ADAPTIVE INFRASTRUCTURE REGULATION:
DESIGNING FOR CLIMATE CHANGE

by

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Abstract

Climate change represents a vexing challenge for infrastructure design. There is increasingly widespread acknowledgement that design practices need to change in order to ensure that structures built today can withstand changes in average climate conditions, growing climate variability, and more frequent and extreme weather events over the coming decades. Yet substantial uncertainty persists with respect to the specific future conditions that structures should be designed for, leading to regulatory paralysis: despite the need for urgent action, regulation continues to require that infrastructure design be based on the assumption that past climate will be representative of future climate. This thesis argues that, in the face of this bedevilling combination of urgency and uncertainty, government regulation will be required to generate the changes in design practices needed to ensure that structures designed today will be resilient and robust to the climate impacts they are likely to confront over their lifetimes.

Using the example of the National Building Code of Canada, this thesis identifies several stress points in existing regulatory frameworks for infrastructure design. In particular, this thesis demonstrates that existing methods for dealing with uncertainty in infrastructure design regulation are likely to be overwhelmed by the deep uncertainties surrounding climate change, and that the poor adaptive capacity of existing frameworks renders them unable to keep pace with the increasingly rapid pace of change. Responding appropriately and proactively to these challenges demands a new regulatory paradigm. This regulatory paradigm should draw guidance from new governance theory in the legal scholarship, as well as a range of ‘adaptive’ approaches developed in other disciplines — adaptive management, adaptive governance, and adaptive policymaking. The core of a new, adaptive regulatory paradigm should be a structured, iterative
regulatory process that is capable of responding quickly and appropriately to new knowledge and unfolding realities, and formal and informal, multi-level networks that foster learning, cooperation, collaboration, and innovation. Without such a paradigm shift, the existing regulatory paradigm will fall into crisis, rendering structures designed today vulnerable to failure in the face of tomorrow’s climate, and thereby compromising substantial infrastructure investments and increasing risks to public safety.
Preface

This dissertation is original, unpublished, independent work by the author, Andrew Higgins.
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Chapter 1: Introduction

Despite near universal acknowledgement that infrastructure\(^1\) needs to be designed for future climate,\(^2\) regulation continues to require structures to be designed and built in accordance with climate values based on historic climate patterns. Engineers Canada\(^3\) recently released a model guideline setting out principles that should guide professional engineering in initiating climate change adaptation actions, which states that:

> [t]he climate is changing. Historical climatic design data is becoming less representative of the future climate. Many future climate risks may be significantly under-estimated. The engineer cannot assume that the future will be similar to the past. Historical climate trends cannot be simply projected into the future as a basis for engineering work.\(^4\)

Yet the National Building Code of Canada (NBCC), while acknowledging that “many buildings will need to be designed, maintained and operated to adequately withstand ever changing..."
climatic loads”, still relies on an assumption of ‘stationarity’ — that is, “the idea that natural systems fluctuate within an unchanging envelope of variability” and therefore “the past climate will be representative of the future climate.” While this assumption of stationarity implies that the loads on a structure — including climate loads — will remain (relatively) stable over its design life, the assumption of stationarity is going to “fall to pieces in the era of climate change.”

Due to climate change, structures being built today — typically designed for a lifespan in excess of 50 years — will increasingly need to withstand more frequent and extreme weather events, more climate variability, and changes in average climate conditions. This thesis argues that a change in design practices is vital in order to ensure that structures being designed today will be resilient and robust to the climate impacts they are likely to encounter over their lifetimes.

Failure to account for future climate risks in the design of structures increases the

5 Canadian Commission on Building and Fire Codes, National Building Code of Canada 2010, 13th ed (Ottawa: National Research Council Canada, 2010), Division B, Appendix C (Climatic and Seismic Information for Building Design in Canada) (“Some regions could see an increase in the frequency and intensity of many weather extremes, which will accelerate weathering processes.”). Also see, Heather Auld et al, The Changing Climate and National Building Codes and Standards (Keystone, Colorado, 2010), sec 6.4 (“While the technical provisions of the current edition of the National Building Code of Canada (NBCC) assume that the past climate will be representative of the future climate, specific text was added to NBCC editions from 1995 to the present to advise users that the assumption of stationarity will become increasingly invalid under climate change as the regional frequencies and intensities of extreme events change. The commentary also highlighted the need for careful consideration of climate variability in estimated values of climatic design loads.”).


7 See Canadian Commission on Building and Fire Codes, supra note 5 at Appendix C.


9 Most infrastructure is built to last for several decades: bridges, housing, commercial buildings, seaports, and rail infrastructure typically require reconstruction or major upgrades every 50-100 years; dams, water supply infrastructure, sewers, and airports have an expected lifecycle of 50 years; and roads and waste management facilities require major upgrades every 20-30 years. See Heather E Auld, “Adaptation by Design: The Impact of Changing Climate on Infrastructure” (2008) 1:3 Journal of Public Works & Infrastructure 276 at 282–83.

10 See, for example, Infrastructure Canada, Adapting Infrastructure to Climate Change in Canada’s Cities and Communities: A Literature Review (Ottawa: Infrastructure Canada, 2006).

11 It is likely to be much cheaper to identify and address infrastructure vulnerability to a future climate during the design and construction process as compared to retrofitting at a later date or restoring or replacing infrastructure
potential for structural failure, elevating risks to public health and safety and potentially forcing the premature reinforcement, reconstruction, or relocation of structures, likely at great expense.\textsuperscript{12} Although private actors will — indeed must — carry out some adaptation actions autonomously, such measures are unlikely to occur on a sufficiently widespread or timely basis. Therefore government regulation is required to facilitate industry-wide change.

This introduction sets out my research question, maps out how I use the term ‘regulation’ in this thesis, explains why I focus on regulatory approaches to climate change adaptation, and provides an outline of the thesis. The central argument of this thesis is that the successful adaptation\textsuperscript{13} of infrastructure to climate change will not simply be a matter of abandoning the assumption of ‘stationarity’ and tinkering with the existing regulatory framework. Rather, fundamental changes to infrastructure design regulation are required in order to appropriately respond to the challenges posed by a changing climate — a new ‘regulatory paradigm’ is needed.\textsuperscript{14}

\textsuperscript{12} See Brian Mills & Jean Andrey, \textit{Climate Change and Transportation: Potential Interactions and Impacts} (Washington, DC: US DOT Center for Climate Change and Environmental Forecasting, 2002) at 78 (arguing that, for infrastructure with long life spans ‘expected changes in climate may occur considerably earlier during the expected service life, possibly forcing expensive reconstruction, retrofit or relocation.’). It is also important to note that small increases in weather and climate extremes have the potential to bring about large increases in infrastructure damage. See Heather Auld & Don C Maclver, \textit{Changing Weather Patterns, Uncertainty and Infrastructure Risks: Emerging Adaptation Requirements} (Downsview: Environment Canada, 2007) at 4 (“Studies indicate that damage from extreme weather events tends to increase dramatically above critical thresholds, even though the high impact storms associated with damages may not be much more severe than the type of storm intensity that occurs regularly each year.”).

\textsuperscript{13} The Intergovernmental Panel on Climate Change (IPCC), the leading international body for the assessment of climate change, defines adaptation as “the process of adjustment to actual or expected climate and its effects.” See Intergovernmental Panel on Climate Change, \textit{Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change} (Cambridge, UK; New York: Cambridge University Press, 2014) at 5 (“In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.”).

\textsuperscript{14} For a discussion of the concept ‘regulatory paradigm,’ see section 2.1.
objectives, the basic assumptions and understandings on which regulation is based, the structure of the regulatory framework, and the regulatory tools and methods used. I argue that this new regulatory paradigm should draw from ‘new governance’ scholarship, as well as a range of ‘adaptive’ approaches developed in other fields — adaptive management, adaptive governance, and adaptive policymaking. While the conversation between these different epistemic communities has been limited to date, this thesis uses the example of the NBCC to demonstrate that there are conceptual and practical advances to be made when these literatures are drawn together. In particular, this thesis makes a contribution to the legal and resilience scholarship through its analysis of the approaches that can productively guide the development of a new regulatory paradigm.

1.1 Research question

In this thesis, I explore the following research question: what should a regulatory framework for infrastructure design that responds proactively to the challenges of climate change look like? In this regard, a broad range of potential adaptation measures is available to accommodate the demands that climate change will place on regulatory frameworks. Legal scholars typically favor procedural changes, such as new decision-making models, modified administrative procedures to enhance agency flexibility, and revised regulatory goals.\footnote{Katherine Trisolini, “Holistic Climate Change Governance: Towards Mitigation and Adaptation Synthesis” (2014) 85 U Colo L Rev 615 at 642.} I argue, however, that piecemeal changes to existing regulatory frameworks will not be sufficient. Rather, as Robin Kundis Craig notes, in an era dominated by climate change, we will need to embrace “both a new way of thinking about what regulation is supposed to accomplish and different kinds of legal
frameworks for accomplishing those new goals.” Accordingly, I argue that the successful adaptation of infrastructure to climate change requires a shift to a new ‘regulatory paradigm’ — a concept that I explore in Chapter 2. In addition, I put forward some integral elements of a new regulatory paradigm.

This is an argument about the role of regulation in facilitating and promoting the adaptation of infrastructure to the impacts of climate change. While climate change mitigation efforts remain crucial — indeed, without them the efforts described in this thesis may not even be sufficient — it is increasingly evident that at least some adaptation efforts will be required even in the unlikely event that atmospheric greenhouse gas concentrations are stabilized in the near future. As the scientific evidence becomes clearer that human interference with the climate system is already occurring and its impacts are projected to grow, greater attention is being paid to climate change adaptation. Efforts to enhance adaptation actions and increase resilience are expected to play a key role in the post-2020 climate agreement to be negotiated under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC) at the Conference of Parties (COP21) to be held in Paris in December 2015. In addition,

17 Climate change adaptation actions differ from mitigation measures in that the former seek to address the impacts of climate change while the latter seek to reduce greenhouse gas emissions and minimize the effects of climate change. Adaptation and mitigation are considered to be complementary strategies for reducing and managing the risks of climate change. See Intergovernmental Panel on Climate Change, Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Geneva: IPCC, 2015) at 17.
18 Although taking drastic mitigation measures now can substantially reduce the risks posed by climate change, adaptation measures will still be required as certain climatic changes are already ‘locked in’ as a result of past and current greenhouse gas emissions. Ibid at 17–18.
governments and engineers increasingly accept that infrastructure will be exposed to the impacts of climate change, which has the potential to substantially affect the effectiveness and lifespan of structures, and accordingly, that there is a need to adapt.

In a scholarly sense, the complexity of climate change adaptation makes it both a more interesting and a more vexing legal problem than climate change mitigation with its one clear regulatory goal: the substantial reduction of greenhouse gas emissions. Nevertheless, until recently, much of the legal attention to climate change has focused on mitigation. As J B Ruhl and James Salzman note,

the demands of climate change adaptation will present new kinds of challenges and conflicts for public and private legal institutions. It is no surprise, therefore, that a flood of recent scholarship has focused on the implications of climate change adaptation for the law—exploring how law will adapt in fields as varied as insurance, environmental, immigration, water supply, torts, energy, and property, to name just a few—while crosscutting issues such as federalism and human rights are also receiving careful attention.

