pathways tended to be either in regards to regime shift or in terms of business development. Regime shift and niche development processes didn’t seem to be so integrated in the minds of niche system quadrant of actors when asked to describe a niche development pathway. This is not to say that these actors saw no relation between these processes, only that there appeared to be a primary way of thinking about niche development that either focused on regime changes or business development.

The Incubator described a development pathway with the most reference to a storage entrepreneur’s business strategy. They described a niche and business development pathway that would allow firms to grow in the near term and be successful in the long term by separating the business purpose from the immediate business case for a product or service. This pathway and related strategy seemed most similar to the interviewed niche implementing quadrant of actors’ expectations for a storage niche development pathway, and for their own business development.

None of these development pathways should be taken to indicate that these respondents were viewing a storage niche in Ontario as a sure thing. Some respondents were more confident than others, and some discussed pathways to commercialization and integration into Ontario’s electricity system in terms of 15 to 20 years, while others expected market access in the order of 5 years based on studies of US markets. All respondents acknowledged that despite the somewhat liner pathways shown above, the niche development and related regime shift would be far from straightforward, and that there would be unsuccessful approaches along the way before any success could be achieved. As one niche-level actor described it:

> ***NS-3:*** *“It’s a classic case of difficult, risky technology on the one hand, market system need on the other, conservative parties all around who don’t want to be the first mover. The government is willing to take the financial risk, sometimes with demonstration. Although a demonstration is*

a two-edge sword, because for every demonstration that fails that probably puts another five to seven years into the system before they'll forget that."

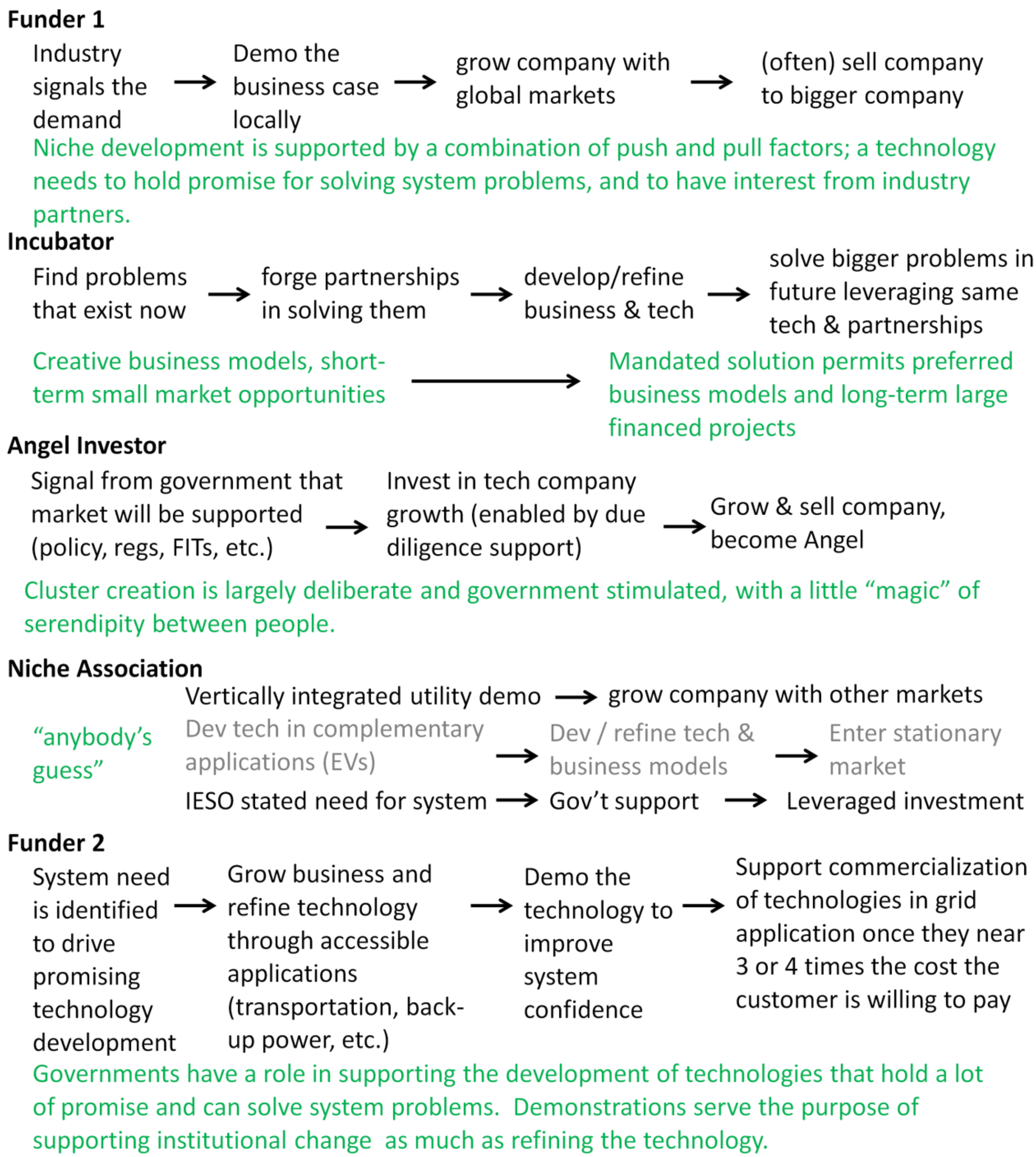

Figure 23: Niche system quadrant actor expectations of storage niche development pathways in Ontario

Preferred business models

To accompany these niche development pathways, storage niche implementing actors were asked about their preferred business models. This was to compare their approach to market formation needs and the possible roles of storage entrepreneurs in developing those markets. The actor responses are shown in Table 8 under the labels of start-up and public company.

Table 8: Preferred business models of storage entrepreneurs and the supporting market need

Actor	Preferred Business Model	Market Need
Start-up 1	OEM & storage solutions vendor for utilities; manage client relations and source the rest of the solution package.	Utilities need solutions that fit easily into their operations and asset management systems. Utilities need a business case that they can use for rate recovery.
Start-up 2	Manufacture, assemble & sell products to developers. Product developer not project developer.	Customers need an environmentally sustainable technology to provide ancillary services at competitive prices to the current solutions.
Start-up 3	Project developer. Manage customers & financing, contract out manufacturing, hire EPC to build rest of package. (Would like to be simply a technology vendor in the long term.)	Customers need support with financing and solutions that match or beat current solution's economics and environmental benefits.
Public company 1	Selling products to companies with the remaining components of the solution. Supply OEMs with this technology component.	Customers need to solve system-wide economic and resource problems with matching supply and demand (such as surplus baseload generation).
Public company 2	Developing battery solutions for utilities, but looking for other customers.	Customers need an environmentally sustainable technology to provide ancillary services at competitive prices to the current solutions.

Referring back to Figure 19, the market needs identified in this table seem to address the needs of LDCs and other large companies providing energy services. Other potential customers do not appear to be the target of storage entrepreneur business models, except for in the case of Start-up 3. Customers outside of LDCs and other large energy companies are likely to require more of a packaged solution, than simply a technology, according to Start-up 3 and the potential customers interviewed from the regime implementing quadrant. In many cases the business models described reflected those that were required to attain an LDC as their reference customer. Looking forward, the start-up firms indicated flexibility in the long-term business model depending on the markets to which these companies gain access. The public companies that had moved beyond start-up phase described more of a business model based on their existing business lines.

Decision-making frameworks

Linking the niche development and business development pathways to regime opportunities, the regime system and implementing and niche system quadrants of actors were asked about their decision-making frameworks for investing in storage technologies. Depending on their role, the actors considered this decision-making as a potential partner in development or as a customer. These actor frameworks were analyzed according to their relationship to regime shift or niche development and are shown in Table 9.

The same analysis of the potential customer and technology development partner decision-making frameworks is presented in Table 10. They are listed under the type of customer or partner to mask the identity of the respondent quotes and in order to facilitate comparison between responses. It should be noted that these decision-making frameworks reflect those described in the interview and do not perhaps reflect the formal decision-making frameworks for their respective organizations. Particularly for the LDC decision-making frameworks, the order that these criteria are listed are according to the emphasis in the interview and not according to current regulation or practice in some cases. They are presented this way in order to offer some insight into the internal mindset of actors in the regime implementing quadrant.

Table 9: Decision-making frameworks of niche system actors for investment in energy technologies

Actor	Decision-making framework	Related process
Funder 1	Companies with potential have an early customer (industry partner for a project) and a predictable commercialization pathway.	Niche development
Incubator	Is the business/product solving a current problem? Are they solving pain spots right now that partners will pay for? Are they addressing climate change problems that society needs solved?	Niche development Regime shift
Angel Investor	Understanding of technology & market Level of regulatory & market uncertainty Is there competition in the sector? External factors (previously focused on internal alone) of support/barriers to sector Standard Angel Investment criteria	Regime shift Niche development
Niche Association	Drivers of funders Opportunities for funding	Regime shift
Funder 2	Rough rule of thumb is that if technology cost is about 3 or 4 times what the customer is willing to pay its ready for demonstration investment.	Regime shift

Table 10: Decision-making frameworks for potential storage customers and development partners

Actor	Decision-making framework	Related process
Residential Low-rise Property Manager	1. Access to funds 2. Payback period (savings) 3. Incentives (must be commercial and installed in competition)	Regime shift
Residential High-rise Property Manager	1. Bottom-line 2. Payback period (savings) (must be commercial)	Regime shift
Residential High-rise Property Manager – Competing for 1st in class	1. Life-cycle analysis (includes payback, also ROI in competitiveness & asset value) 2. Vendor/Partner ability to meet standards (confidence in technology, direct experience with technology, interest in piloting)	Regime shift Niche development
Mixed portfolio Property Manager – competing for 2nd in class	1. Owner demands 2. ↑ profit margins for PM 3. Payback period 4. Low risk/easy to implement (must be commercial and installed in competition)	Regime shift
Commercial High-rise Property Manager - Competing for 1st in class	1. Competitive advantage for building & PM 2. ROI (↑ asset value) • Payback period (3 easy, 7 if benefits are large) 3. Building operations team capacity 4. Helps meet corporate energy targets (should be commercial, established company)	Regime shift
Commercial High-rise Property Manager - Competing for 1st in class	1. Competitive advantage for building & PM 2. ROI (↑ asset value) • Payback period (3-5 preferably) 3. Fits with Sustainability Strategy (should be commercial, confidence in technology, established company, interest in piloting)	Regime shift
University Facility Manager	1. Risk/Impact 2. Payback 3. Access to capital 4. ROI • Image (living lab) (most investments should be proven, tolerance for demonstrations if fail-safe)	Regime shift
Hospital Facility Manager - Competing for 1st in class	1. Payback 2. ROI • Image (Corp citizen, leading in healthcare)	Regime shift

	3. Risk to core business – patient health (has to be proven, can be beta test if fail-safe)	
Energy Consultant	1. Payback (savings in MW, $ and operations) 2. Incentives (should be commercial)	Regime shift
Industry	1. Payback 2. ROI (Arbitrage, market certainty) 3. Regulation (should be proven	Regime shift
LDC-1	1. Access to funding 2. Provincial direction 3. Reliability 4. Risk (R&D, demos + pilots)	Regime shift
LDC-2	1. Reliability + Asset deferral 2. Rate Recovery 3. Public funding 4. ROI (ancillary) (R&D, demos + pilots)	Regime shift
LDC-3	1. Profits to unregulated affiliate company 2. Reliability 3. Strategic asset management (demos + pilots)	Niche development Regime shift

* ROI = return on investment, PM = property manager

As might be expected, all decision-making frameworks for these actors were related to the regime rules. Only two of the respondents indicated decision-making processes that included factors targeted directly at potential niche development. In the case of the property manager, this had to do with a guidance role for innovating firms wishing to sell to them. In the case of the LDC, it was related to a business incentive for the LDC's unregulated affiliate to offer enhanced services at a profit. In each case, the incentive structures for these actors had a connection to niche development in order to become more competitive or increase their asset value. Otherwise these decision making frameworks indicated a level of conservativism that was expected of this quadrant of actors by all other quadrants of actors.

The responses in this table can also be used to reflect on the business models and development pathways presented in Table 8, Figure 20, Figure 21 and Figure 22. As observed earlier, most business models and development pathways were focused on satisfying the needs of LDCs. This choice of target customer is supported by studies into the different market values of potential storage benefits by Sandia Labs (Eyer, 2010) and other research and market analysis firms referenced by respondents. Many of the decision-making frameworks of the potential customers interviewed required the storage entrepreneurs to compete primarily on cost alone. However, some customers identified other elements of the value proposition that could support investment. For property managers competing for first class downtown buildings, this related to the opportunity to increase the value of the building on a market that is increasingly demanding “green buildings,” which may or may not be related to energy savings. As one niche system actor recognized, the business case is often not about money - it's about solving problems. The problems could be pollution, hazards or noise irritation or other NIMBY (not-in-my-backyard) problems with the alternative technology solutions.

Relevance to storage niche development:
The level of shared vision and expectations for storage niche development in Ontario can be interpreted from a comparison of business and niche development pathways, preferred business models and customer decision-making frameworks. Storage entrepreneurs appear to expect a range of development pathways and business models to lead to success for their firms, indicating a lack of a common vision and expectation between firms. What is consistent is that they expect to rely on a local reference customer as part of their business development. They also expect market rules and regulation to change through the participation of the regime system quadrant of actors in niche development and shift toward smart grid. The regime shift does not rely on niche development as indicated by the potential customer decision-making frameworks which focus almost entirely on regime conditions than niche development strategies. Storage niche development does not appear independent of the regime shift to smart grid in that respect, however the support for niche development is not expected to be satisfied completely through local markets.