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20 See, for example, Government of British Columbia, Ministry of Environment, supra note 2 at 1 (“British Columbia will need to adapt to the unavoidable impacts of climate change … Anticipated climatic changes will have real impacts on infrastructure and the costs of construction, maintenance and replacement.”); City of Vancouver, supra note 2 at 14 (“Infrastructure assets provide a significant opportunity for adaptation. They have long operational lifetimes, meaning they will be exposed to both current and future climate. Infrastructure in Canada is relatively vulnerable to climate change as it is aging and over-used with population and development pressures increasing associated expectations for service.”).

21 See, for example, Engineers Canada, supra note 4 at 2; David Lapp, “Engineers and Climate Change: What You Need to Know” (2005) 26:2 Engineering Dimensions 51 at 53 (“Engineers must adapt Climate change is inevitable. Mitigation may slow the rate of climate change, but nothing will reverse current trends. So, as engineers, we have no choice but to incorporate climate change into our practice to adapt and serve the public interest in terms of health, safety and welfare. After all, it is our ethical obligation. Climate change will be a challenge, but it may also offer an opportunity for great engineering innovations.”); CSA Group, National Survey of Canada’s Infrastructure Engineers about Climate Change (Mississauga: CSA Group, 2012) at 10 (“Seventy percent of respondents indicated that a changing climate has already affected or will affect their engineering decisions, with 42% indicating strong agreement with this.”).


While adaptation efforts will need to pervade all aspects of law and society, much of the (rapidly growing) legal literature to date has focused on general principles for the design of laws that will govern adaptation to the ecological and socio-ecological impacts of climate change. For example, Robin Kundis Craig offers five core principles of what she refers to as ‘climate change adaptation law’: monitor and study everything all the time; eliminate or reduce non-climate change stresses and otherwise promote resilience; plan for the long term with much increased coordination across media, sectors, interests and governments; promote ‘principled flexibility’; and accept — really accept — that climate change adaptation will often be painful. In this thesis, rather than focussing on these general principles, I undertake a more thorough analysis of the legal challenges that climate change poses for infrastructure design regulation. In doing so, this thesis makes a contribution to the growing body of climate change adaptation law, delving deeper into the challenging legal problems that climate change raises, and providing practical guidance for the development of proactive regulatory responses.

The key challenges for the existing regulatory paradigm for infrastructure design are the uncertainty, complexity and dynamic nature of climate change. In particular, while it is increasingly clear that stationarity is ‘dead’ and therefore historic climate data can no longer form the basis of engineering design, substantial uncertainty persists with respect to the future

24 See, for example, Craig, supra note 16; Ruhl, supra note 8; J B Ruhl, “General Design Principles for Resilience and Adaptive Capacity in Legal Systems — With Applications to Climate Change Adaptation” (2010) 89 NC L Rev 1373.
25 Craig, supra note 16. On the other hand, J B Ruhl and James Salzman query whether a new, distinct field of law devoted directly to managing climate adaptation is required, or whether legal adaptations are more likely to evolve in response to social and economic adaptations through incremental changes across numerous existing fields of law. See Ruhl & Salzman, supra note 23 at 981.
26 Craig, supra note 16.
conditions that structures should be designed for. As Robin Kundis Craig notes, “although the dynamism/stationarity problem has been recognized, the law has not changed significantly to acknowledge it. Problem recognized does not mean problem solved.” This is because there is no easy ‘solution’ — or perhaps any solution at all — to the “dynamism/stationarity problem.”

In short, regulators and engineers are caught in a conundrum of knowing that future climatic conditions are likely to be very different from those of the past, yet knowing neither the magnitude (or in some circumstances, even the direction) of future changes, nor the timeframes over which they will take place, due to the deep uncertainties surrounding climate change.

Traditional methods for handling uncertainty are likely to be inadequate to address these uncertainties. They are typically designed to either deal with a ‘best guess’ of the future or a range of plausible future conditions, but they are not designed to adapt should conditions change beyond the predictable or plausible. Climate change calls for regulations that acknowledge and accept the uncertainty and dynamism of climatic changes, and respond through a regulatory framework that is both robust and adaptive. In other words, infrastructure design regulations should be designed to remain applicable across a range of plausible future climates (i.e., be robust) and should also be sufficiently flexible and responsive to changing future climate conditions and the state of climate knowledge (i.e., be adaptive). While increased flexibility can

28 For further discussion of the uncertainties that climate change presents, see section 3.3 below.
29 Craig, supra note 16 at 37.
30 For example, it will not simply be a matter of replacing the assumption of stationarity with an assumption of ‘nonstationarity.’ See Gerald E Galloway, “If Stationarity is Dead, What Do We Do Now?” (2011) 47:3 Journal of the American Water Resources Association 563.
31 Kathleen A Miller, “Grappling with Uncertainty: Water Planning and Policy in a Changing Climate” (2010) 5 Envtl & Energy L & Pol’y J 395 at 396; Intergovernmental Panel on Climate Change, supra note 13 at 569 (“There have been studies in increasing numbers of cities to identify measures to adapt housing (and other buildings) and discussions on revising standards, although it is difficult to set standards with uncertain forecasts and scenarios and evolving risks.”).
open the door to potential abuse, a structured, principled process for regulatory adjustments can provide sufficient accountability in order to minimize misuse.

1.2 How does this thesis understand ‘regulation’?

While economists once dominated the study of regulation, over the past few decades regulation has been informed by debates from a range of disciplinary backgrounds — notably law, economics, political science and public policy, sociology, history, psychology, geography, anthropology, management and social administration.\(^{33}\) Given the breadth of perspectives, defining what regulation is (and what it is not) is unsurprisingly a matter of considerable debate.\(^{34}\) As Anthony Ogus notes, “[t]he expression ‘regulation’ is frequently found in both legal and non-legal contexts. It is not a term of art, and unfortunately it has acquired a bewildering variety of meanings.”\(^{35}\) Accordingly, how regulation is conceptualized will often depend on the problem or issue at hand.\(^{36}\) While regulation was traditionally viewed as the “sustained and focused control exercised by a public agency over activities that are valued by a community,”\(^{37}\) the practice and study of regulation has increasingly moved towards broader and more flexible

\(^{33}\) Accordingly, Robert Baldwin, Martin Cave and Martin Lodge suggest that regulation can now be viewed as a field of study that operates between ‘trans–disciplinary’ and ‘inter–disciplinary’ conversations. Robert Baldwin, Martin Cave & Martin Lodge, “Introduction: Regulation—the Field and the Developing Agenda” in Robert Baldwin, Martin Cave & Martin Lodge, eds, The Oxford Handbook of Regulation (Oxford: Oxford University Press, 2010) 3 at 1, 12 (“A trans–disciplinary field can be seen as an area of study where different discipline traditions talk to each other and where work is informed and influenced by these conversations. … [T]here is a conversation across literatures and authors from different traditional disciplines that occurs across all aspects of regulation research and it is arguably at such boundary-lines between different disciplines and methodologies that innovation in the social sciences occurs.”).

\(^{34}\) Ibid at 11–12.


understandings. In this regard, Baldwin, Cave and Lodge suggest that it is now useful to think of ‘regulation’ in the following three senses: the application of targeted rules by a body devoted to this purpose; all state actions that are designed to influence business or social behaviour; and, all mechanisms of social control, by whomsoever exercised. In this thesis, I use the term ‘regulation’ in the first, more traditional, sense described above. That is, I use it to refer to the means by which the state “seeks to encourage or direct behaviour which it is assumed would not occur without such intervention.” While a new regulatory paradigm should be more flexible and responsive, and should involve non-state actors in cooperative and collaborative networks, I argue that government must retain a central role in infrastructure design regulation due to the potentially substantial risks to public health and safety and the importance of infrastructure for society (as discussed further in section 1.3 below).

While the focus here remains on regulations that relate to the design of infrastructure, it must also be acknowledged that design regulations will not be the only, or perhaps even the primary, form of regulation that can facilitate the adaptation of infrastructure to climatic events. In this regard, many view spatial planning regulation (i.e., instruments that seek to influence the location and configuration of structures and settlements) as a critical tool for facilitating efficient

38 Baldwin, Cave & Lodge, supra note 33 at 5 (“[R]egulation is now considered to encapsulate much more than ‘governing by rule’.”).
39 Robert Baldwin, Martin Cave & Martin Lodge, Understanding Regulation: Theory, Strategy, and Practice, 2nd ed (Oxford: Oxford University Press, 2012) at 2–3; Baldwin, Cave & Lodge, supra note 33 at 12 (“Varying definitions of regulation range from references to: a specific set of commands; to deliberate state influence; to all forms of social control. Without entering further into this definitional debate, it can be noted that all three of these definitions suffer from under- and over-inclusiveness.”).
40 Throughout this thesis I also use the term “regulatory framework” to refer to the collection of regulations in a field. I distinguish this from the concept of ‘governance’, which I discuss further in Chapter 2.
41 Ogus, supra note 35 at 1.
42 See, for example, Anna C Hurlimann & Alan P March, “The Role of Spatial Planning in Adapting to Climate Change” (2012) 3:5 WIREs Clim Change 477 (“Spatial planning has been identified as a critical mechanism through which climate change adaptation can be facilitated.”).
and equitable adaptation to climate change, particularly in coastal communities. However, I focus this thesis on infrastructure design regulation for two reasons. First, spatial planning instruments will only be able to facilitate adaptation to a certain extent; in particular, the effectiveness of planning regulation will be limited in locations that are already heavily urbanized. Second, while the design and implementation of spatial planning instruments that facilitate adaptation has been the subject of growing scholarly focus, far less scholarly attention has been paid to the regulatory instruments for the design of infrastructure. This is a gap in the literature that I seek to address in this thesis.

In addition, while climate change is expected to impact a wide range of types of infrastructure — buildings, transport infrastructure, water supply infrastructure, stormwater and

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43 See, for example, Limp, Leap or Learn? Developing legal frameworks for climate change adaptation planning in Australia (Gold Coast, Australia: National Climate Change Adaptation Research Facility, 2013) (focusing on planning instruments that can be used to address climate change-related coastal and bushfire hazards); Andrew Macintosh, Anita Foerster & Jan McDonald, “Policy Design, Spatial Planning and Climate Change Adaptation: A Case Study from Australia” (2015) 58:8 Journal of Environmental Planning and Management 1432 (presenting a typology of spatial planning instruments for adaptation); Jan McDonald, “The Role of Law in Adapting to Climate Change” (2011) 2:2 WIREs Clim Change 283 at 285 (“For many, land use planning will be the most effective tool by which to reduce exposure and sensitivity to extreme whether events. Urban planning and coastal management can limit development in flood-, bushfire-, and erosion-prone areas. Where the nature of climate risks allows for longer term behavioral change, it can employ ‘soft’ planning tools, such as information to prospective purchasers about the risks to their properties. More interventionist measures, such as zoning exposed locations to prohibit or restrict new development and stipulating the performance criteria or other requirements (such as demountability of structures) for development to proceed, may be required in areas exposed to greater, shorter-term risks.”); Elizabeth Wilson, “Adapting to Climate Change at the Local Level: The Spatial Planning Response” (2006) 11:6 Local Environment 609 (arguing that spatial planning at a local level has a critical anticipatory role to play in promoting robust adaptation); Thomas G Measham et al, “Adapting to Climate Change through Local Municipal Planning: Barriers and Challenges” (2011) 16:8 Mitigation and Adaptation Strategies for Global Change 889.

44 McDonald, supra note 43 at 285 (“Adaptation of existing buildings, networks, systems, and institutions will involve either relocation, through policies of ‘planned retreat’, or retrofitting, … Unless they are heavily funded, retreat strategies will involve significant interference with property rights and are therefore likely to be challenged through political and legal avenues.”).

wastewater collection and treatment systems, and marine infrastructure, to name a few — the discussion here is limited to building regulation (i.e., the regulatory frameworks relating to building design). I am particularly interested in how regulation can generate wide-scale change. In this regard, many other (i.e., non-building) types of infrastructure involve capital-intensive, large-scale projects and are more likely to be subject to private, autonomous adaptation. In particular, the application of expensive modeling and planning techniques on a case-by-case basis to ascertain designs that are resilient and robust in the face of climate change can often be justified. For example, the Thames Estuary 2100 Project — which sought to develop a plan to manage tidal flood risk in London and the Thames Estuary over the next 100 years — was one of the first major infrastructure projects to explicitly recognize and address the issue of the deep uncertainty in climate projections, using an approach known as ‘dynamic robustness’ which aims to build flexible strategies that can be changed over time as more is learnt or as conditions change. The building regulatory framework, on the other hand, applies to a vast number of

46 A recent review of climate change adaptation and Canadian infrastructure by the International Institute for Sustainable Development (IISD) identified five categories of critical infrastructure: land transportation, buildings, wastewater management, marine infrastructure and water resources. See Jessica Boyle, Maxine Cunningham & Julie Dekens, Climate Change Adaptation and Canadian Infrastructure: A Review of the Literature (Winnipeg: The International Institute for Sustainable Development, 2013). Also see Engineers Canada, Adapting to Climate Change: Canada’s First National Engineering Vulnerability Assessment of Public Infrastructure (Ottawa: Canadian Council of Professional Engineers, 2008).

47 In accordance with the state-centered understanding of regulation that I adopt in this thesis, I use the term ‘building regulation’ to refer to statutes and subordinate legislation that apply to the design of buildings and which seek to ensure that buildings, when constructed in accordance with regulatory requirements, provide socially acceptable levels of health, safety, welfare and amenity for both building occupants and the broader community. See Brian J Meacham, Performance-Based Building Regulatory Systems: Principles and Experiences (Canberra: Inter-jurisdictional Regulatory Collaboration Committee, 2010) at 28. This definition does not include codes of conduct or other requirements imposed by professional engineering bodies, nor does it include building standards (i.e., technical documents that standardize, generally in terms of quality or performance, building construction materials, design, installation, equipment and testing), except to extent that these standards are referred to and/or incorporated into building codes.

48 See Nicola Ranger, Tim Reeder & Jason Lowe, “Addressing ‘Deep’ Uncertainty over Long-Term Climate in Major Infrastructure Projects: Four Innovations of the Thames Estuary 2100 Project” (2013) 1:3-4 EURO J Decis Process 233. Also see Wall et al, supra note 32 (discussing the application of a “dynamic adaptive planning” approach — that accounts for deep uncertainties by building flexibility and learning mechanisms into plans that
structures of varying types and sizes, and it will often not be feasible to apply expensive planning techniques to individual structures. As such, it is vital that the building regulatory framework is designed to facilitate the adoption of buildings on a wide-scale basis. Despite limiting the focus to building regulation, much of the analysis will be generally applicable to regulatory frameworks applying to other types of infrastructure.  

In analyzing how building regulation needs to change to ensure that structures are adapted to future climates, I use the example of the National Building Code of Canada (NBCC) — the primary form of building regulation in Canada. Over the last three decades, there has been a worldwide shift away from prescriptive building regulations towards objective-, functional- and performance-based regulations. While the approach taken in each jurisdiction understandably differs, the NBCC is an illustrative example of these new forms of building regulation. Accordingly, the analysis of the NBCC in this thesis speaks more broadly — that is, enable continuous adaptation throughout implementation — to a case study of the Oakland approach to the San Francisco-Oakland Bay Bridge; Jaap C J Kwadijk et al, “Using Adaptation Tipping Points to Prepare for Climate Change and Sea Level Rise: A Case Study in the Netherlands” (2010) 1:5 WIREs Clim Chg 729 (applying the concept of “adaptation tipping points” to the flood defense, drinking water supply, and protection of the Rotterdam Harbour).  

Note, however, that unlike other built environment structures, codes and standards relating to the design and management of water infrastructure tends to be less prescriptive, with many decisions relying on professional judgment. See Guy Félio, PIEVC Case Studies: Codes, Standards and Related Instruments (CSRI) Review for Water Infrastructure and Climate Change (Ottawa: Engineers Canada, 2012) at 10.

The National Building Code of Canada is one of five model national construction codes, the others being the National Fire Code of Canada (which provides minimum fire safety requirements for buildings, and addresses fire protection and fire prevention in the ongoing operation of buildings and facilities); the National Plumbing Code of Canada (which covers the design and installation of plumbing systems); the National Energy Code of Canada for Buildings (which provides minimum energy efficiency requirements); and the National Farm Building Code of Canada (which provides relaxations of the requirements in the NBCC to address the particular needs of farm buildings).  

Brian J Meacham, *The Use of Risk Concepts in Regulation*, Report of the IRCC Workshop 17-18 October 2006 (San Francisco: Inter-jurisdiction Regulatory Collaboration Committee, 2007) at 3 (“In these regulations, the focus has shifted from prescribing solutions to identifying objectives, functional requirements, and performance expectations (e.g., design the building so that occupants not intimate with the fire source can safely exit the building before untenable conditions are reached in egress paths), and allowing for a wider selection of compliance options.”).
the challenges that will need to be overcome in adapting the NBCC to facilitate and foster climate change adaptation are likely to be representative of the challenges that other regulatory regimes will encounter. In addition, the NBCC is a compelling example of the challenges faced in incorporating climate change considerations into infrastructure design regulation. Despite growing calls over the last decade for climate change to be incorporated into the NBCC, a gap still exists between rhetoric and practice. While there have been indications that a new edition of NBCC — expected to be released before the end of 2015 — will address climate change, the details remain unclear, although it appears that the new edition will simply provide the “option to include climate change adaptation – given scientific evidence”, 52 rather than mandating wide-scale changes to design practices. Finally, in addition to this analysis having broader applicability and relevance, the NBCC acts as the empirical content of this thesis due to simple accessibility: being based at a Canadian institution, it is this building code that is available and amenable to examination.

Without downplaying the importance of assessing the risks that climate change will pose for existing structures, the NBCC primarily applies to the design and construction of new buildings, and this thesis focuses on the changes that can be made to the existing regulatory framework (i.e., as it applies to new structures). In this context, adaptation is a product of the decisions made during the design process that are typically locked in for the life of the structure. In short, adaptation calls for designs that reduce vulnerabilities, that are resilient and robust, and that are not maladaptive. A resilient structure is one that is able to absorb the impacts of climate

52 See, for example, David Lapp, Vulnerability and Risk Assessment of Public Infrastructure (Waterloo, 2014). Also see Auld et al, supra note 5 (“Ongoing studies will continue to focus on the development of methodologies that can acceptably and realistically incorporate climate change adaptation into the upcoming cycles of national codes and standards.”).
change and continue to function. A robust structure is one that is designed to produce acceptable results across the wide range of plausible future climate scenarios, even if it does not perform optimally in any particular scenario. The design of structures should also seek to avoid maladaptation — that is, “[a]ctions that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future.”

53 I note that the resilience of a system has been defined in two different ways. The above definition, typically referred to as ‘engineering’ resilience, is the more traditional of the two, and focuses on maintaining efficiency of function. The second definition, typically referred to as ‘ecological’ resilience, “emphasizes conditions far from any equilibrium steady state, where instabilities can flip a system into another regime of behavior — that is, to another stability domain.” Ecological resilience focuses on maintaining existence of function. See CS Holling, “Engineering Resilience versus Ecological Resilience” in Peter C Schulze, ed, Engineering Within Ecological Constraints (Washington, D.C.: National Academy Press, 1996) 31 at 33. Also see J de Haan, “Flexible Infrastructures for Uncertain Futures” (2011) 43:9 Futures 921 at 921 (“[R]ather than designing our infrastructure systems to function optimally for a forecasted – within error margins – future, we should equip our systems with an ability to keep on functioning when unexpected things happen.”); Carl Folke, “Resilience: The Emergence of a Perspective for Social–Ecological Systems Analyses” (2006) 16:3 Global Environmental Change 253; Mary Jane Angelo, “Stumbling Toward Success: A Story of Adaptive Law and Ecological Resilience” (2008) 87 Neb L Rev 950.

54 Robert J Lempert & Myles T Collins, “Managing the Risk of Uncertain Threshold Responses: Comparison of Robust, Optimum, and Precautionary Approaches” (2007) 27:4 Risk Analysis 1009 at 1016. The concept of robustness is well developed in engineering, where it refers to the maintenance of system performance either when subjected to external, unpredictable perturbations, or when there is uncertainty about the values of internal design parameters. See, for example, J M Carlson & John Doyle, “Complexity and Robustness” (2002) 99:Suppl 1 Proceedings of the National Academy of Sciences 2538 at 2539 (“By robustness, we mean the maintenance of some desired system characteristics despite fluctuations in the behavior of its component parts or its environment”); David McInerney, Robert Lempert & Klaus Keller, “What are Robust Strategies in the Face of Uncertain Climate Threshold Responses?” (2012) 112:3-4 Climatic Change 547 (defining robustness as trading a small decrease in a strategy’s expected performance for a significant increase in a strategy’s performance in the worst cases).

55 While the adaptation literature is replete with advice to avoid maladaptation, it is not always clear what maladaptation is. The above definition of maladaptation is from the IPCC’s Fifth Assessment Report. See Intergovernmental Panel on Climate Change, Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, UK; New York: Cambridge University Press, 2014) at 1769. However, maladaptation is often conceived more narrowly. For example, Jon Barnett and Sage O’Neill define adaptation as “action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups.” See Jon Barnett & Saffron O’Neill, “Maladaptation” (2010) 20:2 Global Environmental Change 211. In this thesis, I use the broader conception of maladaptation adopted by the IPCC.
1.3 Why does this thesis focus on government regulation?

I conceptualize climate change adaptation measures along three main axes: based on timing; based on intent; and based on the actor driving adaptation (see Table 1.1). Although it must be acknowledged that these distinctions are overly simplistic — for instance, public and private adaptation actions are not diametrically opposed to each other; rather, they can, and often will, complement each other — they provide a useful framing device. In this section, I argue that a proactive, planned, public approach will be integral to the adaptation of infrastructure.