Strategic Niche Management Activities

Looking to bring the analysis back up to a level of abstract understanding regarding storage niche development in Ontario, the evidence was analyzed for their indication of trends in the SNM activities or processes. The three SNM processes are summarized in Figure 25 along with indications of the actor influence on niche development with a push mechanism on regime shift and pull mechanism on niche development. From this analysis it is possible to begin to recognize patterns of regime transition as described in the work of Verbong & Geels (2010) and Geels and Schot (2007).

Articulating vision and setting expectations

This cluster of activities examined whether or not there was a coordination of actor visions and expectations by any of the actors. It looks at who is involved in articulating or developing the vision, and what events or processes are used to manage expectations. As previewed in the Evolution of the enquiry sub-section, the regime shift toward smart grid was seen as a process that is articulating a vision and setting expectations for storage niche development. Figure 24 shows a process of evolving from past and current electricity systems to smarter systems that was derived by the International Energy Agency in their Smart Grids Technology Roadmap in 2011 (IEA, 2011). In this roadmap storage technologies are depicted throughout the electricity system at the transmission, distribution, and customer level. This sub-section presents evidence used to analyze the relationship between the articulation of a vision and setting expectations for smart grid, and articulating a vision and setting expectations for developing a storage niche in Ontario's electricity sector.

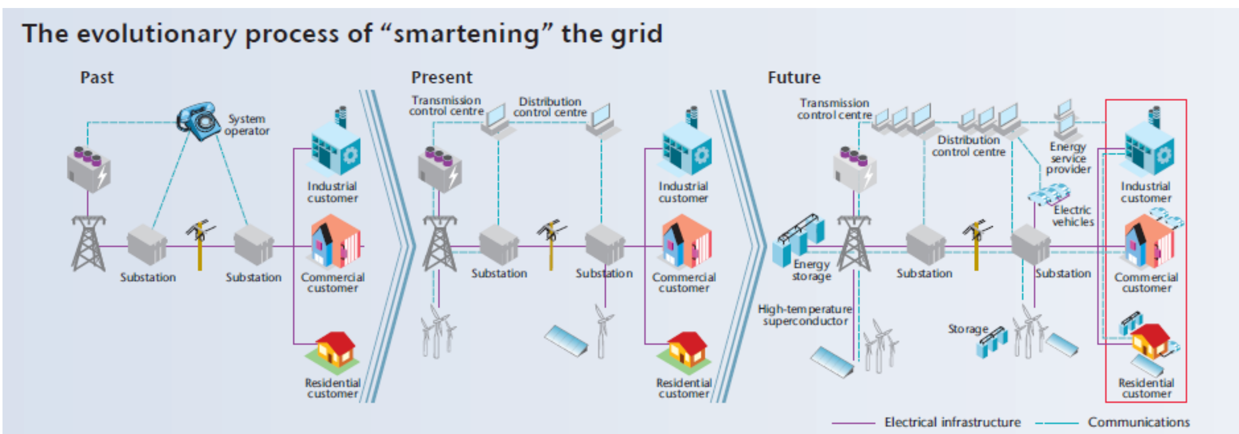

Figure 24: International Energy Agency (IEA) smart grid evolutionary process. Image taken from IEA Smart Grids Technology Roadmap (IEA, 2011)

The evidence presented here does not imply that the development of the storage niche in Ontario is necessary to the regime shift to smart grid in Ontario. Interviews with individual actors still produced evidence that indicated that support for storage technology development and integration was highly conditional. In the words of one niche systems actor:

> ***RI-4:*** *"So, watching the smart grid space, I see a lot of small companies that have a technology. Some proprietary technology or some proprietary approach. Enbala's an example, they've got a business model that's proprietary. Where they're going to try to aggregate and sell regulation services and make some money off of that. But who I think the market leaders are on smart grid, and the ones I watch are the big global companies. IBM, GE. Those are the 2 companies that I think are foremost in this. IBM's making a big bet on it. It seems to me their whole smart planet branding -- and they have a global practice. GE's the same. And there's the other metering companies, Johnson Controls, Honeywell... You know, these big companies, again the global companies. You know if these guys start investing in it, or marketing it or talking about it then it has the potential scale to be viable. If it isn't viable in the US, China and India then it's not viable*

in Ontario. We kind of delude ourselves a little bit into thinking that we can do things that they can't. But we can't. Not forever.”

A niche system actor similarly recognized that storage technologies were but one of many technology innovations that could deliver the benefits that smart grids are to capture. They identified demand response technologies, in particular, as competing for similar markets with similar benefits to offer.

> ***NS-3**: “...couple of things that might be missing in your framework is you didn’t talk at all about competition because certainly from my perspective is the problem...-- not problems right now but the fear of problems in the future with intermittent renewables to the operation of the grid. I mean the system operator, is the organization that's in the firing line.... And right now, there are two probable solutions... that’s why the system operator there is interested in storage projects in principle alone, but they’re also interested in demand response. So the competitor for storage is, in my opinion, is demand response.”*

Despite the lack of evidence of a causal relationship, there was evidence that the development of the storage niche is facilitating a regime shift toward smart grid. This was most visible in Ontario Ministry of Energy documents and the activities of the Smart Grid Forum described earlier in this analysis section. The Directive to the OEB (2010) in particular set initial expectations for how the development of storage technologies and the development of innovative technologies for smart grid in general would support the province’s objectives for smart grid. The development of a framework for integrating cost-effective storage technologies into Ontario’s grid by the Smart Grid Forum Working Group further develops the vision and sets expectations as described earlier. The participation in this framework development by the Energy Storage Working Group provides evidence that the Forum enables a positive relationship between the regime shift toward smart grid and the development of a storage niche. This positive relationship was also outlined in the smart grid objectives set by the Ministry of Energy. As one storage developer described:

> ***NI-2:** “And I think we all see that -- everyone agrees storage will benefit the grid, but it’s not advancing because regulations are in the way but no one really understands what, so we’re just trying shine light on, and saying, here’s the things that we need change, not these pie-in-the-sky, give us a FIT rate for storage and all those things, we say, you’ve got all of these options you’ll figure those out over time, but here are the tactical things you can do in the next year to two years that’ll bring storage on the grid today, and where it’s economical today. So we’re just trying to focus on those tactical things.”*

In parallel with the big picture vision and expectations for smart grid and storage evolving in Ontario, are evolving technology expectations for storage. Several respondents referred to storage as the “holy grail” for sustainability problems on the grid. This regard gives an indication of the value perceived between storage technologies and smart gird. In general, expectations for the technology attributes of storage were acknowledged as coming from either the niche system quadrant or as landscape influences.

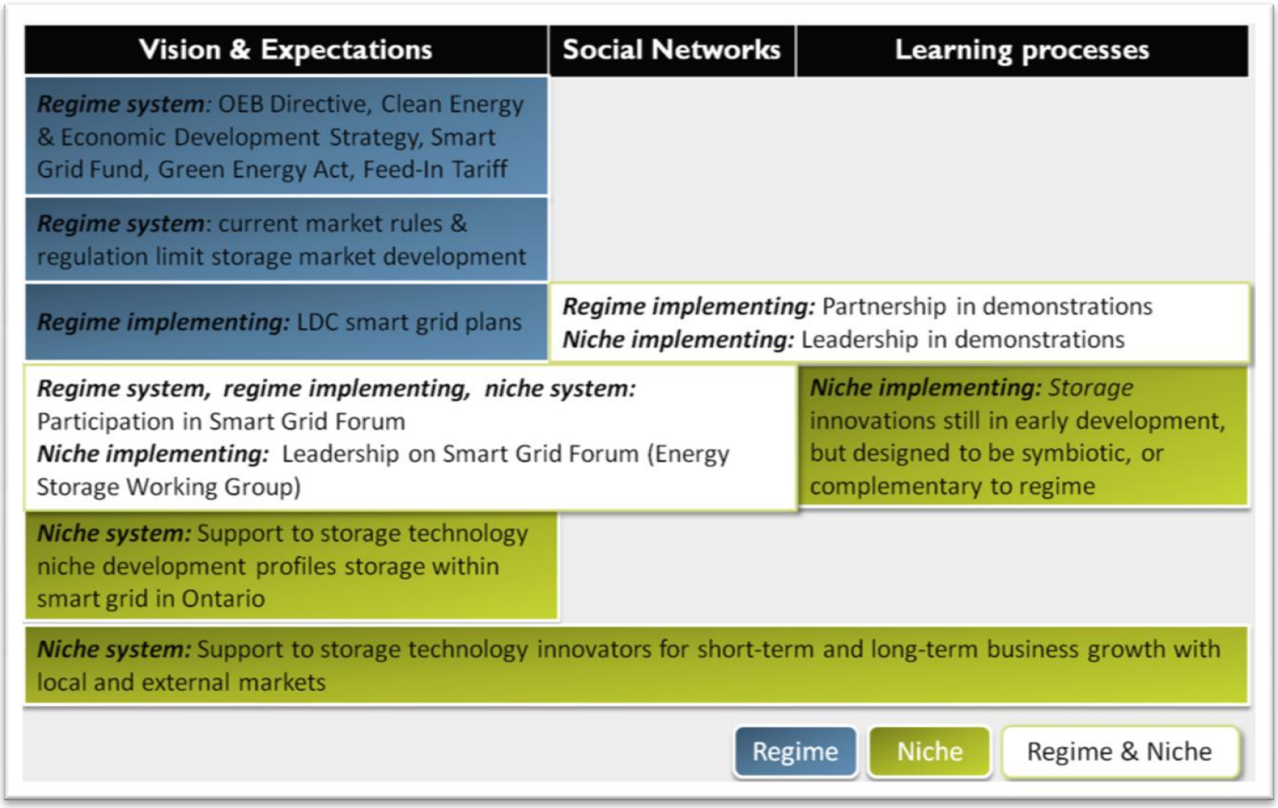

Figure 25: Strategic Niche Management processes observed in the development of a storage niche in Ontario

LDC smart grid plans were identified as playing a role in creating a vision and setting expectations for the LDC role in niche development. These plans indirectly link regime system actor activities to niche development in the way that LDCs use those plans to engage storage developers. In this way the OEB can be considered to indirectly support the strategic management of the niche by virtue of instructing LDCs to create smart grid plans.

The MaRS Market Insights Group in Toronto published a report called “Ontario Utilities and the Smart Grid: Is there room for innovation?” (Briones & Blase, 2012). This report provided some evidence of current and recommended activities for coordinating the development of a smart grid vision and expectations for actors under that vision. Those LDCs that shared their smart grid vision with the authors had storage technologies specifically recognized within the suite of smart grid technologies. This report concludes with recommendations to LDCs, regulators and entrepreneurs in smart grid technologies. Amongst these recommendations the report calls for a common definition of smart grid to be employed in LDC smart grid plans. It also encourages entrepreneurs to understand electricity sector regulation and policy in order to support a regime shift to smart grid, and to understand local and global challenges that LDCs face, above all maintaining a global perspective. The report summarized further evidence that there is a coordination of the development of a smart grid vision and expectations that will be relevant to the development of a storage niche in Ontario. It also illustrated how the vision and expectations would continue to be developed with contributions from all quadrants of actors.

Relevance to storage niche development:

The vision for storage technologies in the electricity system appears to reside within a vision for smart grid. Without a vision for smart grid, the vision for new storage technologies would likely remain tied to small markets such as those that need non-emitting back-up power applications. The articulation of a common vision and expectations for smart grid in Ontario appears to be mainly the result of regime-level actor efforts. Because that vision includes storage technologies, it provides an opportunity for storage developers to participate in the further development of the vision. The support provided to the articulation of this vision and expectations by the Energy Storage Working Group in the Smart Grid Forum provides a more visible tie between the regime shift to smart grid and the development of storage technologies. In this way the development of a local storage niche facilitates the development of the vision for smart grid in Ontario. The regime shift to smart grid, however, does not rely on the development of local solutions, and there is an expectation that many of those solutions will come from industries outside of Ontario.

Despite the fact that there is a shared vision for smart grid at a high level, there continues public debate about how smart grid will be implemented. LDCs or utilities vary in their characteristics across the world and even across the province. The high-level vision for smart grid on its own is not enough to understand the nature of the relationship between smart grid development and the development of a storage niche in Ontario. That relationship is explored in the later sub-section on learning processes.

Building social networks

Closely related to the coordinated development of a vision and expectations for smart grid and storage niche development is the process of building the networks that contribute to those visions and expectations. The Smart Grid Forum committees, incubator activities and the R&D and demonstration project partnerships between LDCs, suppliers and storage entrepreneurs provided the most visible networks of actors. This mix of formal and informal network relationships seemed critical to niche development as this storage entrepreneur reflected:

> ***NI-2:*** *"So we really appreciate all their support that they have done, and then the grant programs in Ontario in Canada are fantastic... SDTC is fantastic. Here we've lot of success with OCE. So, yeah I think it's a pretty good environment to be in.*
>
> *And the incubators are great...I mean but they open doors to venture capital firms. They give you some mentoring and counseling, they connect with other start-ups that might be going through similar issues. And just generally you can be kind of lonely out there, especially if you've had a couple bad meetings, you get kicked out of some offices. You're like kind of down in the dumps. It is good place to go when you get a lot of sympathetic years and kind of get you back on your feet again and that sort of thing.*
>
> *So yeah, they are good, just gives you a -- feels like you've got a place to go, kind of a home base and that sort of thing... it's a little more qualitative some of the stuff they provide"*

While organizations were credited with the support to storage niche development in Ontario, there was evidence that, at this stage of niche formation, much of the building of social networks could be attributed to individuals within those organizations. These individuals served as champions within their organization and between organizations as discussed in the fuzzy front end and new product development literature review of champions and boundary spanners (Reid & De Brentani, 2004). A number of these individuals moved between actor quadrants during their careers and continued to actively engage actors in quadrants outside of their own.