<table>
<thead>
<tr>
<th>Timing</th>
<th>Proactive adaptation</th>
<th>Actions taken in anticipation of future climate change</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Reactive adaptation</td>
<td>Actions taken in response to observed climate impacts</td>
</tr>
<tr>
<td>Intent</td>
<td>Autonomous adaptation</td>
<td>Actions taken without being explicitly or consciously focused on addressing climate change</td>
</tr>
<tr>
<td></td>
<td>Planned adaptation</td>
<td>Actions taken as the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state</td>
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</table>

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56 Adaptation actions can be, and have been, distinguished and categorized in various ways. See, for example, Intergovernmental Panel on Climate Change, Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, UK: Cambridge University Press, 2007) at 720 (identifying several “dimensions” along which adaptation practices can be differentiated); Arun Malik, Xin Qin & Stephen C Smith, Autonomous adaptation to climate change: A literature review, IIEP Working Paper (Washington, D.C: George Washington University, 2010) at 4; Samuel Fankhauser, Joel B Smith & Richard S J Tol, “Weathering Climate Change: Some Simple Rules to Guide Adaptation Decisions” (1999) 30:1 Ecological Economics 67. I have adapted these various categorizations to focus on the three key dimensions, or ‘axes’, along which actions can be distinguished, in order to provide a useful conceptual framework for analyzing adaptation actions.

57 Intergovernmental Panel on Climate Change, supra note 56 at 869 (defining autonomous adaptation as “[a]daptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems.”).

58 Ibid.
Table 1.1 Axes of adaptation actions

<table>
<thead>
<tr>
<th>Actor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private adaptation</td>
<td>Adaptation that occurs when measures are implemented by individuals or private entities</td>
</tr>
<tr>
<td>Public adaptation</td>
<td>Adaptation that takes place when there is an intervention from the government to support adaptation</td>
</tr>
</tbody>
</table>

The time that adaptation measures are implemented is likely to have significant impact on their cost and success.\(^{59}\) Accordingly, a key decision that must be made is when to adapt.\(^{60}\) To date, adaptation efforts have tended to be reactive or event-driven.\(^{61}\) Furthermore, the evolution of engineering design practices (and also the laws regulating the design of infrastructure) generally tends to be reactive to past experiences — and, in particular, structural failures — rather than in anticipation of developing or potential hazards.\(^{62}\) Given the uncertainties


\(^{60}\) Jean Palutikof et al, “The Past, Present and Future of Adaptation” in Jean Palutikof et al, eds, Climate Adaptation Futures (Chichester: Wiley-Blackwell, 2013) 1 at 7 (“Humans have always adapted to climate variability and change, usually in a reactive, autonomous way, with varying degrees of success. However, as we start to gain a better understanding of future climate change in relation to anthropogenic greenhouse gas emissions, we are in a better position to recognise that we need to be more proactive in adaptation planning.”).

\(^{61}\) Intergovernmental Panel on Climate Change, supra note 13 at 877 (“[R]esearch has shown that local governments that have started implementing adaptation plans mostly tend to adopt a reactive or event-driven approach to adaptation relying on technical measures. Often the focus is on climate variability and current weather extremes rather than long-term climate change. Climate adaptation efforts reported on at present are often piecemeal and fragmented approaches, dealing with partial solutions and approaches to climate adaptation, rather than more full-scale implementation.”) (references removed); Ian Burton, Elliot Diringer & Joel Smith, Adaptation to Climate Change: International Policy Options (Arlington: Pew Center on Global Climate Change, 2006) at 10 (“[A]daptation historically has been largely if not entirely reactive.”). For example, almost all of the major river and bay bridges destroyed by Hurricane Katrina surge waters were rebuilt at higher elevations, and the design of the connections between the bridge decks and piers were strengthened. See Lance R Grenzeback & Andrew T Luckmann, Case Study of the Transportation Sector’s Response to and Recovery from Hurricanes Katrina and Rita (Washington, D.C.: Transportation Research Board, 2006) at 41.

\(^{62}\) William M Bulleit, “Uncertainty in the Design of Non-prototypical Engineered Systems” in Diane P Michelfelder, Natasha McCarthy & David E Goldberg, eds, Philosophy and Engineering: Reflections on Practice, Principles and Process (Dordrecht: Springer Netherlands, 2013) 317 at 323 (“Since the type of feedback that the engineering community receives is often related to failures of the system, information about failures that is suppressed, say by insurance companies, can increase the length of the feedback cycle and even produce more failures. Design
surrounding climate change, some may advocate the continued reliance on a reactive, ‘wait and see’ approach. In other words, the introduction of regulatory adaptation requirements should be delayed until the uncertainties surrounding climate impacts have been reduced or eliminated, so that regulatory changes can be supported by ‘sound scientific knowledge’ and their costs and benefits can be quantified. I contend that a reactive approach is unwise in these circumstances — and that a proactive approach to the adaptation of infrastructure is required in order to sufficiently and efficiently adapt infrastructure to climate change — for several reasons. First, given the long lifespan of infrastructure, design decisions are typically locked in for (at least) several decades. As such, the adoption of a reactive approach that fails to account for future climate risks increases the likelihood of structural failure as climate impacts grow, thereby increasing risks to public health and safety and disruptions to economic and social activity. Second, there is substantial public and private investment in infrastructure. Given the long time-lags between the identification of future changes in climate and the occurrence of those changes, waiting to act until climatic changes have occurred will likely prove more costly than taking proactive measures that anticipate climate change. While the adaptation of new

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63 This is currently the case for new building requirements in the NBCC. For a further discussion, see section 3.2.
64 Intergovernmental Panel on Climate Change, supra note 13 at 844 (“In some cases a supposed lack of relevant and legitimate information has been used as a rationale for inaction.”).
65 For example, Canada’s public and private infrastructure assets are currently valued at approximately $4 trillion. See Casey G Vander Ploeg & Mike Holden, At The Intersection: The Case for Sustained and Strategic Public Infrastructure Investment (Calgary: Canada West Foundation, 2013).
infrastructure is likely to result in higher up-front capital costs, a reactive approach may require the premature reinforcement, reconstruction, or relocation of structures that are unprepared for future climate impacts. Moreover, the cost of adaptation is relatively small in relation to other factors that can influence the future costs of infrastructure.

Third, while I do not deny that the uncertainties surrounding climate change present a substantial challenge for the development of regulatory adaptation requirements, the precautionary principle supports the adoption of a proactive approach in the face of uncertainty. While the precautionary principle does not have one universally agreed-upon formulation, decision-making in the face of scientific uncertainty about harm is considered to be the fulcrum of the principle. There are commonly considered to be two threshold conditions or ‘triggers’

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67 For example, a 2010 World Bank study estimated that the net cost of adapting infrastructure to climate change is likely to be in the realm of 1-2% of the total cost of providing that infrastructure. This estimate was generated through a global analysis of the costs of adapting infrastructure to climate change over the period from 2010 to 2050. See Gordon Hughes, Paul Chinowsky & Ken Strzepek, The Costs of Adapting to Climate Change for Infrastructure (Washington, D.C: World Bank, 2010) at 43.

68 See, for example, Mills & Andrey, supra note 12 at 2.

69 Hughes, Chinowsky & Strzepek, supra note 67 at 43.

70 Institute for Catastrophic Loss Reduction, A Plan Forward: Building Practices to Increase the Resilience of Homes to Severe Weather (Toronto: ICLR, 2012) at 14 (noting that even the most senior climate specialists are uncertain about how to incorporate climate change impacts into infrastructure design codes and standards).

71 Since the early 1980’s the precautionary principle has received widespread endorsement and adoption, having been incorporated into nearly 100 international agreements and many domestic laws. See Chris Tollefsen & Jamie Thornback, “Litigating the Precautionary Principle in Domestic Courts” (2008) 19:1 J Envtl L & Prac 33 at 36.

72 In the climate change context, the most relevant formulation is that set out in the United Nations Framework Convention on Climate Change — of which Canada is a signatory — which provides that “[t]he Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost.” See United Nations Framework Convention on Climate Change (New York, 9 May 1992), Article 3(3). This formulation is based on Principle 15 of the Rio Declaration, the most commonly cited version of the principle (“Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.”). See Rio Declaration on Environment and Development, 14 June 1992, UN Doc A/Conf.151/26 (Vol I) (1992), 31 ILM. 874, online: United Nations Environment Programme <http://www.unep.org>.

that need to be satisfied to justify the principle’s application: a damage threshold that specifies how severe a possible threat must be (e.g., “threats of serious or irreversible damage”); and, a knowledge threshold that specifies the required level of scientific understanding or uncertainty (e.g., “lack of full scientific certainty”) regarding either the extent of the potential impact or the causal connections between the relevant activity and the harmful effect, or both. However, assessments as to what constitutes a ‘threat’ or the level of ‘uncertainty’ that exists will inevitably be impacted by differing stakeholder values, objectives, and risk perceptions, and therefore these triggers should only be used as “rough guides rather than specific criteria which must be ‘proved’ before precaution can be applied.” Once a decision has been made to apply the precautionary principle, the next step is to determine what precautionary measures should be taken. The precautionary principle does not (indeed, should not) dictate the taking of any particular measures; rather, precaution is a question of degree. A review of the literature on the precautionary principle recognizes three critical factors to consider when designing

Procedural Version of the Precautionary Principle Erring on the Side of Environmental Preservation” in Marcel Boyer, Yolande Hiriart & David Martimort, eds, Frontiers in the Economics of Environmental Regulation and Liability (Aldershot; Burlington, VT: Ashgate, 2006) 19 (arguing that the “minimal core” of the precautionary principle is “to justify intervention in the absence of scientific certainty. In other words, uncertainty per se should not preclude regulatory actions undertaken to protect human health and the environment.”).

Most authors believe such a threshold must be set in order to avoid the principle being watered-down through overuse. See Nicolas de Sadeleer, Environmental Principles: From Political Slogans to Legal Rules (Oxford: Oxford University Press, 2002) at 162–63.

Per Sandin, “Dimensions of the Precautionary Principle” (1999) 5:5 Hum Ecol Risk Assess Int J 889 at 892 (“It seems clear that in order to take precaution, there has to be some sort of uncertainty. ... From almost every formulation of the Precautionary Principle, it is clear that the uncertainty in question is scientific uncertainty.”).

See, for example, Marko Ahteensuu & Per Sandin, “The Precautionary Principle” in Sabine Roeser et al, eds, Handbook of Risk Theory (Dordrecht; New York: Springer, 2012) 961 at 974 (“The application of the principle is fundamentally a normative (and political) choice. The degree to which we are prepared to take precautions is related to the values which we attach to the nature and human well-being.”).


Fisher, supra note 77 at 319.
precautionary measures. First, the design of any precautionary measures must reflect the regulatory context, the nature of the risk and the scientific uncertainties involved. Second, the desired level of protection is a normative choice, and as such, precautionary responses should also be developed through participatory, deliberative processes. Third, a range of economic and political factors will invariably temper the level of precaution. In this respect, all core definitions of the precautionary principle associate it closely with, and in effect limit it by, some version of the concept of proportionality. Proportionality is likely to be an important consideration when designing adaptation measures — while structures can always be ‘over-designed’ to protect against climate impacts, measures that result in substantially higher upfront costs are likely to be considered infeasible and resisted by industry stakeholders. In summary, the precautionary principle supports proactive regulatory adjustments notwithstanding the

79 See, for example, Noah M Sachs, “Rescuing the Strong Precautionary Principle from Its Critics” (2011) 2011 U Ill L Rev 1285 at 1297 (“Like any principle, [the precautionary principle] outlines a framework or stance toward decision making, not a meticulously detailed prescription for action. The details of regulatory design and the timing of response are determined through legislation, not the Principle itself. They will necessarily vary from one regulatory context to another. … No serious analyst would contend that a one- or two-sentence principle is the total guidance that regulators need to manage complex health and environmental risks.”); Arie Trouwborst, Precautionary Rights and Duties of States (Leiden: Martinus Nijhoff, 2006) at 190 (“Incontestably, the precautionary principle is not an exhaustive algorithm for decision-making in the field of environmental risks. Although a throng of measures, including EIA, moratoriums, safety margins, clean production methods, and research, is closely associated with its implementation, in the majority of cases the principle does not prescribe any specific measures.”); Fisher, supra note 77 at 320.
80 René von Schomberg, “The Precautionary Principle and its Normative Challenges” in Implementing the Precautionary Principle: Perspectives and Prospects (Northampton, Mass: Edward Elgar Publishing, 2006) 19. In particular, there needs to be an emphasis on understanding and addressing the levels of risk that the community deems acceptable in the face of climate change, as what is deemed to be tolerable and intolerable risk will inevitably vary. See Intergovernmental Panel on Climate Change, supra note 13 at 926.
81 Mike Feintuck, “Precautionary Maybe, but What’s the Principle? The Precautionary Principle, the Regulation of Risk, and the Public Domain” (2005) 32:3 JL & Soc’y 371 at 378 (“The apparent problem is that the precautionary principle itself, unless greatly elaborated in any particular context, will not provide ready-made answers. Rather, the values to be prioritized in any given situation … are likely to derive as much or more from the political and economic background as from the principle itself.”).
82 Ibid at 376; Trouwborst, supra note 79 at 150 (“From the start, proportionality has been a crucial feature in the application of the precautionary principle, in the sense that precautionary responses to environmental threats ought to correspond to the perceived dimensions of the risks involved.”). For example, both the Rio Declaration and UNFCCC formulations state that precautionary measures should be ‘cost-effective.’
83 Auld & MacIver, supra note 12 at 11.
uncertainty that exists, although it only provides general guidance as to what measures should be taken. This thesis explores what such proactive, precautionary measures should look like.

Autonomous adaptations are mostly — although not exclusively — reactive in nature and initiated by private actors instead of governments. While the adaptation of infrastructure is already being — and will continue to be — carried out autonomously, private actors are unlikely to have the incentives, resources, knowledge and skills to adjust to the extent required. In this regard, Julia Hertin and her co-authors suggest that members of the building industry are likely to have limited motivation to engage proactively with climate change due to the inherent uncertainty surrounding climate change, the absence of strong external pressure to incorporate climate change issues into decision-making (e.g., through regulatory requirements, financial mechanisms etc), and the existence of forces that directly work against adaptation measures being adopted (e.g., the cost of climate-related measures, limited liability for future buildings, etc). For example, in a 2012 survey of Canadian infrastructure engineers, only 28% of engineers indicated that they mostly or always consider the impacts of a changing climate in their engineering decisions. In short, although some autonomous adaptations may take place over the long term, the need to change design practices across the board, and to make these changes now, necessitates the development and implementation of planned adaption measures, including adjustments to infrastructure design regulations. Nevertheless, as discussed further in

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85 Hertin et al note that the exception to this is where adaptation measures can be shown to be consistent with short-term financial interests. See Julia Hertin et al, “Climate Change and the UK House Building Sector: Perceptions, Impacts and Adaptive Capacity” (2003) 31:3/4 Building Research & Information 278.
86 Of this, only 10% of engineers always consider the impacts of a changing climate in their decisions. See CSA Group, supra note 21 at 11 (“There may be several causes for this, including a lack of general knowledge around the impacts of a changing climate, constraints placed on practitioners by decision-makers, variability in terms of need, and the absence of regulatory requirements.”).
Chapter 3, building regulations typically only establish minimum standards (not best practices), and the regulatory framework should therefore also be designed to encourage private parties to take autonomous adaptation measures that exceed these minimum standards.

Adaptation to climate change is a process of adjustment or transformation that will require a combination of technological, behavioral, informational, economic, and regulatory changes, rather than a singular focus on any one type of action, and both private and public actors will understandably have a role to play in the development and implementation of these actions. Some consider that existing and emerging economic instruments can be used to foster adaptation by providing incentives for anticipating and reducing climate impacts. However, effective adaptation of long-term infrastructure investments is unlikely to occur through market dynamics alone as private actors have little incentive to make substantial investments today to

88 Department for Environment, Food & Rural Affairs, Climate Resilient Infrastructure: Preparing for a Changing Climate (London, UK: The Stationery Office Limited, 2011) at 33 (“Government ... has an important role to play in boosting the climate resilience of infrastructure — by providing appropriate policy and regulatory frameworks, information and support. However, it is action by others — investors, owners and operators, and the engineering and construction sectors — that will be essential to implementing adaptation action enabling climate risk to national infrastructure to be effectively managed.”).
89 For example, insurance is often considered to be one of the principal tools for managing climate risks. While typically one of the primary tools for providing relief after damaging weather events (i.e., shifting losses after they occur), insurance can also be an important tool in controlling and incentivizing behavior prior to the occurrence of losses. Omri Ben-Shahar & Kyle D Logue, “Under the Weather: Government Insurance and the Regulation of Climate Risks” (2015) Public Law Leg Theory No 499, online: <http://chicagounbound.uchicago.edu/public_law_and_legal_theory> at 3. However, the potential contribution that the insurance sector can make in driving infrastructure adaptation is limited, as “[i]nsurance policies generally have duration of a single year, a period at odds with the lifespan of a building (~50 years) and the time scale at which impacts on property losses caused by climate change amplification of extreme weather might become measurable. This mismatch makes it difficult for insurers to materially influence adaptation to future climate change except through the rigorous pricing of the extant risk.” See John McAneny et al, Market-Based Mechanisms for Climate Change Adaptation: Assessing the Potential for and Limits to Insurance and Market Based Mechanisms for Encouraging Climate Change Adaptation (Gold Coast, Australia: National Climate Change Adaptation Research Facility, 2013) at 23; Shardul Agrawala & Samuel Fankhauser, eds, Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments (Paris: OECD, 2008) at 5 (“Insurance can incentivise adaptation if premiums are well designed; it is, however, not a panacea.”).
avoid as yet unknown losses for future generations. Given the uncertainty surrounding climate change, and the fact that the impacts of climate change on infrastructure are not expected to manifest for many years, if not decades, regulators, politicians and the public are likely to be affected by temporal myopia — or ‘short-termism.’ That is, people are likely to irrationally over-weigh the costs of adapting infrastructure (e.g., the increased construction costs of more resilient and robust infrastructure) and under-weigh the costs of inaction (e.g., the potential for widespread damage caused by climate impacts), thereby eroding their willingness to take actions that adequately address the long-term risks posed by climate change. In short, economic instruments alone are unlikely to deliver the full response required to deal with the challenge of climate change. Governments will be required to play a strong, central role in developing and implementing planned adaptation measures.

Samuel Fankhauser, Joel Smith and Richard Tol argue, for example, that the government’s role is to provide a “conducive environment” for adaptation, including the right legal, regulatory, socio-economic environment to support autonomous adaptation. In the infrastructure context, I argue that this requires a regulatory framework that sets minimum adaptation requirements, but that is also designed to encourage and incentivize private actors to undertake further actions that exceed these minimum requirements.

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91 See, for example, Lynne L Dallas, “Short-Termism, the Financial Crisis, and Corporate Governance” (2012) 37:2 J Corp L 265.
93 Intergovernmental Panel on Climate Change, supra note 13 at 948 (“There are also other reasons for public action such as overcoming barriers, developing technologies, representing current and future equity concerns, and other items”). Also see Gerrard & Katrina Fischer Kuh, supra note 22 at 15.
94 Fankhauser, Smith & Tol, supra note 56 at 74.
1.4 Thesis overview

This thesis explores what proactive, planned, and public regulatory adaptation measures should look like. The legal literature recommends some general approaches to adapting regulatory regimes, but it provides little in the way of “how to” proposals. As Stephen Dovers and Adnan Hezri note, to date there has been little analytical attention given “to the mechanisms of policy and institutional change, to structures and processes within public policy and administrative systems at national and sub-national (state, provincial, local) jurisdictional scales—the means to the ends of adaptation.” This is a crucial gap, one that I seek to address in this thesis in the context of infrastructure adaptation.

In Chapter 2, I conduct a review of various literatures that should guide the development of a regulatory framework that is capable of responding quickly and appropriately to new knowledge and unfolding realities and fostering collaboration and innovation. ‘New governance’ theory, developed in legal scholarship, sets forth various principles and models of collaborative, multi-party, multi-level, adaptive, problem-solving governance that can be used to shape a new regulatory paradigm. In particular, I focus on ‘experimentalist’ approaches, which are intended to enable local variation and adaptation to changing circumstances. While experimentalist approaches provide valuable guidance as to how an adaptive process should be structured, they are not capable of addressing the deep uncertainties surrounding climate change, nor do they have a sufficiently structured process for the adaptation of regulation. In order to address these

96 Stephen R Dovers & Adnan A Hezri, “Institutions and Policy Processes: The Means to the Ends of Adaptation” (2010) 1:2 WIREs Clim Chg 212 at 219, 223 (“Most discussion in the adaptation literature is about what should happen (policy integration, dealing better with uncertainty, etc.), rather than how that might be achieved (policy and institutional structures and processes).”).
deficiencies, I look to other fields that have developed various ‘adaptive’ approaches — adaptive management, adaptive governance, and adaptive policymaking — that I argue should inform the design of an intentional, structured, adaptive regulatory framework that responds to the dynamism, complexity and uncertainty of climate change.