In future it could be expected that many of these storage entrepreneurs will become competitors, but at this stage the Energy Storage Working Group and the inter-firm relationships seemed to indicate that there was a supportive network for niche development forming beyond individual firm efforts. As one niche system actor observed: "for now we're all cooperating" (NS-2). Another storage developer commented:

> **NI-4:** *"We are working collaboratively because we know that we have to knock down barriers for any of us to be able to participate in these markets.*
>
> *I think we set aside our differences and take the position that we have a common goal to use these new technologies to make the grid a better and that's what -- that's certainly been the sentiment in our groups, whether it's demand response or whether it's other forms of energy storage technology."*

These social networks were also taking the shape of an emerging cluster in the language of some actors. This type of social network building was often seen as a result of deliberately having all of the right ingredients together and then letting the magic happen from this "primordial soup" (NS-4). MaRS was credited with providing this role for storage niche development, and the growth of its client firms within that niche.

Relevance to storage niche development:
Two social networks appear to be the most influential to storage niche development in Ontario, one is the network that supports technology innovation in Ontario, and the other is the network supporting smart grid in Ontario. The network of incubators, universities and other organizations supporting storage technology innovation in Ontario existed before it became part of the network for smart grid in Ontario, however many of the new storage entrepreneurs have been introduced following the creation of the Smart Grid Forum. The growth of a social network to support the development of storage technologies in Ontario is enabled by individuals within each of the quadrants of actors. These individuals serve as champions within their own organizations and between organizations to develop the niche and shift to smart grid. At this stage of the niche formation, actors are more willing to collaborate as a means of accessing resources and removing common market barriers.

Learning processes

Building on the strengths of the vision, expectations and social network activities are learning opportunities. The learning process occurs primarily through the planning and execution of storage demonstration and pilot projects. This SNM process appears to be the least advanced of the three in Ontario. For each of the storage entrepreneurs interviewed, these learning processes are in the early stages of planning and execution. At this point it is difficult to identify cycles of experimentation that have lead to a shift in the vision and expectations, and the bringing in of other stakeholders into the network. R&D projects conducted prior to the demonstration projects resulted in bringing in stakeholders for the demonstration projects, but it wasn't evident that these had lead to a shift in actor vision and expectations for storage and smart grid in Ontario.

Table 11 provides a snapshot of the larger public R&D and demonstration projects and business development for storage entrepreneurs in Ontario over the last 3 years. In some cases the OCE, MaRS and IDF support are leveraged funding for the SDTC and NRCan projects. There are more than five storage entrepreneurs in Ontario, but not all have been seeking or securing public funding for demonstrations or business development support from public organizations in the past three years.

Respondents commented on the influence of these funding and business development supports and other learning opportunities.

Table 11: Public funding and support for Ontario electricity grid storage R&D and demonstration projects

Public funding and support organization	Storage entrepreneur, project size ($,MW if available)	Period (if available)
Ontario Centres of Excellence (OCE)	Temporal Power Hydrostor Electrovaya	2010 2012 onward 2012 onward
MaRS Cleantech clients	Temporal Power eCAMION Hydrostor Hdyrogenics	Current
Ontario Innovation Demonstration Fund (IDF)	Temporal Power Hydrostor	2011- 2012-
Sustainable Development Technology Canada (SDTC)	Temporal Power ($8.3 M project, 10x500 kWh) eCAMION ($16.7 M project, 2x750 kWh) Hydrostor ($7.4 M project, 4 MWh)	2011-2015 2011-2015 2012-2016
Natural Resources Canada (NRCan) Clean Energy Fund	Electrovaya ($7.6 M project)	2010-2014

**this list of public funding and support is not exhaustive for these companies, but highlights larger sources of funding. Other organizations referred to by respondents included York Region - VentureLabs, Durham Strategic Energy Alliance – Spark, Toronto Business Development Centre and the Mississauga - RIC Centre. This list does also not include all of the public funding opportunities available to storage companies, for a more exhaustive list please see www.marsdd.com/funding.*

These supports had a direct benefit to storage entrepreneurs by making projects more attractive to potential project partners and customers. One prevailing observation was that without public funding for demonstrations, LDCs would not be able to participate in demonstration projects because they lack the funding mandate to do so under the current regulatory environment. This funding also reduced the risk for other private partners and funders to invest in these storage entrepreneurs, enabling them to participate in learning processes directly.

Indirectly, the portfolio monitoring that SDTC and MaRS in particular offer to investors by tracking past and current client activities, engages follow-on investors directly in the years following the initial demonstration projects. In this way these demonstration projects address the learning needs of actors from the niche system and regime implementing quadrants beyond the years of funding.

Business strategies

Despite not having gone through complete learning processes, there was evidence that these past and current projects had affected the business strategy of storage entrepreneurs and their ability to form expectations for storage technology development. This was visible in the business and storage niche development pathways illustrated in Figure 20, Figure 21, Figure 22 and Figure 23. In addition to the expected practices of developing a solid business case and business plan to deliver the project, storage entrepreneurs were able to get valuable feedback direct from customers and partners regarding short-term and longer-term strategy. During niche interviews, Toronto Hydro and Hydro One were identified as LDCs that were particularly active in this respect. Their partnership in the demonstration projects identified in Table 11 is further evidence of that. For most entrepreneurs, this either lead to (or supported) strategies for capturing short-term opportunities in niche markets outside of Ontario, using Ontario customers as reference customers through demonstration projects. These strategies are being supported by trade commissioners and officers from the Department of Foreign Affairs and other international technology programs administered at a national level.

While the connection between storage technologies and smart grid has been made in several ways, the question of how strategic it is for the regime actors to support the development of a local storage niche remains. Analyzing the learning processes in the Ontario electricity sector related to storage niche development, LDCs emerge as critical partners in the formative stage. Therefore, the question of how strategic a storage niche development in Ontario is to the development of smart grid relies in many ways on the strategic intent of these LDCs with regard to their participation in storage demonstration projects. For the LDCs interviewed in this study, storage technologies were identified as solving existing or anticipated system problems. Still, these LDCs could just wait for technologies to be developed outside of Ontario before adopting them. The motivation provided by Ministry of Energy policy and the resulting regulation can be attributed to motivating LDC participation, but many LDCs are participating in these demonstration projects without rate recovery. For Hydro One, owned by the province, the strategic intent could be related in part to satisfying the demands of their shareholder. For other LDCs the shareholder pressure is less related to provincial policy. The strategic intent for developing storage solutions in Ontario appears to be related more to opportunities for revenue and to ensure that the solutions developed are tailored to an LDC’s specific needs.

A scan of the over 70 LDC infrastructure and characteristics in Ontario reveals a broad range of customer density, age of equipment, integration of variable generation, capital budgets, capacity to manage demonstration projects, and geographic conditions. The combination of these and other factors impacts the value to LDCs of participating in the development of storage solutions locally. Based on the publicly funded demonstration project partners, and the interview responses, for those LDCs with the capacity to participate in demonstration projects, there appears an incentive to ensure that storage solutions are developed that are appropriate to their specific needs and assets. For the LDCs without the capacity to participate in R&D and demonstration projects, the strategic intent appears to be to adopt technologies developed elsewhere.

An example of the opportunity for increased revenue and potentially profits can be seen in Burlington Hydro's GridSmart City project[3]. Under this project the LDC's unregulated affiliate company, Burlington Electricity Services Inc. manages the program with the strategic intent of being able to offer profitable services to residents in the Burlington area in the future. The consortium of companies includes S&C Electric, which along with their history in power systems technologies is a developer of storage technologies. Having already commercialized their uninterruptable power supply in other applications such as NASA's Goldstone Deep Space Communication Complex, S&C Electric is working with the GridSmart City project and looking at integrating their storage technologies into the project (GridSmart City, 2012).

Technology demonstrations

Given the above business strategy that has emerged, publicly funded technology demonstrations appear not just supportive to niche development, but critical. Securing an LDC or similar public utility as a demonstration partner was considered essential to developing the technology and the business. One entrepreneur related the challenge of employing this strategy this way:

> **NI-4:** *"...if you're going to develop grid scale technologies, you need a utility who is willing to work with you and willing to allow you to look at data, willing to allow you to connect the grid and try out the solutions.*
>
> *[Utilities are] gatekeepers, and rightfully so. So it's something that will be a challenge for any energy storage company looking to prove itself on the grid level."*

For these entrepreneurs, there didn't appear to be an alternative to securing partners for technology demonstrations and to serve as reference customers. One storage entrepreneur reflected that this has

[3] www.gridsmartcity.com

resulted in a number of different consortiums for demonstrating a number of related technologies. However, these consortiums are often exclusive memberships involving only a single storage entrepreneur. For storage companies, the challenge then becomes to find consortiums and demonstration opportunities for which they are the exclusive partners, which results can be highly resource intensive in the early stages of niche development. Toronto Hydro and Hydro One have both created "smart zones" to try to support this type of competition between entrepreneurs in technology development. This pattern of niche development has policy implications that are discussed in the Discussion and Conclusion section.

Relevance to storage niche development:

Regime and niche-level actor participation in publicly funded storage demonstration projects appears to be the most visible representation of the development of a storage niche in Ontario. LDCs are essential partners in the demonstrations, and in this role they appear to manage the relationship between niche development and regime shift. Because LDCs revenue and investment is regulated by the OEB which is in turn directed by the Ontario Ministry of Energy, the strategic intent of these LDCs is in some respects determined by the Ministry policy. In this way the investment of LDCs in storage technologies could be considered a form of procurement policy by the government.

In Ontario the policy influence on LDC activities is more with regard to smart grid than it is to storage. From this it does not appear that the strategic intent is a result of the procurement policy alone. The strategic advantage for these LDCs to participate in storage demonstration projects appears to be solving technical problems in a way that satisfies their shareholders (which for one LDC is the province), in creating revenue opportunities for their unregulated affiliate company, or in ensuring that solutions are developed that are suited to their particular and potentially unique needs.

Taken together, the regime appears to be following a transition pattern that Verbong & Geels (2010) and Geels & Schot (2007) described as the *reconfiguration* pathway described in Table 3, where a new regime is formed by the existing regime actors. The symbiotic relationship between niche innovations the regime is explored in the next section on the effects of complementarity.

Using SNM and TIS to understand the effects of complementarity on storage niche development in Ontario

The literature review explores the concept of complementarity under the TIS and SNM analysis frameworks. In this sub-section, evidence of the effects of complementarity on niche development was analyzed in terms of the development of positive externalities (TIS function) and of symbiotic relationships affecting transition pathways (multi-level perspective of transitions).

Bergek et al. (2008) expect to find legitimacy and the development of positive externalities more predominantly in the formative TIS phases. They recognize the effects of the development of positive externalities on a TIS by the strength of the relationship between various functions and other emerging innovation systems. As discussed in the literature review, the development of positive externalities also deals with the potential for competition. For the storage innovation system in Ontario, the broader category of smart grid appears to connect several innovation systems as positive externalities. Innovations such as integrating renewable generation from wind, integrating electric vehicles (EVs) and developing demand response capabilities in the electricity network are all considered key components of smart grid (IEA, 2011).

Table 12 summarizes the analysis of the responses that actors gave indicating an effect of complementarity. This complementarity was expressed through the TIS function *development of positive externalities* and in the SNM described *symbiotic relationship* between the electricity system and storage technologies. Evidence of four cases of the development of positive externalities was found in the actor discussions of the storage business case and the system needs. These were: the development of renewable generation projects, the development of electric vehicles (EVs) and charging infrastructure, the development of demand response capabilities, and the implementation of smart grid in Ontario. Evidence of a symbiotic relationship between the current electricity grid operation and storage technology benefits was found in two cases: the grid integration of wind and solar generation, and the system-wide benefits identified for the broad category of storage technologies.

Most of the effects of the development of these positive externalities and the symbiotic relationship between storage technologies and the current grid operation were evidenced by actor remarks during the interviews. In some cases the effects were evident in the development pathways or business cases described. Additional evidence was sourced from documents and communications available from stakeholders.

Table 12: Analysis of the effects of the complementarity of storage on the storage niche development and electricity system shift to smart grid

Evidence of complementarity	Perceived effect on storage niche development	Perceived effect on Ontario electricity system shift to smart grid
Positive Externalities: **Development of renewable generation projects**	Offers business case for renewable generation project developers and customers by increasing power quality from the generation project. Investing in and financing renewable energy projects facilitate the development of capacity to invest and finance other cleantech projects with storage technologies. NIMBY (not-in-by-back-yard) attitudes of customers create problems that can be solved by some storage technology applications. Customers recognize a trend in "green" or cleantech that begins to set expectations for a shift in product and service offerings, potentially with storage.	Government and politicians have a motivation to support technologies and means of leveraging the value of Ontario's "clean energy experience." Investing in and financing renewable energy projects facilitate the development of capacity to invest and finance other cleantech projects with smart grid technologies. Customers recognize a trend in "green" or cleantech that begins to set expectations for a shift in product and service offerings from smart grid.
Positive Externalities: **Development of EVs and charging infrastructure**	Electric vehicles offer technology development and demand opportunities for batteries. Strengthens business case for battery storage technologies. Balancing needs for charging infrastructure strengthens business case for storage technologies.	Analyzing the future requirements of charging infrastructure and the role of storage technologies in meeting those requirements facilitates the regime shift to smart grid. Regime system and niche support organizations are challenged with being fair to all technologies on the grid that offer the same benefits. The complexity of system and market planning required to integrate these technologies slows the pace of integration.
Positive Externalities: **Development of demand response capabilities**	Demand response technologies face many of the same regulatory and market barriers to entry. These companies are coordinating efforts to remove these barriers. Demand response technologies can	Analyzing the cost and benefits of demand response technologies and storage technologies and their possible points of entry into the system and market facilitate the regime shift to smart grid.

	leverage the value of storage technologies as part of a multi-faceted system solution to balancing supply and demand.	Regime system and niche support organizations are challenged with being fair to all technologies on the grid that offer the same benefits. The complexity of system and market planning required to integrate these technologies slows the pace of integration.
Positive Externalities: **Development of smart grids**	LDC plans for the implementation of smart grid guide and can support storage integration. Smart grid design and objectives provide a vision for storage technologies.	Smart grid technologies in operation add confidence to the direction and further shape vision and expectations.
Symbiotic relationship: **Grid integration of wind, and to a lesser extent solar generation**	Strengthens the business case for storage technologies. The Feed-In Tariff contributed to market development through a resulting increased system need for technologies to compensate for variable generation.	LDCs with a lot of wind and solar connected reported this as a primary contributor to the business case for storage technologies. IESO recognized this as a major contributor to the business case for storage technologies.
Symbiotic relationship: **System-wide benefits**	Strengthens the business case for storage entrepreneurs, and is in some respects a requirement for their partnership with LDCs and eventual sales to them. Regulatory and market barriers are more complex because there is not a single point to market entry, but many. Storage technologies are in competition with technologies currently solving problems throughout the grid such as NG peaking plants, and emerging technologies such as demand response. The ideal customer tends to be the LDC, but this is not entirely clear because multiple stakeholders can benefit. This can confuse the market strategy and offer opportunities to diversify their market.	LDCs are expected to mange most of the storage value chain, and need to be able to claim this attribute to justify rate-recovery for projects. The potential ability of storage to solve Ontario's problems with surplus baseload generation provide motivation to integrate storage technologies. Regime system and niche support organizations are challenged with being fair to all technologies on the grid that offer the same benefits. The complexity of system and market planning required to integrate these technologies slows the pace of integration. Other customers found this potentially a disincentive as it may give them no advantage over their competition.

The Smart Grid Forum reports and Discussion Paper for developing a framework for the integration of storage (discussed earlier in this Analysis section) provided evidence for the effects of these complementarity attributes. Additional resources include:

- The effects of developing renewable generation projects on regime shift to smart grid was evidenced in the launch of the Clean Energy Economic Development Strategy (Ministry of Energy, 2012), where specific reference to exploring the potential of energy storage included in the press release.
- The effects of the development of EV technologies and charging infrastructure was evidenced from current demonstration project descriptions linking EV batteries to power applications.
- The effects of the development of demand response technologies was evidenced in the Energy Storage Working group membership and recommendations.
- The effects of smart grid implementation were observed in LDC smart grid strategies or plans.

Relevance to storage niche development:

Looking at the combined positive and negative effects of these complementarity attributes on storage niche development and the system shift to smart grid, a relationship starts to emerge between the business case and the barriers to entry. In the same way that the symbiotic relationship with the grid operation strengthened the business case for storage technologies, the regulatory and market barriers also tended to increase because multiple benefits and applications require multiple changes to the rules.

It also becomes possible to see a relationship between the storage niche development and the regime transition to smart grid around the points of complementarity. Niche and regime appear to share in the development of a vision and expectation for smart grid and for storage technologies, where each served to develop the other.

Discussion and Conclusion

This section presents a model of the dynamics observed in this exploratory case study. Storage niche development is discussed in terms of its relationship to Ontario's transition to a smart grid electricity system. The findings of this study are compared to recently published models of innovation in Canada, as a way to identify implications of these findings and opportunities for future research. As a means of checking the validity of these findings and conclusions, participant feedback was sought and is presented in this section. Participants were also asked to comment on the usefulness of the model developed and insights presented in this study. The discussion closes with reflections on the methodology used to apply the frameworks in this research, the limitations of the findings in this study and opportunities for future research. The section concludes with a summary of the sections in this thesis.

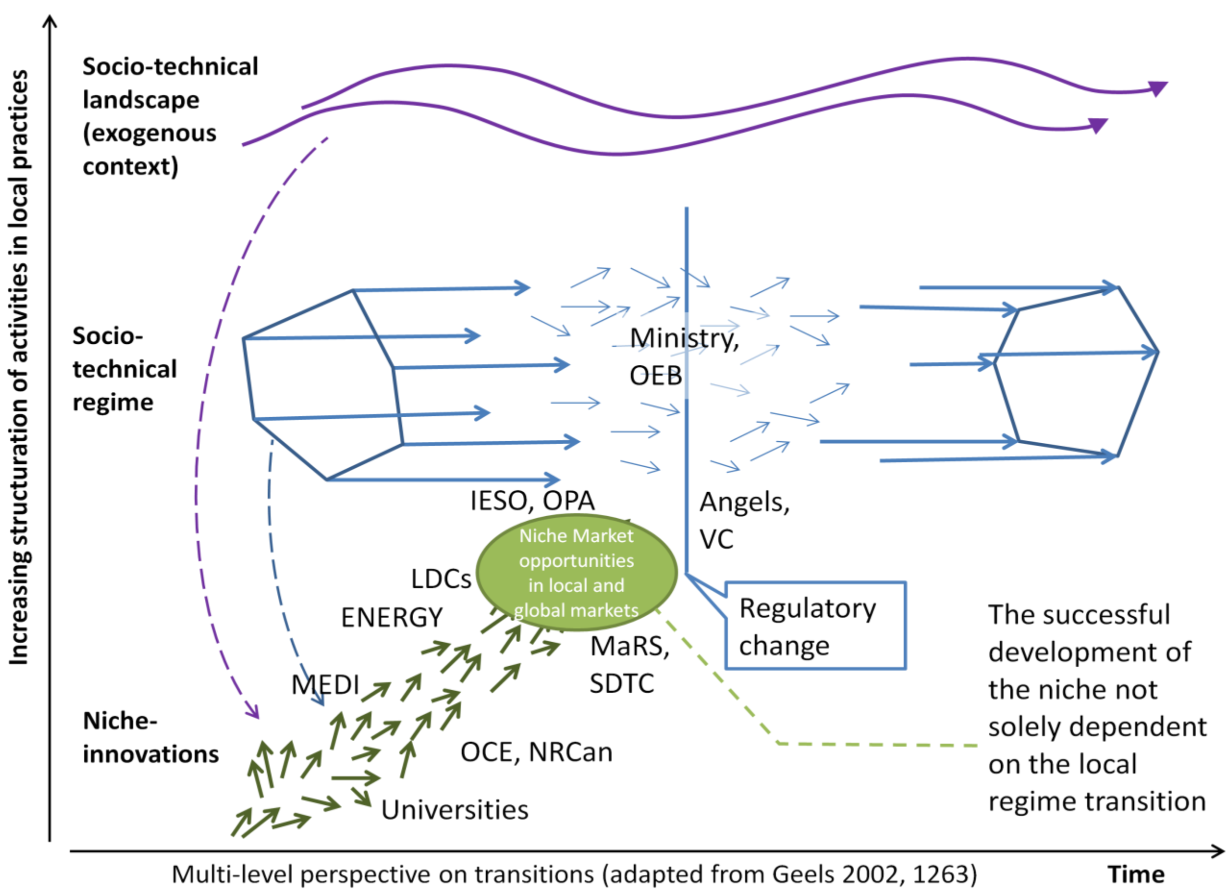

Figure 26: Storage niche development pathway in Ontario and its relation to regime transition to smart grid

Storage niche development

Based on the opinions and experiences of the respondents and other sources used in this study, I believe that the storage niche in Ontario is being strategically managed. I believe this to be because storage is recognized by regime actors as complementary to the current electricity regime, and because it is a component innovation of smart grid. More specifically, the evidence suggests that regime-level actors have a strategic intent guiding their involvement with the storage niche management. This intent is to satisfy shareholder demands, solve operational problems and increase revenue streams and earn profits by developing these solutions with local storage developers. Were it not for Ontario electricity regime actors being engaged in a smart grid transition, I do not believe the storage niche could be strategically managed in Ontario. The evidence does not suggest that the Ontario electricity sector shift is dependent on the development of the storage niche. It does, however, suggest that the development of the storage niche supports the transition because it facilitates learning processes needed to shift the policy, market preferences, technology, industry and culture aspects of the Ontario electricity regime.

Mapping these SNM processes back onto the multi-level perspective on transitions shown earlier in Figure 6, the process of storage niche development and the related smart grid transition could appear as in Figure 26.

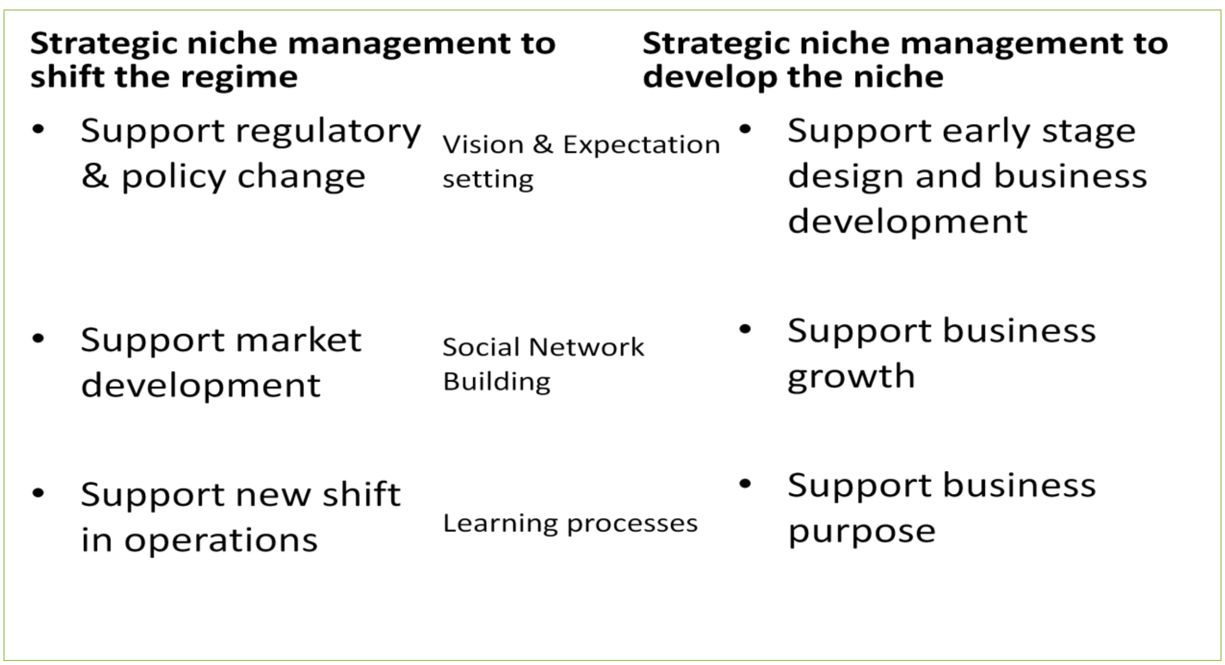

Figure 27: Connections between storage niche development and regime shift along the lines of Strategic Niche Management processes

The three processes of SNM were found to connect the storage niche development and regime shift to smart grid in the general ways illustrated in Figure 27. The activities that contribute to developing a vision for storage technology and business attributes appear to help shape the frameworks for regulatory and policy change. Likewise, the vision for smart grid provided guidance for the development of the storage technologies and business models. The same networks that support the development of storage technologies and businesses also appear to support the market development for smart grid. The learning processes were mainly demonstration projects. These appear to enable hands on learning to support storage business growth and regime stakeholders to adjust their operations and rules to integrate storage technologies.

Mapping the dynamics between regime shift to smart grid and storage technology development on to the emerging technical trajectory presented in Figure 4 in the literature review presents another perspective of this complementary model of niche development.

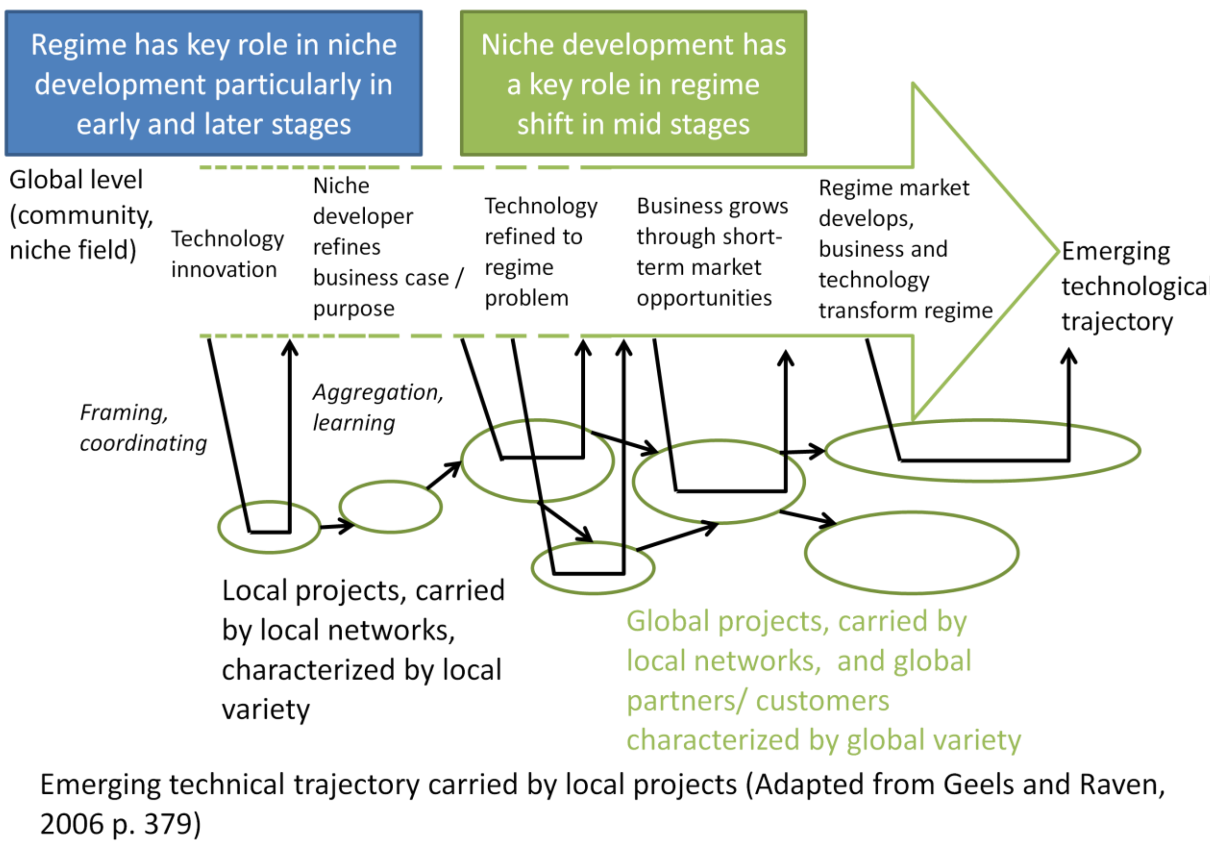

Figure 28: Strategic Niche Management view of storage niche development in Ontario through a series of projects

Figure 28 illustrates the niche development pathway progression supported by the regime shift to smart grid and influenced by its barriers to development. The same niche development process, only with a focus on the regime actor participation, is described in Figure 29. The regime appears to have the most influence on niche development in the early stages of niche development with guidance of the search, resource mobilization and legitimacy functions. As the storage companies began to settle on their technology, business case and business models, they begin to have more of an influence on the vision and expectations for the regime shift to smart grid. The storage niche expectation is that once the Ontario market opens up, storage developers will be able to execute their primary growth strategies. In this way, the later stages of niche development appear to rely more on the regime shift to smart grid than the shift to smart grid relies on the development of the storage niche. This influence is illustrated in Figure 29.