Although it will likely prove easier to implement adaptation strategies within existing regulatory frameworks rather than to create new regimes, legislators need to proceed with caution when “mapping new problems onto old formats.” Victor Flatt suggests that when altering an existing legal regime — as is the case here — one should consider how legal and policy alterations can address the points where climate change puts pressure on the operation of the current system or points in the system that constitute barriers to adaptation. Accordingly, in Chapter 3 I explore four ‘stress points’ in the existing regulatory framework — a fragmented structure that restricts the development of local adaptation measures; poor adaptive capacity; an inability to handle the uncertainties posed by climate change; a structure that fails to foster innovation, sharing, learning and collaboration — that I submit, when viewed together, represent a ‘crisis’ in the current regulatory paradigm. Yet, the existence of a crisis is not sufficient to

98 Veerle Heyvaert, “Governing Climate Change: Towards a New Paradigm for Risk Regulation” (2011) 74:6 Mod L Rev 817 at 839 (“[We need] a clear understanding of the distinctiveness of its climate change risk discourse, and of the different programmatic and strategic needs of climate change regulation, to avoid mapping new problems onto old formats and to design and select risk control strategies commensurate to the task of climate change mitigation and adaptation.”).
99 Flatt, supra note 95 at 287 (arguing that adjustments should seek to preserve the original legislative purposes and also consider both distributive justice and efficiency). Also see, Palutikof et al, supra note 60 at 13 (“Existing legislation and regulations that conflict with (counter) adaptation, and those that do not provide the necessary signals to support adaptation, are often seen as key barriers to adaptation.”).
trigger the conversion to a new paradigm; a viable alternative must also be developed.¹⁰⁰ In Chapter 4, I map the contours of two regulatory mechanisms that have the potential to facilitate the adaptation of infrastructure. First, I examine how the creation of an adaptive regulatory framework that is flexible but not formless — through the use of precommitments to make regulatory adjustments combined with constraints on how much regulatory requirements can be adjusted to reflect changing knowledge and conditions — can provide the necessary flexibility to respond to the evolving knowledge regarding climate change while at the same time providing a structured approach that maintains accountability, transparency and (some level of) stability for stakeholders. Second, drawing on adaptive governance scholarship, I investigate how the NBCC’s ‘alternative solutions’ process can be augmented through the development of multi-level networks of cooperation and collaboration that enable the dissemination and sharing of information that can facilitate learning and collaboration, and stimulate the development and adoption of innovative design solutions.

¹⁰⁰ Thomas S Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962) at 158 (“[C]risis alone is not enough. There must also be a basis … for faith in the particular candidate chose. Something must make at least a few scientists feel that the new proposal is on the right track.”).
Chapter 2: Literature review

The key challenges for the existing regulatory paradigm are the dynamic nature of, and the unprecedented uncertainty surrounding, climate change. Accordingly, a new regulatory paradigm needs to accept — really accept — the dynamic, complex and uncertain world that we live in, and develop new regulatory tools and techniques that respond to these challenges. I introduce the concept of paradigms in section 2.1, outlining how I use the concept of ‘regulatory paradigms’ in this thesis. I also explore when, why and how paradigms change, arguing that a shift to a new regulatory paradigm is required for infrastructure design regulation to effectively respond to the challenges presented by climate change. In determining what a new regulatory paradigm should look like, I argue that a new paradigm needs to respond to the maladaptive features of the existing paradigm, and also increase the robustness and adaptive capacity of the regulatory framework.

At the outset, it must be acknowledged that most policies change over time, and that an incremental approach to policy making is not new. For example, Charles Lindblom coined the term ‘muddling through’ in a seminal 1959 article to refer to an approach to policy development that emphasizes incremental, iterative adjustments. As Lindblom noted: “[p]olicy is not made once and for all; it is made and re-made endlessly.” While iterative approaches to regulation

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101 See, for example, Lawrence E McCray, Kenneth A Oye & Arthur C Petersen, “Planned Adaptation in Risk Regulation: An Initial Survey of US Environmental, Health, and Safety Regulation” (2010) 77:6 Technological Forecasting and Social Change 951 at 952 (“In any society, rules are constantly subject to change. Such change often comes as a result of a "reality bites back" failure. A rule fails to prevent some highly visible calamity, or its political opponents undermine its legitimacy, and thus its revision is forced by events.”).

102 Lindblom referred to this approach as ‘successive limited comparisons’.

103 See Charles E Lindblom, “The Science of ‘Muddling Through’” (1959) 19:2 Public Administration Review 79 at 86 (“Making policy is at best a very rough process. Neither social scientists, nor politicians, nor public administrators yet know enough about the social world to avoid repeated error in predicting the consequences of policy moves. A wise policy-maker consequently expects that his policies will achieve only part of what he hopes
may not be novel, very few policies adopt an intentional, structured adaptive strategy.\textsuperscript{104} Accordingly, in this chapter I draw on various literatures that I consider should guide the development of an adaptive regulatory framework that is capable of responding quickly and appropriately to new knowledge and unfolding realities and fostering collaboration and innovation. Such an approach can ensure that a new regulatory paradigm does more than simply ‘muddle through.’

‘New governance’ theory has developed within legal scholarship in response to the perceived shortcomings of traditional, rigid, command-style regulatory approaches when faced with new realities and changing needs. I survey the new governance literature in section 2.2, highlighting various principles and models of collaborative, multi-party, multi-level, adaptive, problem-solving governance that can be used to shape a new regulatory paradigm. In particular, I focus on ‘experimentalist’ approaches, which are intended to be used in circumstances where neither regulatory ends or means can be definitively articulated at the outset, and are therefore designed to enable local variation and adaptation to changing circumstances. While such approaches provide guidance as to how to structure an adaptive process, they are typically designed to address a lack of knowledge or understanding about the appropriate regulatory strategy to adopt. That is, they do not seek to understand or address uncertainties arising out of the complexity of the system that is the subject of regulation (e.g., uncertainty about how structures will respond to a changing climate) — what I refer to as ‘internal’ uncertainty — or arising out of the system’s external environment that is outside the control of the regulators (e.g.,

\textsuperscript{104}Intergovernmental Panel on Climate Change, supra note 13 at 210.)
uncertainty about the magnitude and timing of climatic changes) — what I refer to as ‘external’ uncertainty. In short, the new governance literature does not provide any guidance as to how an adaptive framework should be structured to respond to internal and external sources of uncertainty. In addition, experimentalist processes are primarily focused on obtaining information that facilitates learning about regulatory means and ends, assuming that revision will simply follow learning, and therefore providing little structure around the revision process. I argue that a structured process is required to provide some measure of accountability to the evolution of regulation.

In order to address these gaps in the new governance literature, in section 2.3 I look to other fields that have developed approaches that respond to uncertainty in more structured ways. I examine a number of concepts and strategies in other fields that have been labeled as ‘adaptive’ — adaptive management, adaptive governance, and adaptive policymaking105 — that I argue can provide valuable guidance in designing an intentional, structured, adaptive regulatory framework. Adaptive management adopts a scientific approach to the design, implementation, and evaluation of management strategies, allowing action to be taken in the short term despite the existence of uncertainty, but also seeking to reduce uncertainties and close information gaps over the longer term, thereby facilitating learning and adjustments to initial actions in order to improve management outcomes. Although adaptive management provides some valuable guidance regarding the establishment of an intentional, structured, adaptive process, its inward-focus (i.e., adaptive management is primarily focused on uncertainties that are internal to the

system being managed) is at odds with the primarily ‘external’ uncertainties that face infrastructure design regulation. Adaptive policies, on the other hand, seek to monitor, learn about, and adjust policies in relation to external uncertainties (e.g., the future climate that infrastructure will need to be designed to withstand). Adaptive policymaking recognizes and accepts the inherent uncertainty that exists when developing policies for a dynamic and unpredictable future, and implements a structured approach to the design and implementation of policies that considers learning, continuous improvement, and adaptation of the policy to be a natural part of the policy life-cycle. Adaptive policymaking therefore represents a promising and viable means by which to account for climate change uncertainties. Rather than forming an additional structured, adaptive approach, the adaptive governance literature examines the type of governance that is required to manage complexity and uncertainty. Adaptive governance provides useful guidance through its emphasis on the need to focus on the broader social and institutional context in which adaptive strategies must operate, and on the development of formal and informal networks in order to increase participation and collaboration. I argue that the guidance drawn from the ‘adaptives’ literature can build on new governance scholarship, providing valuable guidance for the development of a new regulatory paradigm that responds to the dynamism, complexity and uncertainty of climate change.

2.1 Regulatory paradigms

In a seminal 1962 book, The Structure of Scientific Revolutions, Thomas Kuhn used the concept of ‘paradigms’ to refer to a common framework within which theories are developed and

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scientific discussions are pursued. A paradigm involves a common scientific language, a common set of concepts and a common basic world-view. Kuhn argues that paradigms are used in scientific communities to organize problem-solving efforts. In what Kuhn describes as “normal science,” practitioners who “have undergone similar educations and professional initiations” use their shared paradigm as the determinant of “legitimate methods, problems, and standards of solution.” Kuhn and other commentators do not limit the concept of paradigm to scientific communities; rather, any definable community can possess a paradigm. In this regard, the legal community can have its own ‘legal paradigm’ — what Jean Cohen describes as “an integrated set of cognitive and normative background assumptions informing legislative and juridical interpretations both of the relationship the law should establish between state and society and of the appropriate forms of legal regulation.”

Taking the concept of paradigm one step further, Michael Taylor use the term ‘regulatory paradigm’ to describe both the techniques of regulation and the environment in which they are embedded. Taylor’s conception of a regulatory paradigm involves a combination of three major elements. First, the policy objectives of the regulatory system, including basic assumptions

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107 Kuhn, supra note 100.
109 Kuhn, supra note 100 at 5, 144.
110 Ibid at 177.
111 Ibid at 48.
112 See Ibid at 208 (“To the extent that this book portrays scientific development as a succession of tradition-bound periods punctuated by non-cumulative breaks, its theses are undoubtedly of wide applicability. But they should be, for they are borrowed from other fields. Historians of literature, of music, of the arts, of political development, and of many other human activities have long described their subjects in the same way.”).
113 Jean L Cohen, Regulating Intimacy: A New Legal Paradigm (Princeton: Princeton University Press, 2002) at 3. Also see Hoecke & Warrington, supra note 108 at 513–14 (“Lawyers also have their "paradigm": a hard core of shared understandings, of basic theories and concepts, a common language, a common methodology.”).
114 See Michael Taylor, “The Search for a New Regulatory Paradigm” (1997) 49 Mercer L Rev 793 at 794 (“This paradigm includes both the techniques of regulation and the environment in which they are embodied, including the institutional arrangements and certain basic assumptions about the objectives of regulation and about the nature of the industry being regulated.”).
about the extent to which governments should seek to manage or reduce risk. Second, the institutional arrangements that are established for administering the set of regulatory requirements flowing from policy objectives (e.g., the manner in which regulation is organized, the structure of regulatory agencies, the type and nature of the powers that are conferred on them, etc). Third, the specific techniques and methods used by regulators to achieve regulatory objectives (e.g., the type and nature of information that regulators gather from regulated firms, the standards that regulators apply, the methods they use to ensure compliance with those standards, etc).\textsuperscript{115} I adopt Taylor’s definition in this thesis. In short, I use the term ‘regulatory paradigm’ to refer to the objectives of regulation, the basic assumptions and understandings on which regulation is based, the structure of the regulatory framework, and the specific techniques and methods used by regulators. Such a conception encapsulates the components of the existing infrastructure design regulation that will need to change in order to address the challenges posed by a changing climate.

Under Kuhn’s ‘normal science’, ideas that are inconsistent with the existing paradigm are often rejected or disregarded by a community. As Kuhn explains,

[n]ormal science … is predicated on the assumption that the scientific community knows what the world is like. Much of the success of the enterprise derives from the community’s willingness to defend that assumption, if necessary at considerable cost. Normal science, for example, often suppresses fundamental novelties because they are necessarily subversive of its basic commitments.\textsuperscript{116}

\textsuperscript{115} \textit{Ibid.}
\textsuperscript{116} Kuhn, \textit{supra} note 100 at 5.
Nevertheless, a problem will inevitably be identified that is not susceptible to problem-solving efforts under the existing paradigm and cannot be bracketed for the future.\textsuperscript{117} Where such an ‘anomaly’ comes to be generally recognized by the profession, and more and more attention is devoted to it by more and more of the field’s most eminent practitioners, it can provoke a “transition to crisis and to extraordinary science.”\textsuperscript{118} Where a scientific community cannot resolve the crisis by solving the problem under the paradigm or bracketing the problem for the future, it leads to a “period of pronounced professional insecurity” where the paradigm itself is called into question.\textsuperscript{119} This leads to what Kuhn refers to as a ‘scientific revolution’ — or a paradigm \textit{shift} — whereby a new paradigm replaces the old one. As Kuhn explains:

\begin{quote}
\textit{[t]he transition from a paradigm in crisis to a new one ... is far from a cumulative process, one achieved by the articulation or extension of the old paradigm. Rather it is a reconstruction of the field from new fundamentals, a reconstruction that changes some of the field’s most elementary theoretical generalizations as well as many of its paradigm methods and application.}\textsuperscript{120}
\end{quote}

Whether the new paradigm takes hold is not simply a matter of logical argument, as no ‘logical’ choice is available when there is ongoing “disagree[ment] about what is a problem and what a solution.”\textsuperscript{121} Rather, Kuhn asserts that the transfer of allegiance from one paradigm to another is a “conversion experience” that cannot be forced.\textsuperscript{122} In this regard, “if a paradigm is ever to triumph it must gain some first supporters, men [sic] who will develop it to the point where hardheaded arguments can be produced and multiplied.”\textsuperscript{123} This thesis seeks to articulate some

\textsuperscript{117} \textit{Ibid} (“Sometimes a normal problem, one that ought to be solvable by known rules and procedures, resists the reiterated onslaught of the ablest members of the group within whose competence it falls.”).
\textsuperscript{118} \textit{Ibid} at 82–83 (noting that “formerly standard solutions of solved problems are called in question”).
\textsuperscript{119} \textit{Ibid} at 67–68.
\textsuperscript{120} \textit{Ibid} at 84–85.
\textsuperscript{121} \textit{Ibid} at 109.
\textsuperscript{122} \textit{Ibid} at 158 (“[N]ew paradigms [do not] triumph ultimately through some mystical aesthetic.”).
\textsuperscript{123} \textit{Ibid}.
“hardheaded arguments” regarding the features of a new regulatory paradigm for infrastructure design regulation, hopefully spurring further discussion, exploration and enhancement, and ultimately paving the way for a conversion to a new regulatory paradigm.

As Kuhn notes, the “[f]ailure of existing rules is the prelude to search for new ones.”\textsuperscript{124} Accordingly, as Taylor argues, “[o]nly if we recognize that we are in the middle of a regulatory paradigm change can we begin to deal with what appears to be the crisis of regulation”.\textsuperscript{125} In this respect, I argue that the deficiencies or ‘stress points’ in the existing regulatory paradigm, which I will explore in Chapter 3, are not simply ‘anomalies’ that can be solved or set aside; rather, they represent a crisis in the existing regulatory paradigm, and a transition to a new regulatory paradigm is required if building regulation is to effectively foster the adaptation of infrastructure to climate change. However, while it may be clear that responding to climate change calls for a new regulatory paradigm, it is less clear what that paradigm should look like. As noted above, Kuhn asserts that it will require “a reconstruction of the field from new fundamentals.”\textsuperscript{126} In undertaking such a reconstruction, Taylor implores us “to think radical thoughts about the aims, scope, and techniques of regulation.”\textsuperscript{127} Such radical thoughts will be required to address the profound challenges posed by climate change.

\textsuperscript{124} Ibid at 68.
\textsuperscript{125} Taylor, supra note 114 at 797.
\textsuperscript{126} Kuhn, supra note 100 at 84–85.
\textsuperscript{127} Taylor, supra note 114 at 797.
2.2 New governance

In recent years, ‘new governance’ has emerged as a school of thought that focuses on the significance of institutional design and culture for effective and legitimate regulation.\(^{128}\) While the concept of ‘new governance’ is by no means settled,\(^{129}\) it is typically used to describe a broad family of approaches to regulation.\(^{130}\) The moniker connotes two central elements. First, the term ‘governance,’ which is commonly defined as “the structures and processes by which societies share power, [and which] shape[] individual and collective actions.”\(^{131}\) Governance is used to emphasise a shift away from hierarchic and bureaucratic ‘government’ to governance in and by collaborative networks involving both public and public actors.\(^{132}\) Second, the term ‘new’

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\(^{130}\) Bradley C Karkkainen, “‘New Governance’ in Legal Thought and in the World: Some Splitting as Antidote to Overzealous Lumping” (2004) 89:2 Minn L Rev 471 at 496 (“New Governance is not a single model, but a loosely related family of alternative approaches to governance, each advanced as a corrective to the perceived pathologies of conventional forms of regulation. New Governance scholarship encompasses not just a single idea or school of thought, but many competing, sometimes incompatible schools, related perhaps in their broadest outlines, but nonetheless distinguishable along major fault lines...”); Burca & Scott, supra note 129 at 2 (“[New Governance] is a construct which has been developed to explain a range of processes and practices that have a normative dimension but do not operate primarily or at all through the formal mechanism of traditional command-and-control-type legal institutions.”); Cristie Ford, “New Governance in the Teeth of Human Frailty: Lessons from Financial Regulation” (2010) 2010:2 Wis L Rev 441 at 444 (“The term ”new governance“ is something of a big tent that captures several discrete but related approaches.”).

\(^{131}\) See Oran R Young, “The Effectiveness of International Institutions: Hard Cases and Critical Variables” in James N Rosenau & Ernst Otto Czempiel, eds, Governance Without Government: Order and Change in World Politics (Cambridge: Cambridge University Press, 1992) 160; Lous Lebel et al, “Governance and the Capacity to Manage Resilience in Regional Social-Ecological Systems” (2006) 11:1 Ecology and Society 1 (“Governance includes laws, regulations, discursive debates, negotiation, mediation, conflict resolution, elections, public consultations, protests, and other decision-making processes.”). David Levi-Faur, on the other hand, identifies at least four meanings of governance in the literature: a structure, a process, a mechanism, and a strategy. See David Levi-Faur, “From ‘Big Government’ to ‘Big Governance’?” in David Levi-Faur, ed, The Oxford Handbook of Governance (Oxford: Oxford University Press, 2012) 3 at 8 (“As a structure, governance signifies the architecture of formal and informal institutions; as a process it signifies the dynamics and steering functions involved in lengthy never-ending processes of policy-making; as a mechanism it signifies institutional procedures of decision-making, of compliance and of control (or instruments); finally, as a strategy it signifies the actors’ efforts to govern and manipulate the design of institutions and mechanisms in order to shape choice and preferences.”).

signifies that the regulatory approaches which fall under the new governance banner, although not necessarily novel, need to be approached in a new, more coherent way, in order to respond to the perceived inadequacies of traditional or ‘old’ regulatory approaches when faced with new realities and changing needs.133

New governance approaches vary in their emphases, encompass different schools of thought, and apply varying institutional and political approaches to a range of policy problems. While these schools and approaches may sometimes be competing, or even incompatible, some broad commonalities can nevertheless be drawn.134 For example, Orly Lobel has identified eight dimensions or clusters of new governance approaches: (i) increased participation of non-state actors; (ii) public–private collaboration; (iii) diversity and competition within the market; (iv) decentralization; (v) integration of policy domains; (vi) flexibility and non-coerciveness (or “softness in law”); (vii) adaptability and dynamic learning; and (viii) coordination.135 Lobel

state through government, but rather emerges from the interactions of many actors, including the private sector and not-for-profit organizations.”); Lester M Salamon, “The New Governance and the Tools of Public Action: An Introduction” (2001) 28:5 Fordham Urb LJ 1611 at 1623 (“Such an approach is necessary because problems have become too complex for government to handle on its own, because disagreements exist about the proper ends of public action, and because government increasingly lacks the authority to enforce its will on other crucial actors without giving them a meaningful seat at the table.”); Lobel, supra note 128 at 65 (“From a regulatory perspective, new governance theory systemically maps the range of possibilities in the interaction between regulation and regulated actors.”).

133 Grainne De Burca & Joanne Scott suggest that the term is defined more by what it is not, than by what it is. See Burca & Scott, supra note 129 at 2. Also see Douglas NeJaime, “When New Governance Fails” (2009) 70 Ohio St LJ 323 at 342 (“[N]ew governance strategies spring from a discontent with the results produced by traditional techniques.”); Salamon, supra note 132 at 1623–24 (“[New governance] builds on a rich history of past thinking, changing emphases and incorporating new elements, but hardly replacing all that has gone before.”); Chris Tollefson, Anthony R Zito & Fred Gale, “Symposium Overview: Conceptualizing New Governance Arrangements” (2012) 90:1 Public Administration 3 at 5 (“Perhaps what is most ‘new’ about ‘new governance’ is its clustering of a range of values that depart from how governments have governed in the past.”).

134 Cameron Holley, “Facilitating Monitoring, Subverting Self-Interest and Limiting Discretion: Learning from New Forms of Accountability in Practice” (2010) 35 Colum J Envtl L 127 at 131; NeJaime, supra note 133 at 331–37 (noting that it is difficult to extract concrete principles that guide New Governance thought, or at least to give those principles adequate meaning).

135 See Lobel, supra note 128. While Lobel first articulated these eight dimensions almost a decade earlier in Orly Lobel, “The Renew Deal: The Fall of Regulation and the Rise of Governance in Contemporary Legal Thought” (2004) 89 Minn L Rev 342, Lobel’s categorization is still highly relevant and widely cited today due to the way it
argues that these eight dimensions represent the “organizing principles” operating together within the governance model.136 While some of these organizing principles are certainly oversimplistic, they nevertheless provide a useful way of organizing and analyzing the diverse features of the broad array of new governance approaches. As such, I use this analytical framework when evaluating the elements of new governance scholarship that should inform the development of a new regulatory paradigm. In short, new governance theory turns away from traditional models of command-style, fixed-rule regulation, and towards new models of collaborative, multi-party, multi-level, adaptive, problem-solving governance.137

New governance scholars make explicit or implicit normative claims that new governance approaches will deliver effectiveness, legitimacy, and democratic benefits as compared to traditional regulation.138 However, new governance scholarship has also faced a litany of criticisms. In particular, serious concerns are often raised about the workability, transparency, and accountability of new governance structures.139 Without diminishing the

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136 Lobel, supra note 135 at 371–403.
137 Karkkainen, supra note 130 at 473. Also see Burca & Scott, supra note 129 at 2 (“[T]he common features which have been identified involve a shift in emphasis away from command-and-control in favour of ‘regulatory’ approaches which are less rigid, less prescriptive, less committed to uniform outcomes, and less hierarchical in nature.”).
138 Holley, supra note 134 at 133.
significance of new governance scholarship and the benefits it can provide, it cannot be denied that new governance approaches face very real challenges. Accordingly, careful consideration must to be given to the circumstances in which it is appropriate to implement new governance strategies as well as the necessary conditions for their success — what Susan Sturm refers to as “the ‘how’ and the ‘where’ of new governance.” While I am wary of a move away from state-centered regulatory and the wholehearted embrace of new governance, I submit that new governance is not an all-or-nothing proposition. While this thesis retains a fundamentally centralized conception of regulation, I believe that several aspects of new governance theory can help to improve the effectiveness of the existing regulatory framework in adapting infrastructure to climate change.