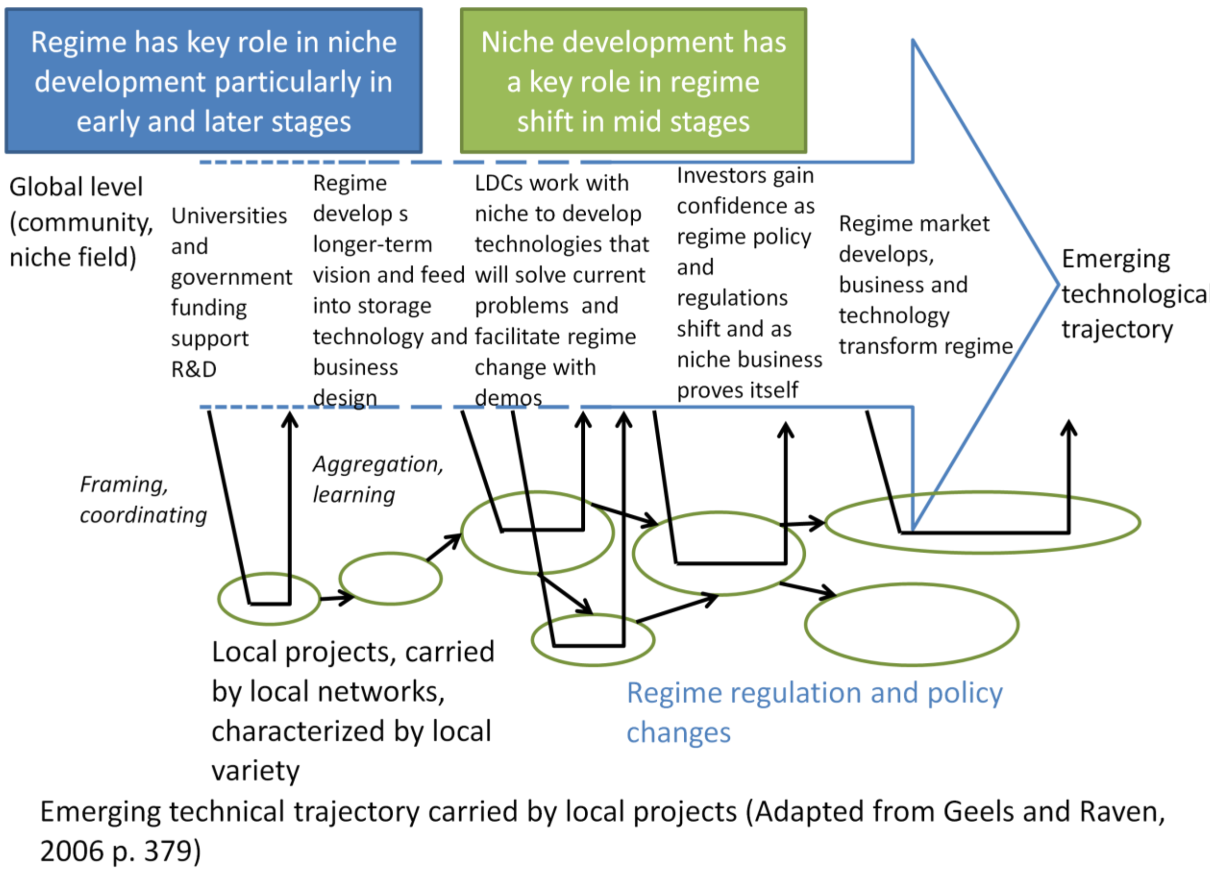

Figure 29: Strategic Niche Management view of regime shift to smart grid in Ontario through a series of projects

Two key points about how this regime is managed have emerged. The first is that the strategic management of this niche is not from end-to-end. In other words, stakeholders manage different stages of the niche development, but the hand-off between niche system actors and regime implementing actors is not necessarily coordinated or managed. The stakeholder management of the niche are also subject to political drivers given the reliance on public funding and the regulated activities of LDCs. This makes the momentum and trajectory of the development pathway less certain. One regime system actor described in detail how the complexity of smart grid, and the “nicheness” of storage can afford it less attention when new Ministers and ministerial staff come to office. The second point is that policies and activities that would support the regime market development appear less present.

Niche-level players recognized procurement policies as having the potential to support market development. This is partly due to expectations set under the current Feed-In Tariff programs intended to support the development of a renewable energy generation industry in Ontario. In the same breath, niche entrepreneurs were careful to distinguish that their business case was trying to be developed without relying on government subsidies. Still, some level of procurement policy was desired with the strategy of retaining a local reference customer and refining business models to suite local customer needs. These entrepreneurs expect to leverage those customer relationships in future. This could be through LDC investments that are approved by the OEB for cost recovery through customer rates, which can be interpreted as a form of procurement policy.

Acknowledging the value that the Smart Grid Forum has offered to storage developers, its role in niche development should not be oversold. As a network initiative the Smart Grid Forum, chaired by the IESO, affords legitimacy to the smart grid transition and storage niche development. It also provides a valuable role in coordinating the development of a smart grid vision. Other industry-lead networks have not had the same power to apply recommendations and maintain continuity in the work. Several policy instruments appear to support the operation of this less formal network of key stakeholders, including the Green Energy Act (2009) and the Directive to the OEB on implementing smart grid (2010). While the less formal nature of the Forum has been identified as a strength, the consequence is that it has no power to implement change in the regime, and certainly no responsibility to develop niches. Thus while the Forum supports the development of a niche, it cannot be relied upon for the other niche development activities beyond high-level vision and expectation setting and networking for stakeholders. The other aspects of strategic niche development are conducted outside of the Forum’s direct influence. An organization with a mandate to strategically manage the development of niches, could maximize the value of the relationship between smart grid and storage technology development, if incorporated the value that the Forum offers in this respect into its design and operation. This is discussed in the policy implications later in this section.

Just as Geels & Schot (2007) cautioned in their review of criticisms to the SNM model, the development of the storage niche cannot be regarded as deterministic. One might think that with this niche development process underway, many of the regime-level players would be thinking in terms of niche development or innovation systems. This generally wasn't the case, instead:

- A number of system players appear to think primarily within a technology development or commercialization mindset, not an innovation systems mindset which would recognize the dynamics of regime shift connecting to niche development.
- The free market model seems to influence actor perspectives or expectations for technology development, despite being in a regulated market subject to sustainability objectives that are hard to value in economic terms. Neither of which attributes permit the strict application of free-market decision-making frameworks according to Geels et al. (2008).
- Storage technologies as complementary technologies seem to suffer more conceptually from market uncertainties, lock-in mechanisms in the competitive environment, and free-rider problems than technologies such as renewable generation, making their development within Ontario less certain for many regime-level actors.

Still, there appears to be sufficient evidence in this exploratory case study to justify proposing this model of a strategically managed co-evolution of the storage niche development and electricity system shift to smart grid in Ontario. A test of this model and of the generalizability of these findings is left for future research.

Ontario the reference customer

Locally developed component-innovations leading to smart grid are part of Ontario's transition to smart grid because economic development for Ontario-based companies was included within Ontario's Smart Grid Objectives in the Directive to the Ontario Energy Board. The co-evolution of vision and expectations as storage technologies are developed means that support for the development of innovations has preceded the support for local market development. Regulators and policy makers in particular, are approaching the processes of consultation and learning to develop appropriate new rules for governing the regime. The result is that the storage niche is currently receiving the most support from the regime in the initial development stages up until the point of demonstration. From there niche actors are trying to time their growth to match Ontario's market, or targeting other accessible markets (often international markets) to continue technology development and firm growth. A strategy has emerged from this environment to use LDCs and other demonstration partners in Ontario as reference customers for storage developers to access other markets.

Under this arrangement, the more value firms can gain from Ontario reference customers, the more strategic this development stage will be. Based the current pathways that are emerging, in order to support the availability of reference customers Ontario needs to do more than make demonstration funding available. It needs to ensure that regime implementing actors have a vision and expectations for the smart grid transition that make the development of storage (or any other technologies) strategic. Without the longer term vision and expectation that the Ontario market would open to storage, the LDCs would not currently have the incentive to partner with storage developers in demonstrations, and storage developers would be less likely to choose Ontario to conduct R&D and demonstrations.

The benefits to accessing international markets are more direct for the storage developers. However, having Ontario companies exporting and growing in external markets could continue to benefit the regime shift to smart grid. External market trends in electricity already affect markets in Ontario, particularly given the interconnectedness of Canadian and U.S. electricity grids. According to niche-level respondents, the Ontario market potential seems to be experiencing influences from the U.S. with FERC rulings for integrating new storage technologies, and the trailblazing that Beacon Power did for storage in U.S. markets, as examples noted during the interviews. For the Ontario transition to smart grid to increase the value it can receive from Ontario storage companies exporting their technologies, regime-level actors need to understand international markets and international smart grid transitions. A method of tying regime and niche learning from international projects would all for value to be transferred back to the regime level in Ontario, beyond the indirect benefits of economic growth in the province.

Comparing this case to a firm-centric business innovation model

As a means of drawing insight from this case, the dynamics of the storage niche development in Ontario was compared to a firm-centric model of the business-innovation process presented in a recent report looking at R&D and innovation in Canada (Expert Panel on Federal Support to Research and Development, 2011). Dynamics between a regime shift and a niche development were not expressly explored, and as such, key challenges to the model presented applying to what is observed in this case are listed along the margins of this Figure 30.

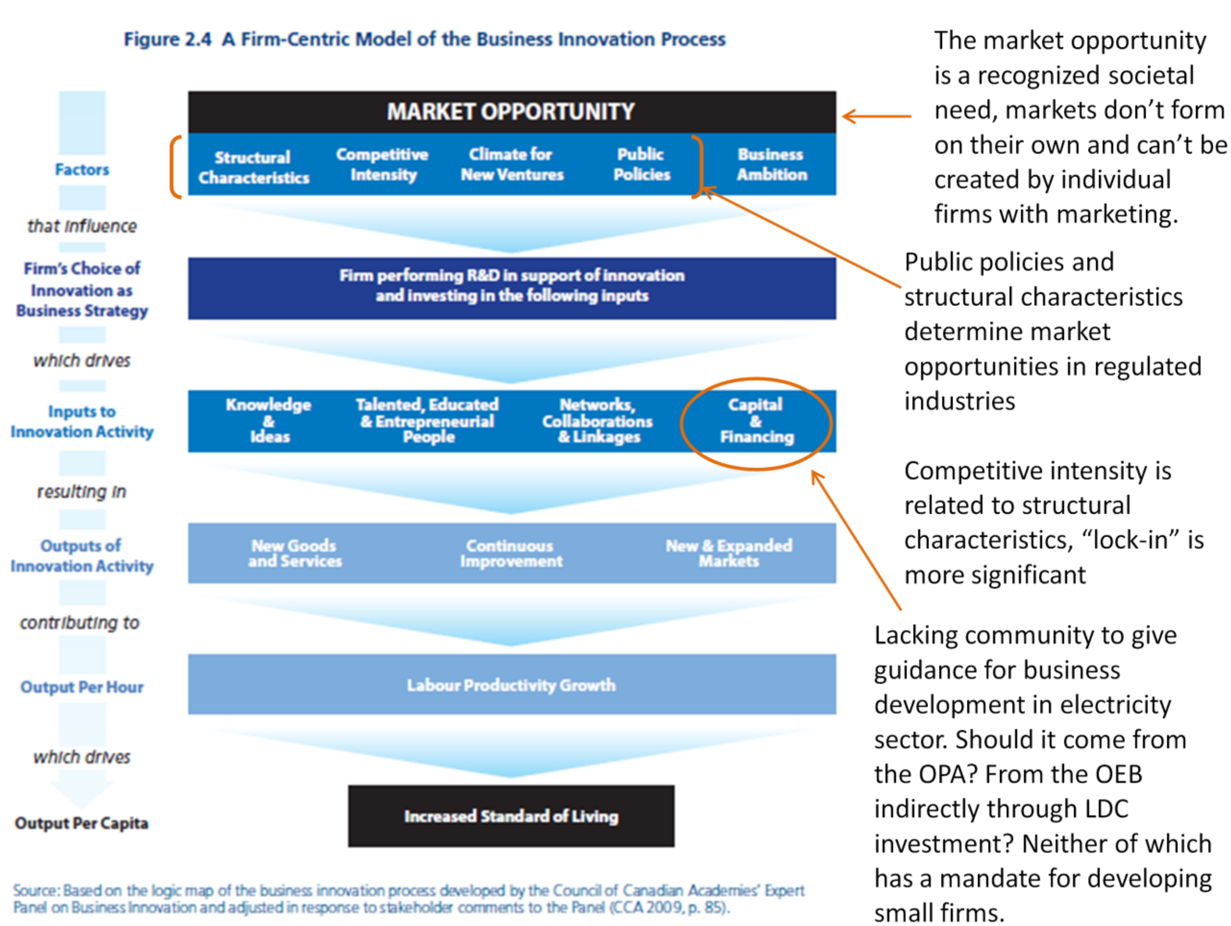

Figure 30: Differences between the business innovation process within free markets and regulated markets

A model of the business innovation process for storage developers would need to incorporate the following differences:

- Market Opportunity
  - Storage developers recognize a societal need that may not be current or local, as markets do not form on their own and cannot be created by individual firms with marketing.
  - The regulatory and market rules change is slow but moving. In the meantime, demonstrations and international markets are critical to growing and supporting the firm until local markets open. This is facilitated in early development phases through Smart Grid Forum.
- Factors that influence the firm's choice of innovation as a business strategy
  - Changes are required for storage technologies to capture local market opportunity.

These lag the decision to innovate, which itself influences the policy and resulting structural characteristics. The climate for new ventures is the most influential and relates to the inputs available.

- Inputs to the innovation activity
    - Regime focus for early stage storage niche development is on the inputs to innovation through incubators, public funds e.g.: OCE, MaRS, SDTC. The decision to innovate in storage is based more on the availability of these inputs than on other factors.
    - Government funding for demonstration projects is essential given the cost of demos. Investment community is fairly sophisticated, and becoming more sophisticated in assessing risk. Many companies access more than one.
    - Incubators provide valuable Information in early stages, and connections to funders in later stages through key individuals within the incubator with talent.
    - SR&ED, IRAP helpful but not really accessible or appropriate for start-ups.

These challenges to the model presented in Figure 30 are not meant to indicate that the business innovation process cannot function in a regulated environment. In fact this study found that storage developers think Ontario is very supportive to new entrants in energy/clean tech: "Ontario has a very good innovation ecosystem" (NI-4), including resources for early stage development and supply chains for production. But in this case, the inputs seemed to have more influence on the storage firm decision to innovate than the market factors, or at least more than the immediate market factors.

Reflecting on this disparity between public discussions about promoting innovation in Canada, and what is observed in this case could pose several policy implications that are proposed later in this section.

Participant feedback

Participants in this study were asked to review the model proposed for its accuracy in representing the dynamics of storage niche development in Ontario. They were also asked to comment on the usefulness of the model and the insights and analysis presented in this thesis to their work. Their responses, along with the corresponding revision to the claims in this thesis are presented in this sub-section.

Validity of case findings

Regarding the accuracy of the case findings, participants generally found the description of the dynamics to be accurate, and regarded storage as an "early stage niche" that is emerging in Ontario. That the niche development is currently in a fragile or vulnerable state was a common sentiment stressed in participant feedback. As one niche system participant commented:

> *"I also agree that there is clearly an identifiable group of 'insiders' who are attempting to manage the 'regime' component of this transition. My only point here is the one I mentioned to you – my past observation that unanticipated events, or the emergence of a champion or a powerful detractor (e.g.: an elected official) can either accelerate or derail the process. "*

This comment is consistent with other actor accounts of the particularly influential role of politics in the system. One regime system actor provided a quite detailed account of the routine struggle to inform new politicians and political staff in the Ministry on all of the issues surrounding smart grid amongst other major issues in the energy sector. Storage ends up being a minor issue that only comes up after a new Minister comes up to speed with other energy issues under public debate. I believe this to be reflected in the discussion regarding how niche development is not strategically managed from end-to-end. More emphasis was added to communicate that the strategic management of the niche is often subject to political drivers given the reliance on public funding and the regulated activities of LDCs.

Commenting on the fragile nature of the strategic management of the storage niche another regime system actor offered 2 main points of feedback that were incorporated into the discussion of this thesis:

- The first point was that while they agreed that certain parts of the development of the storage niche are being strategically managed, there is no end-to-end strategic management of the niche development. This was consistent with the evidence that I received. The findings were qualified further to reflect that the hand-off between organizations working with the storage developers was not managed consistently from idea to commercialization, and that the transfer between supports was not always successful.
- The second point related to the Smart Grid Forum. The respondent agreed that the Forum plays a role in coordinating a very high-level vision, but argued against presenting this Forum as having any responsibility or role in strategically managing the niche, particularly at an implementing level. This is because the Forum has no mandate to implement or initiate change in the system. Individual members of the Forum have this responsibility, but the Forum itself has no formal role within the system. In response to this I have addressed the discussion to be clear that the Smart Grid Forum plays a role in supplying a vision, but that it is the members of that Forum that actually strategically manage elements of niche development, as opposed to the Forum playing this role.

Usefulness of case findings

Regarding the relevance or practical application of the findings, participants commented on the timeliness of the results and usefulness of the policy implications. The policy implications were regarded as relevant; moreover actors felt that in order to maximize the value that can be received from storage niche development, policy supports need to be developed to help Ontario companies compete globally. Regime and niche actors made the following recommendations for the policy implications of this case study:

- Ontario's Clean Energy Institute that was announced June 2012 is intended to address a coordination gap recognized throughout niche development and including market development and regime shift. As such, my policy implications should be relevant to the design of this Institute. Acknowledging this, the policy implications were modified to speak more directly to the design of the Clean Energy Institute.
- Incentives that are revenue neutral to Ontarians should be recommended. Revenue neutral options would redistribute value through the system, as opposed to other options such as tariffs or subsidies. Monetizing the value to the electricity system of kWh from storage or demand response would be an example of a way for new players to receive value from the energy market in Ontario. This is consistent with the recommendations proposed by the Energy Storage Working Group included in Appendix 5 of this thesis. Specific methods of monetizing the value of storage in the system are beyond the scope of this thesis.

These actors encouraged me to find a more accessible way of sharing the findings and policy implications of this study. To this end, I intend to make an executive summary available to all participants and interested stakeholders.

Implications on theory

The primary theoretical goal of this research was to contribute to the growing literature on innovation systems and system transitions with empirical evidence from the development of a niche in Ontario. This study accompanies the existing literature which focuses predominantly on European jurisdictions. A secondary theoretical goal, related to my second research question, was to explore the notion of complementarity using the TIS and SNM frameworks with empirical evidence.

This research has presented evidence to meet each of these goals. This research explains how the TIS and SNM frameworks were employed with a level of detail that is often not explicit in the literature.

There are ongoing development of these individual frameworks, and efforts to integrate them theoretically (Coenen & Díaz López, 2010; Markard & Truffer, 2008b)(Chang & Chen, 2004). This study presents a methodology that leverages the analytical strengths of each of them without looking for a way to turn them into a theoretically integrated framework. The theoretical links between the two frameworks are forged when it was helpful for the analysis. For this study a link was helpful in the analysis of complementarity, which led to an increased understanding of the niche development.

This research also suggests ways that the business literature relating to the development of sustainable technologies could be enhanced by a study of innovations at a systems level, and into the co-evolution of technologies and institutions. The greatest implications have to do with the understanding of markets and firm decision-making factors for innovation.

Implications on policy

The findings of this research have several potential implications on policy. In many cases this is because policy that supports regime shift and policy that supports niche development has been developed by different bodies within government with very different mandates. With the complementary relationship between smart grid and storage, policy for smart grid should leverage the opportunities for learning from storage niche development. Likewise, innovation policy in support of storage technologies, and perhaps other smart grid technologies, should incorporate and contribute to the vision and expectations for smart grid in Ontario.

The following areas of policy focus are therefore suggested:

- The development of policy for smart grid needs to leverage lessons learned from the development of the component innovations of smart grid, including storage, in order to facilitate an effective shift to smart grid and simultaneously promote economic growth from innovation.
- For Ontario to more strategically manage storage niche development, from idea to implementation, there would need to be an organization with a mandate to both develop niches and transfer the value from local niche development to the transition to smart grid in Ontario. The Clean Energy Institute announced in January 2012 could be the organization to offer this coordinating and value transfer role. In which case, the strengths of the Smart Grid Forum's coordinating role should be studied and integrated into the design and operation of the Clean Energy Institute.

- If it is anticipated that regulation and policy will lag local technology development, then the niche needs support for a development pathway that includes accessing other markets, often outside of Ontario. The policy developed should consider supporting innovation development pathways that include external markets. For example:
    - For niche entrepreneurs to continue to grow in international markets, particularly in emerging markets, they may need access to financing for those projects.
    - If Ontario is to provide reference customers for early stage growth, then LDCs need the mandate to participate in demonstrations, and funding for demonstrations need to be available.
    - For Ontario technologies to be implemented in external markets they need to comply with international standards. Ontario companies should be encouraged to participate in committees and other activities where they can help develop them, and get a competitive lead on understanding them.
- For markets to develop in Ontario, outside of LDCs, potential customers need to have opportunities to participate in learning processes, such as demonstrations. To access those customers, projects need results that increase the value of the building or customer firm. Those customers also need to be able to deliver feedback to the entrepreneurs based on current and future customer needs. Policy and funding programs that support engaging these customers with their desired value proposition should be explored.
- Investors need confidence that there will be a future market that the niche entrepreneurs can grow within. This confidence is expected to be provided by governments through regulation and market rules and supports. One more direct form of instilling confidence through policy could be through procurement policy. An example of this in Ontario is the Feed-In Tariff program for renewable generation. OEB approvals for cost of service rate recovery could also be interpreted as procurement policy. The model presented in this thesis indicates a lack of policy support through the later stages of storage niche development from the regime. Thus policy makers should develop policy which facilitates local investment in cost-effective technologies.
    - Aside from government policy, two organizations were identified as playing key roles in building investor confidence, SDTC and MaRS. The lessons learned from these organizations should be captured, and a continued relationship or similar service offering should be available should one or more of these programs not continue to deliver these services.

Reflections on the methodology

A theoretical goal of this research was to explore the effects of complementarity on niche development using the TIS and SNM analysis frameworks in order to demonstrate a method for leveraging the strengths of both. The Strategic Niche Management (SNM) framework and Technology Innovation System (TIS) framework provided useful concepts and language for exploratory research into change that is currently underway in Ontario's electricity sector. The TIS framework provided useful guidance for the data collection by providing a format to the interview protocol, and language that was readily understood by practitioners in the system. It also helped to link certain dynamics in the system that have multiple objectives for both regime transition and niche development. The SNM framework, and its related transition frameworks, worked well with the desired scope of my research being geographically tied to Ontario. It also facilitated the identification of target respondents, and the ultimate answer to my research questions. The more abstract concepts of the co-evolution of society and technology in these frameworks facilitated the interpretation of meaning from the interview responses and documents relative to promoting innovation and smart grid in Ontario. To analyze the specific dynamics of niche development, apart from the regime transition, the SNM framework proved most helpful for linking individual firm strategies to overall systems change.

Several authors have published on the comparisons of these approaches to understanding systems change in technology industries, (Chang & Chen, 2004; Coenen & Díaz López, 2010; F. W. Geels et al., 2008; Markard & Truffer, 2008b; Markard & Truffer, 2008b) including the authors of these frameworks (F. W. Geels et al., 2008). I believe my research experience to be more consistent with the theoretical findings of Coenen & Lopez (2010) and Geels et al. (2008). As found in this study, the emerging storage innovation system is roughly equivalent to the development of the storage niche and the related regime shift. The TIS framework proved most helpful for discussing and analyzing technology development pathways with respondents. The SNM frameworks proved most helpful for understanding the dynamics of systems change between actors and in relation to the existing regime structure. Graphically the two frameworks shared common cycles of observed behaviour by mapping the SNM processes onto typical cycles of TIS development, presented earlier in Figure 14.

Limitations to the findings

There are a number of limitations to the findings of this research.

First I make no claims to the generalizability of these findings. Further research would be required to determine the generalizability of these observations and findings across actors in Ontario, in other jurisdictions and with other technologies. The purpose of this exploratory study was to propose a theory for the development of the storage niche in Ontario, but testing it is left to future research.

The interviews used in this study were conducted before and after an election in Ontario. Energy policy was a major campaign issue in Ontario during the 2011 election, and that political will was seen to highly influence policy related to smart grid and the development of energy innovations within Ontario. It is therefore quite possible that the uncertainty about the coming election, and the decrease in political activity during the time preceding the election influenced the actor responses.

Due to a number of factors outside of this research, the interviews were conducted over approximately a 1 year timeframe. In addition to the election, the government announced the recipients of its Smart Grid Fund, launched a Clean Energy Economic Development Strategy, opened the Future of Energy Summit with a focus on storage, and announced the formation of a Clean Energy Institute tasked (among other things) to promote the development of storage technologies, and assigned the CEO and chair of an energy storage company to the head of a Clean Energy Task Force for the province. This is by no means a comprehensive list of all that happened in Ontario's energy sector in 2011 and 2012. In light of all of these events, some of the respondents interviewed first could be expected to have evolved their opinion regarding the development of a storage niche in Ontario.

Outside of the analysis of complementarity, this research has deliberately left a comparative analysis of the value of various business cases and potential benefits of storage out of scope. That subject continues to be reviewed by prominent organizations in this field. Actors in this study referred to the Electricity Storage Association (ESA), the Electric Power Research Institute (EPRI) and Sandia Labs in this regard. Respondents did discuss the attributes of various business cases and storage benefits during these interviews. The primary interest in this study was how complementarity affected the business case, the degree to which these assessments of value were shared and by whom.

Future research

A practical goal of this research was to produce insight that might be valuable during the course of transition and development in Ontario's electricity system. As such, this research relied on the actor and researcher interpretations of events currently underway, and expectations of future events. As an exploratory case study, it produced theories about the dynamics in the system that could be tested in future research. In future, empirical research could be conducted ex-post, using more quantitative methods such as historical event analysis or qualitative case study narratives given the benefit of hindsight. A comparison of this case study developed when the system was in an early stage of transition and niche development, to a historical case study of a transition, could yield important insights as to the usefulness of the SNM framework and the predictability of transitions. It could also compare development pathways of storage technology companies that existed years before the smart grid transition in Ontario, to those that entered into the sector during the transition to smart grid. This could further test the theory of the strategic link between the smart grid transition and niche development.

To develop confidence in the generalizability of these findings, even within Ontario, a deductive approach, across a larger sample of actors, could test the presence of the dynamics described between the four categories of systems and implementing actors at the regime and niche levels. According to the participant feedback, however, greater value would be added by focusing on methods of market and policy development that would apply to the case of Ontario. In which case the policy implications provided in this thesis could also lead to future research.

The Smart Grid Forum appears to be quite an influential network in this case. Future research could compare and contrast the roles and effects of similar industry-lead and publicly lead networks.

Conclusion

Motivated by the sustainability challenges that jurisdictions are facing globally, with particular regard to resources, the environment and the economy, this research set out to understand (at least in part) how innovation is occurring within the Ontario energy sector. This research objective was addressed by answering the research question, “how is the electricity storage niche developing for distribution systems in Ontario?” with empirical evidence using an exploratory case study methodology. This study finds evidence to suggest that the electricity storage niche is being developed strategically in Ontario. To determine that, this study also asked the question, “how do complementary innovations influence the niche formation?” This study finds evidence to suggest that the complementarity of storage to the existing electricity system, and to other technology innovations related to smart grid, supports dynamics that link the storage niche development and the system shift to smart grid strategically. That effect of storage niche development appears to promote the shift to smart grid, but does not drive it. The effect of the shift to smart grid appears to promote and drive the development of the storage niche more in the beginning phases of niche development, than the later phases. In the later phases other supports, such as those to accessing external markets, begin to influence the development of the niche more.

In order to arrive at these conclusions, a literature review examined the existing literature studying innovation and systems change. This section found that the Technology Innovation System (TIS) and Strategic Niche Management (SNM) frameworks of analysis could be used to explore the research questions.

The Methodology section described how these frameworks were employed in developing a case study of electricity storage technologies developing in Ontario. Due to the exploratory nature of the study, the analysis was designed to build on previous findings throughout the course of the study to compare and contrast evidence for the emerging theory of how the storage niche was developing.

The Data Analysis described the evolution of the enquiry throughout the analysis phases. It then presented evidence that was used to analyze the development of the storage niche in Ontario using elements of the TIS and SNM frameworks. During the analysis, a model of system actors emerged that divided the regime-level and niche-level actors into roles and perspectives at a system and implementing level. The result was four actor quadrants that allowed for a more structured analysis of the different actor roles within the scope of the study. The analysis of the niche development and the effects of complementarity on that development, lead to a model of niche development that integrates elements of the electricity system shift to smart grid and storage technology and business development.

The Discussions presented following the analysis reflects on how the model of niche development can be represented in terms of the literature reviewed. The attempts to map the model onto models presented in the theory demonstrates how this evidence can be used to further develop the models, and to propose a methodology for integrating both frameworks. It also reflects on the implications of the findings on the related policy. In general, the policy for smart grid is developed separately from the policies for promoting innovation, although there are explicit references to each other. This research suggests that these policies may need to be further integrated in order to maximize the value from the observed dynamics of a co-evolution of smart grid and storage niche visions and expectations. The limitations and related recommendations for future research recognize the opportunity to test the proposed model of storage niche development in Ontario, and test its generalizability to other technologies and jurisdictions.

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Appendix 1 – Case Study Protocol

Plan for conducting a case study of the effects of Li-ion batteries in the Ontario electricity system

Purpose:

The purpose of this study is to contribute to the growing theory on the formation and influence of complementary innovations on the dynamics of change within a large technical sector. Specifically it will explore the case of Li-ion batteries in the Ontario electricity sector as a master's thesis for Jennifer Hiscock of the Ted Rogers School of Management at Ryerson University. Practically, this research aims to provide stakeholders with a better understanding of the internal dynamics of change in Ontario's electricity sector with regard to Li-ion batteries as an electricity storage option. Information collected during this study will be in regards to the role of actors, networks and institutions in the following events surrounding Li-ion batteries in Ontario's electricity sector:

- Entrepreneurial activities
- Knowledge development
- Knowledge diffusion
- Guidance of the (R&D) search
- Market formation
- Resource mobilisation
- Creation of legitimacy/counteracting resistance to change

Overview:

Participants will be selected from multiple perspectives to represent a holistic picture of the Ontario electricity system in the Toronto and surrounding area. They will include participants from government (regulators, planning authorities and funders), local distribution companies, suppliers of electricity Li-ion batteries, entrepreneurs in electricity storage, and entrepreneurs in renewable electricity generation.

This study is supported in part by Ryerson's Centre for Urban Energy through a research award funded by Toronto Hydro. A preliminary report of findings regarding market formation will be presented to these parties in agreement with the award.

Benefit to Participants:

The applied research goal of this study is to provide greater insight into the internal dynamics change in Ontario's electricity system, and the role of electricity storage technologies, amidst external pressures from economic, societal and political arenas. Participants are also stakeholders in this system, and as such are expected to have an interest in the findings of this report. As part of the validation process participants and experts within the system will be invited to review the findings and suggest any necessary changes. As a final step, these findings will be made available to all participants in the study.

Procedure:

Information will be collected from these participants through available documentation and semi-structured interviews. Publically available documentation will be collected through the Lexus Nexus database and relevant patent databases. Further documentation will be sought as it becomes evident during the study through interviews with the participants. Participant interviews will be conducted in either a one-on-one or group setting, depending on the availability of the participants. If the interviews take place in multiple settings they will be analyzed in a way that reflects the implications of conducting interviews in a group session versus one-on-one.

The interview questions will be open-ended with regard to the 7 areas stated in the purpose and as categorized in the table below. Interview questions are detailed in the Interview Protocol that follows.

Function	Event category
Entrepreneurial activities	Project started Contractors provide turn-key technology
	Project stopped Lack of contractors
Knowledge development	Desktop assessments, feasibility studies, reports, R&D projects, patents
Knowledge diffusion	Conferences, workshops, platforms
Guidance of the search	Positive expectations of electricity storage technologies. Positive regulations by government on electricity storage technologies
	Negative expectations of electricity storage technologies. Negative regulation by government on electricity storage technologies.
Market formation	Tax regimes/feed-in rates, environmental/technical standards, consumer awareness/interest
	Expressed lack of tax regimes/feed-in rates, environmental/technical standards, consumer awareness/interest
Resource mobilisation	Subsidies, investments
	Expressed lack of subsidies, investments
Creation of legitimacy / counteracting resistance to change	Lobby by actors/networks to improve technical, institutional and financial conditions for particular technology related to electricity storage
	Expressed lack of lobby by actors/networks
	Lobby for other technologies that compete with electricity storage technologies
	Resistance to change by actors/networks in regime or niche level

<u>Confidentiality:</u>

All information collected in this case study will be related to the dynamics of change within the electricity sector in Ontario.

No proprietary or confidential information on specific technologies will be collected or retained.

All information regarding confidential business strategies will only be reported in aggregate, without indication of the source or identity of the individual participants. The information collected regarding confidential business strategy will not be retained following the study.

The identity of the interview participants will not be released. The identity of the organizations within which the participants belong will be included in the final case narrative ***only*** as necessary, and ***only*** with informed consent from the participants.

<u>Interview Protocol:</u>

Technical overview:

Interviewer: Brief description of Li-ion batteries and their development for the electric vehicle industry, and use in the electricity sector. It would include something like:

"You've likely heard of Li-ion batteries for your phone or your computer. The same technology is available on a larger scale and has been used in the design and development of electric vehicles for recreational, commercial or industrial purposes for decades. Increasingly they are being used in more mainstream markets in the last few years with vehicles like the newer Toyota Prius, and the Nissan LEAF. As their capacity has begun to increase and reliability has begun to improve, Li-ion batteries have begun to be installed into electricity grids for distributed electricity storage. Other countries such as Japan have recently begun to install units into its electricity grid, but we have yet to see widespread application in Ontario's electricity system.

These batteries can be used in conjunction with renewable technologies such as solar and wind to improve their reliability, but they can also be used to offset peak electricity needs by charging them during the night and drawing from them during the day. The modular units of battery banks such as Li-ion would be about the size of a cargo container that could fit into a standard parking spot."

1. Entrepreneurial activity

Interviewer: To what extent is there experimentation with Li-ion batteries as an electricity storage technology in Ontario? Is there variety in the experimentation?

a. Do you know of any companies experimenting with Li-ion batteries either in their business model, or technically?
    i. <u>PROBE:</u> Are there currently any strategies for developing and implementing Li-ion batteries or similar technologies?
b. What are the different ways that battery technologies are being developed for urban electricity storage? Is there a dominant design you see emerging?

2. Knowledge development

Interviewer: Wherein lies the knowledge related to the state of development and competitive edge of electricity storage? (Look for references to assessments, feasibility studies, reports, projects, patents, etc.) How broad or narrow is the knowledge base in this area? What degree of variety is there in the relevant knowledge? What kind of application specific knowledge is generated?

a. How much does your organization know about batteries for urban electricity storage?
b. Are there significant gaps in the knowledge in either technical or business respects that prevent the adoption or diffusion of this technology?
    i. <u>PROBE:</u> Are there significant questions you have regarding the state of the value chain (suppliers, maintenance/service, etc.) supporting Li-ion batteries or batteries in general for electricity storage?

3. Knowledge diffusion

Interviewer: To what extent does the knowledge base cover the whole value chain? Is the electricity sector progressing through a learning curve with regards to Li-ion batteries as electricity storage options?

a. Are you building off of previous experience with battery technologies for electricity storage?
b. Where are you gaining most of your knowledge from regarding this field?

4. Guidance of the (R&D) search

Interviewer: Is there a belief in the growth potential of electricity storage solutions for the Ontario electricity system? Is there a belief that Li-ion batteries or batteries in general will be part of these electricity storage options?

a. What factors or events lead you to believe whether or not electricity storage is a growing field in the Ontario electricity sector?
    i. <u>PROBE:</u> What factors or events lead you to believe whether or not Li-ion batteries or batteries in general will be part of these electricity storage options?
b. Are there any organizations that are facilitating the integration Li-ion batteries or other electricity storage technologies into the Ontario electricity system?

Are customers experimenting with or articulating a need for new solutions?

b. Are you aware of any customer demand for urban electricity storage beyond back-up generators?
    i. <u>PROBE:</u> Can you describe any successful or unsuccessful cases where customers have installed batteries into their electricity systems for these purposes?
c. [CONSUMER VARIATION]: Are you interested in installing electricity systems with battery storage?
    ii. <u>PROBE:</u> Can you describe any successful or unsuccessful cases when you or others you know of have installed batteries into their electricity systems?

What is the combined effect of regulations?

d. How is the current regulatory environment effecting the development and diffusion of Li-ion batteries as an electricity storage option in Ontario?

5. Market formation

Interviewer: In what phase is the market for Li-ion batteries in the Ontario electricity market? Who is playing a role and in what way? Are there institutional stimuli for a market formation, or is institutional change needed? What hinders use? Are there uncertainties facing potential investors/buyers?

a. What phase is the Ontario electricity market in for Li-ion batteries?
    i. <u>PROBE:</u> Nursing? Bridging? Mature?
b. Has a demand for Li-ion or other battery technologies been articulated within the Ontario electricity sector? By whom?
c. Who are the users of Li-ion batteries and what do their adoption/purchasing processes look like?
d. What is the degree to which experiments are made with new applications of Li-ion batteries or other battery storage technologies?

e. Are there incentives or other stimulus for implementing Li-ion batteries or similar electricity storage options, or is there a lack of these programs?
    ii. PROBE: What is promoting or hindering the use of Li-ion batteries or similar electricity storage options?
    iii. PROBE: Are there uncertainties preventing potential buyers from investing in Li-ion batteries or electricity storage options in general?

6. Resource mobilization

Interviewer: Is there sufficient access to human capital in Ontario in specific science and technology, entrepreneurship, management and finance fields for the diffusion of Li-ion batteries as an electricity storage option? Are the requisite products, services, and network infrastructure in place for the diffusion of electricity storage options such as Li-ion batteries?

a. How does your organization make decisions about investing in energy technologies that could compare to an urban electricity storage technology such as Li-ion batteries?
    i. PROBE: Who is involved in making this decision? What is their relevant background and experience with these types of technologies?
b. How do you perceive Li-ion batteries affecting the value of your current technologies, infrastructure or services?
    i. PROBE: Is there a strategic value to you promoting, investing in or supporting Li-ion batteries or other electricity storage options?

7. Creation of legitimacy / counteracting resistance to change

Interviewer: How receptive are the potential stakeholders (incumbents, government policy, the public, etc.) to Li-ion batteries and electricity storage (outside of large hydro reservoirs) in the Ontario electricity system? What kind of organized support is evident for Li-ion batteries in the electricity system?

a. How do you perceive Li-ion batteries (or other electricity storage) fitting into the current electricity system business model?
    i. PROBE: Who would own them?
    ii. PROBE: How would they be paid for?
b. What factors are leading your organization to make or not make investments into Li-ion batteries or other electricity storage technologies?
c. Do you see any opportunities above and beyond what is currently proposed for Li-ion batteries or other electricity storage technologies starting to emerge in the field?
    i. PROBE: Currently the highlighted benefits include power quality, reliability and energy arbitrage for consumers. For distribution companies they include peak shaving and reliability. For generators they include power quality, load levelling and managing spinning reserve. Outside of fitting into this system do you see other electricity opportunities?
d. Do you perceive the integration of Li-ion batteries and electricity storage technologies into the Ontario electricity system to be separate from renewable electricity technologies? In what way?
e. Do you see political support from government or citizen groups for Li-ion batteries?
f. Are you seeing signs that Li-ion batteries or urban electricity storage is being developed in a way that addresses key industry and market issues?

g. Who do you think could support the development of technologies for electricity storage to make the field more legitimate in the eyes of consumers, local distribution companies, government funders or other stakeholders in the Ontario electricity sector?
h. Are you aware of undesirable consequences from implementing Li-ion batteries or other electricity storage technologies into the system?

Appendix 2 – Respondent terms and their relation to TIS and SNM processes

Several themes that were not merely synonyms for the 8 TIS functions or SNM processes were used by interview respondents. They are described below as they related to innovation system functions and strategic niche management processes below.

- A **business case** must be determined before storage can be seen as fully legitimate, and before it can be supported by multiple stakeholders. The business case may not be enough to support storage on the market on its own, but for regime system actors it may be enough to justify public support. There's sort of a "public good" business case that the system perspective regime players are looking to see first and foremost, before they apply expectations of an economic business case. The economic business case seems to weigh-in most heavily in people's assessments of a technology's potential or legitimacy, but this wasn't always a strict payback calculation. For some customers in the niche implementers quadrant, the business case could be in increasing the value of the customers assets in other ways beyond cutting costs. This seems to have almost equal influence on building of social networks and visioning and expectation setting.

- There is a certain tolerance for and expectation that **change is complex and messy**, this is almost expressed as matter of fact. This description seems to be of both niche development being uncoordinated and regime change being uncoordinated during much of the learning process. This had almost entirely to do with visioning and expectation setting and legitimation.

- In part related to the "public good" business case, there is a view from the systems change perspective that **change is dependent on political processes**. This seems to have the most significant implication on the building of social networks. To some degree politics are viewed as deciding legitimation, as opposed to legitimation being something organically arrived at. In turn, "politics" are not solely the realm of politicians; there are many methods of influence that are exercised by niche entrepreneurs, markets and regime players.

- The principle of **fairness** within the regime appeared to be central to the regime system perspective. Fairness seemed to have a stronger influence on the building of social networks and resource mobilization, and significance to visioning and expectation setting and influence on the direction of the search and legitimacy.

- The concept of **roles** featured prominently in many points of conversation with the system and implementing perspective regime players. Roles had to do with using rules to identify of the types of activities or responsibilities that different regime and niche actors participate in or under. Most of this was related in a diagnostic way, as opposed to a prognosis of the way things should be done. This had a lot to do with the building of social networks and vision and expectation setting.

- **Risk aversion** was a common theme from the regime systems, implementing and systems perspectives, often referred to as a barrier to integrating new technologies into the system. Niche implementers acknowledge risk aversion but not as a problem or barrier so much as an influence on business strategy. Risk aversion appeared to strongly influences the building of social networks and resource mobilization. This is related to the business case and also the perspective of roles.

- For a number of system perspective regime players the concept of a **technical need** governed vision and expectation setting as sort of a "truth" to the situation regarding storage technology development. Descriptions of the legitimation of storage technologies were often tied to this technical need, as well as descriptions of influences on the direction of the search. This technical need was tied to a "problem" that storage is supposed to solve. The importance of that problem or identification of it however varied.

- The **valuation of non-economic benefits** was a theme that also featured as having significant influence on assessments of business cases and technical need. It affects legitimaion, and the building of social networks and visioning and expectation setting.

- Storage is in **competition with other smart grid technologies and processes** for market share and resources. This affects the perceived business case and legitimacy of storage technologies, particularly on cost issues. To use Porter's (2008) terms, the most significant competitive forces would be from the threat of substitution followed by the bargaining power of buyers. This seems to have the greatest implication on the building of social networks and legitimation.

Appendix 3 - Ontario Smart Grid Principles and Objectives

Principles and objectives taken from the Ontario Minister of Energy Order-in-Council 1515/2010, November 23, 2010 section 4, and Appendices 'A' 'B' and 'C' – the complete version of the directive can be found on the Ontario Energy Board (OEB) website.

OVERVIEW: This table includes the principles/objectives that are to be considered by the provincial regulator, when considering the smart grid activities and plans of licensed, regulated utilities in the province of Ontario.

GENERAL OBJECTIVES TO BE CONSIDERED BY THE OEB IN EVALUATING SMART GRID ACTIVITIES OF REGULATED ENTITIES

EFFICIENCY: Improve efficiency of grid operation, taking into account the cost-effectiveness of the electricity system.

CUSTOMER VALUE: The smart grid should provide benefits to electricity customers.

COORDINATION: The smart grid implementation efforts should be coordinated by, among other means, establishing regionally coordinated Smart Grid Plans ("Regional Smart Grid Plans") including coordinating smart grid activities amongst appropriate groupings of distributors requiring distributors to share information and results of pilot projects, and engaging in common procurements to achieve economies of scale and scope.

INTEROPERABILITY: Adopt recognized industry standards that support the exchange of meaningful and actionable information between and among smart grid systems and enable common protocols for operation. Where no standards exist, support the development of new recognized standards through coordinated means.

SECURITY: Cybersecurity and physical security should be provided to protect data, access points, and the overall electricity grid from unauthorized access and malicious attacks.

PRIVACY: Respect and protect the privacy of customers. Integrate privacy requirements into smart grid planning and design from an early stage, including the completion of privacy impact assessments.

SAFETY: Maintain, and in no way compromise, health and safety protections and improve electrical safety wherever practical.

ECONOMIC DEVELOPMENT: Encourage economic growth and job creation within the province of Ontario. Actively encourage the development and adoption of smart grid products, services, and innovative solutions from Ontario-based sources.

ENVIRONMENTAL BENEFITS: Promote the integration of clean technologies, conservation, and more efficient use of existing technologies.

RELIABILITY: Maintain reliability of the electricity grid and improve it wherever practical, including reducing the impact, frequency and duration of outages.

CUSTOMER CONTROL OBJECTIVES	POWER SYSTEM FLEXIBILITY OBJECTIVES	ADAPTIVE INFRASTRUCTURE OBJECTIVES
ACCESS: Enable access to data by authorized parties who can provide customer value and enhance a customer's ability to manage consumption and home energy systems.	DISTRIBUTED RENEWABLE GENERATION: Enable a flexible distribution system infrastructure that promotes increased levels of distributed renewable generation.	FLEXIBILITY: Provide flexibility within smart grid implementation to support future innovative applications, such as electric vehicles and energy storage.
VISIBILITY: Improve visibility of information, to and by customers, which can benefit the customer and the electricity system, such as electricity consumption, generation characteristics, and commodity price.	VISIBILITY: Improve network visibility of grid conditions for grid operations where a demonstrated need exists or will exist, including the siting and operating of distributed renewable generation.	FORWARD COMPATIBILITY: Protect against technology lock-in to minimize stranded assets and investments and incorporate principles of modularity, scalability and extensibility into smart grid planning.
CONTROL: Enable consumers to better control their consumption of electricity in order to facilitate active, simple, and consumer-friendly participation in conservation and load management.	CONTROL AND AUTOMATION: Enable improved control and automation on the electricity grid where needed to promote distributed renewable generation. To the extent practical, move toward distribution automation such as a self-healing grid	ENCOURAGE INNOVATION: Nest within smart grid infrastructure planning and development the ability to adapt to and actively encourage innovation in technologies, energy services and investment/business models.

PARTICIPATION IN RENEWABLE GENERATION: Provide consumers with opportunities to provide services back to the electricity grid such as small-scale renewable generation and storage. CUSTOMER CHOICE: Enable improved channels through which customers can interact with electricity service providers, and enable more customer choice. EDUCATION: Actively educate consumers about opportunities for their involvement in generation and conservation associated with a smarter grid, and present customers with easily understood material that explains how to increase their participation in the smart grid and the benefits thereof.	infrastructure to automatically anticipate and respond to system disturbances for faster restoration. QUALITY: Maintain the quality of power delivered by the grid, and improve it wherever practical.	MAINTAIN PULSE ON INNOVATION: Encourage information sharing, relating to innovation and the smart grid, and ensure Ontario is aware of best practices and innovations in Canada and around the world.

Appendix 4 – Ontario Smart Grid Forum Members

Chair: Paul Murphy, President and CEO, Independent Electricity System Operator (ieso.ca)

Michael Angemeer, President and CEO, Veridian Corporation (veridian.on.ca)

David Collie, President and CEO, Electrical Safety Authority (esasafe.com)

Norm Fraser, Chief Operating Officer, Hydro Ottawa Limited (hydroottawa.com)

Anthony Haines, President, Toronto Hydro-Electric System Limited (torontohydro.com)

Jim Huntingdon, President, Niagara-on-the-Lake Hydro (notlhydro.com)

Ivano Labricciosa*, Vice-President, Asset Management, Toronto Hydro-Electric System Limited (torontohydro.com)

Keith Major, Senior Vice President, Property Management, Bentall Kennedy Real Estate Services (bentallkennedy.com)

Craig Martin, Director, Eastern Canada Power, TransCanada (transcanada.com)

David McFadden, Past Chair, Ontario Centres of Excellence (oce-ontario.org)

Dan McGillivray*, Managing Director, Ontario Centres of Excellence and Sector Lead: Energy & Environment (oce-ontario.org)

Dr. Jatin Nathwani, Ontario Research Chair in Public Policy and Sustainable Energy Management, University of Waterloo (wise.uwaterloo.ca)

Andrew Pride, VP Conservation, Ontario Power Authority (powerauthority.on.ca)

Wayne Smith, SVP, Grid Operations, Hydro One Inc. (hydroone.com)

Don Tench, Director, Market Assessment and Compliance, Independent Electricity System Operator (ieso.ca)

Observers:
Aleck Dadson, Chief Operating Officer, Ontario Energy Board (ontarioenergyboard.ca)

Brian Hewson, Senior Manager, Networks & Smart Grid, Ontario Energy Board (ontarioenergyboard.ca)

Jon Norman, Director, Transmission and Distribution Policy, Office of Energy Supply, Ontario Ministry of Energy (ontario.ca)

Appendix 5 – Energy Storage Working Group recommendations presented to the Smart Grid Forum

April 16th 2012

Presentation and recommendations are available from the Smart Grid Forum Meeting Materials on the IESO website: http://www.ieso.ca/imoweb/pubs/smart_grid/materials/20120416/SGF-20120416-CPC_Storage_Group-Presentation.pdf

Hurdle	Recommendation
1. Current market rules would penalize Energy Storage applications because the Global Adjustment, Debt Retirement, Uplifts and T&D Costs would be charged twice—once when energy is captured and again when used by the end consumer.	**Modify market rules to recognize the inherent differences and benefits of Energy Storage applications.** • Charge Global Adjustment, Debt Retirement, Uplifts and T&D Costs on a "net consumption" basis and pass through these fees to the end customer • Apply to large scale, distributed and aggregated Energy Storage applications • Consider precedents set for "Station Service" with pumped hydro facilities, energy export classification, and demand response • Provide outright exemption for demonstration plants
2. Regulation Service contracts were designed with generation assets in mind because generators have historically provided these services.	**Change structure of IESO ancillary service contracts so that Energy Storage assets are eligible where it makes economic sense.** • Removal of contracting and registration barriers to entry (RFP evaluation criteria, licensing aggregation requirement, etc.) • Differentiated regulation service class for fast responding resources (along lines of FERC 755) • Longer term ancillary service contracts needed to make business case for investors for Energy Storage applications
3. Energy Storage delivers system-wide benefits, including reduced congestion and deferral of capital, that are compelling in totality but are difficult to monetize because benefits accrue to multiple stakeholders.	**Establish a consistent, transparent mechanism to value the defused benefits to the ratepayer.** There are two alternative approaches to address this issue: a) Permit Energy Storage assets to be included in rate base applications of Local Distribution Companies (and Hydro One for rural distribution) b) Design a programmatic (FIT) approach

Appendix 6 – Glossary of Terms and Abbreviations

ENERGY	Ontario Ministry of Energy
EV	Electric Vehicle
IESO	Independent Electricity System Operator
FIT / micro-FIT	Feed-In Tariff Program offered from the Ontario Power Authority
LDC	Local Distribution Company
MaRS	MaRS Discovery District
MEDI	Ministry of Economic Development and Innovation
MLP	Multi-level Perspective of transitions analysis framework
MWh	Megawatt hours
NG	Natural Gas
NRCan	Natural Resources Canada
OCE	Ontario Centres of Excellence
OEB	Ontario Energy Board
OPA	Ontario Power Authority
R&D	Research and Development
SDTC	Sustainable Development Technology Canada
SG Forum	Smart Grid Forum
SNM	Strategic Niche Management analysis framework
TIS	Technology Innovation System analysis framework
VC	Venture Capital