In considering how ‘old’ regulatory approaches can work alongside new governance, David Trubek and Louise Trubek contend that there is a cognitive dissonance between new governance theory on the one hand and core concepts of the nature of law and the legal process on the other. They suggest that this poses a paradox: while scholars and policymakers may be fully aware of the limits of conventional regulatory approaches and may consider some new governance practices to be appealing, there is often real anxiety about abandoning conventional


140 Susan Sturm, “Gender Equity Regimes and the Architecture of Learning” in Grainne De Burca & Joanne Scott, eds, Law and New Governance in the EU and the US (Oxford ; Portland, Or: Hart Publishing, 2006) 323 at 324. 141 Cristie Ford suggests that, when contemplating the partial approaches, we need to consider whether “new governance [is] ‘modular’—that is, does it still confer benefits when applied partially or imperfectly—or does it fail to achieve good regulatory results unless all the elements are in place?” In this thesis, I consider that the partial application of new governance theory can provide positive results when applied in a fashion that respects the regulatory context. See Ford, supra note 130 at 442.

forms of legal process and adopting new approaches. Such “new governance anxiety” should motivate the development of new structures and processes that maximize the advantages of the new without sacrificing the values of the old. Trubek and Trubek suggest that so-called ‘hybrid’ approaches represent a promising way to achieve this balance. In an influential 2007 article, Trubek and Trubek asserted that there are three potential trajectories for the relationship between conventional forms of regulation and new governance approaches: complementarity, rivalry, and transformation. First, new governance and regulation may be complementary — that is, they may operate in parallel in the same policy domain but not fuse together in a single system. Second, when new governance tools are designed to perform the same tasks as traditional regulation and are thought to do it better, or a choice between the two is (or appears to be) required, we may speak of rivalry. The third category involves the integration of new governance and traditional regulation into a single system in which the functioning of each element is necessary for the successful operation of the other. In this situation, traditional regulation and new governance “become yoked together in a hybrid form and interact” creating a “real transformation in the law.” This third approach represents the most promising trajectory for improving regulatory outcomes, reaping the benefits of both the new and the old.

Grainne De Burca and Joanne Scott also explore the role of this third, hybrid approach in creating a more optimistic and constructive relationship between regulation and new governance.

143 Ibid.
144 Ibid at 725.
146 Ibid at 542 (“Where both systems co-exist, there are numerous possible configurations and relationships between them. Thus, one might simply be used to launch the other, as when formal law is used to mandate a new approach. Alternatively, they might operate independently yet both may have an effect on the same policy domain.”).
147 Ibid at 543.
148 Ibid at 541.
They envisage three different forms of ‘hybridity’ that facilitate the co-existence and engagement of law and new governance. First, *baseline hybridity*, which eschews, both descriptively and normatively, the idea of pure, unadulterated new governance. Instead, it seeks to place some constraints on new governance approaches, implementing “a regulatory bottom line below which experiments in new governance may not be permitted to take us.”

Second, *developmental hybridity*, in which new governance arrangements are integrated into laws and regulations in order to enhance their flexibility and effectiveness. As De Burca and Scott explain, developmental hybridity “connotes interaction between old and new, with the new providing an institutional framework for the elaboration (and continuous transformation) of the old.”

Third, *default hybridity*, in which traditional regulations provide (often rigid and hyper-demanding) default sanctions for actors who do not respond appropriately to new governance arrangements. Rather than regulation simply providing safeguards or imposing ‘penalty’ defaults, I consider that developmental hybridity represents a more positive approach to the interaction of new governance principles and regulation. Accordingly, in this thesis I evaluate how developmental hybridity can best be achieved.

In the remainder of this section, I argue that several of the ‘organizing principles’ of new governance can and should be adopted in order to coordinate a new regulatory paradigm for infrastructure design that is more effective in the face of climate change. First, however, it must be acknowledged that several of the organizing principles are likely to be inappropriate in this

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149 Burca & Scott, *supra* note 129 at 6.
150 *Ibid* at 7.
151 *Ibid*.
152 *Ibid* at 8.
153 *Ibid*.
context. For example, with respect to decentralization — which indicates a “movement downward and outward, transferring responsibilities to state and localities and to the private sector”155 — while I advocate the increased involvement of local government in adaptation, I do not consider it appropriate for responsibility for the design, implementation or enforcement of infrastructure design regulations to be devolved to the private sector.156 I agree with David Bayley that we should “not get carried away with a giddy sense ... that the state is passé.”157

With respect to flexibility and non-coerciveness, J.B. Ruhl suggests that “[g]overnance institutions will need a broader array of instruments, ranging from “hard” prescriptive mandates to “soft” incentive- and information-based tools, to test for leverage over the more tractable attributes of climate change adaptation problems over time.”158 The adaptation of infrastructure will undoubtedly require creative responses, and therefore some flexibility or ‘softness’ will be required. However, given the importance of infrastructure to society and the need to maintain minimum standards of health and safety, such ‘softness’ needs to be carefully cabined and should only operate in concert with harder legal rules that set the overall context.159 In sum, I consider that the infrastructure design regulation should retain a fundamentally directive, public, and centralized nature.

The first of new governance’s ‘organizing principles’ that can and should be adopted in a new regulatory paradigm is the increased participation of non-state actors in the regulatory process. Whereas conventional regulatory processes typically assume that government agencies

155 Lobel, supra note 128 at 67.
156 See, for example, Gilmour & Jensen, supra note 139.
158 Ruhl, supra note 8 at 425.
159 Karkkainen, supra note 130 at 488.
have superior knowledge, information, and expertise, new governance approaches seek to engage multiple actors — along with their diverse types of expertise and experience — at various stages of the regulatory process.\footnote{Lobel, supra note 135 at 373 (“Increased participation permeates the many levels and stages of legal process—legislation, promulgation of rules, implementation of policies, and enforcement.”); Jody Freeman, “Collaborative Governance in the Administrative State” (1997) 45 UCLA L Rev 1 at 96 (“It may turn out that many kinds of knowledge are relevant to the design and implementation of rules, including knowledge that has not traditionally been regarded as expert.”).} As Orly Lobel explains, “[m]ultiparty involvement is understood as a way of creating norms, cultivating reform, and managing new market realities.”\footnote{Lobel, supra note 135 at 374 (“The exercise of normative authority is pluralized.”).} However, it must be acknowledged that shifting citizens from passive to active roles will not necessarily be straightforward or unopposed.\footnote{Ibid at 373.} In this regard, Jody Freeman argues that:

\begin{quote}
[t]he challenge [in making such a shift] is to resist the notion that agency cultivation of broader, more direct participation in governance, in specific regulatory contexts, necessarily erodes governmental power, or that it always undermines the legitimacy of the administrative regime. To argue that the government should cultivate the capacity of nongovernmental groups does not detract from the legitimacy of regulatory decisions; it increases legitimacy.\footnote{Freeman, supra note 160 at 96–97.}
\end{quote}

While participation has the potential to result in more legitimate and democratic regulation, legislators need to be conscious of the danger that new governance participatory processes will promise meaningful participation for outsider interests but actually cede little or no power, thereby perpetuating existing power dynamics.\footnote{NeJaime, supra note 133 at 362–63 (“Effective participation in New Governance collaboration—participation that has real implications for process and outcomes—requires a meaningful seat at the proverbial table.”).}

Orly Lobel asserts that the commitment to collaboration in the new governance literature naturally flows from the commitment to participation of non-state actors, “since an inclusive structure facilitates multiparty cooperative exchanges.”\footnote{Lobel, supra note 135 at 376.} As opposed to traditional patterns of
hierarchical, top-down regulatory control, new governance instead advocates “the adoption of cooperative governance based on continuous interaction and sharing of responsibility. It signifies a move to partnership, to horizontal relationships, and to two-way communications.”\textsuperscript{166} The development of a collaborative regime that facilitates cooperation and communication between parties, and encourages them to work together to realize their interests and goals in a mutually respectful way, can help to improve regulatory outcomes.\textsuperscript{167} However, I argue that it is inappropriate for government’s role in the field of infrastructure design to shift from regulator and controller to facilitator and partner.\textsuperscript{168}

Given the focus of this thesis on developing regulation that responds to the uncertainty about, and dynamic nature of, future climate, the seventh of Orly Lobel’s ‘organizing principles’ — the need for adaptability and dynamic learning — is particularly important. As Lobel notes, the traditional regulatory model “has often proved stagnant and sluggish, curtailing revision and improvement.”\textsuperscript{169} For example, in the climate change adaptation context, J.B. Ruhl argues that “[r]igidly relying on fixed, uniform regulatory instruments, such as technology standards and regulatory prescriptions, forecloses adaptation to the kind of evolving, complex problems climate change adaptation will present.”\textsuperscript{170} In addition, existing regulatory development processes also typically generate resistance to revision and adaptation.\textsuperscript{171} In the infrastructure context, frequent

\textsuperscript{166} Ibid at 377.
\textsuperscript{167} Ibid at 379.
\textsuperscript{168} Ibid at 377.
\textsuperscript{169} Ibid at 395.
\textsuperscript{170} Ruhl, supra note 24 at 1395–96.
\textsuperscript{171} Freeman, supra note 160 at 14 (“This resistance may stem from four factors. First, a rule may be viewed as a discrete event—a transaction rather than a process. Second, the enormous resources required to successfully promulgate a rule under current conditions can create disincentives to reconsider it. Third, frequent revision is viewed as creating uncertainty for parties that must make decisions based on their expectations of the rule. Finally, a rule is usually intended to be universally applied, not tailor-made to specific contexts or parties.”).
revision is likely to be resisted due to the perceived instability that it creates for industry participants.\textsuperscript{172} New governance, on the other hand, embraces “the inevitability and the fertility of change”, treating uncertainty as “an opportunity rather than a burden to overcome.”\textsuperscript{173} Viewed in this light, regulation should be designed to promote practices that allow revision and improvement.\textsuperscript{174} As Bradley Karkkainen notes, some new governance approaches “aspire[] to be adaptive, claiming both the capacity and the necessity to continuously generate new learning and to adjust in response to new information and changing conditions, systematically employing information feedback loops, benchmarking, rolling standards of best practice, and principles of continuous improvement.”\textsuperscript{175} The most prominent and well developed of these are so-called ‘experimentalist’ approaches.\textsuperscript{176}

Experimentalism takes its name from John Dewey’s political philosophy. Dewey considered that policies should be “experimental in the sense that they will be entertained subject to constant and well-equipped observation of the consequences they entail when acted upon, and subject to ready and flexible revision in the light of observed consequences.”\textsuperscript{177} Charles Sabel and William Simon argue that experimentalist approaches are especially well suited for circumstances in which effective public intervention requires local variation and adaptation to changing circumstances.\textsuperscript{178} In contrast to conventional regulation, which claims “a modest

\textsuperscript{172} Heather Auld & Don C Maclver, \textit{Cities and Communities: The Changing Climate and Increasing Vulnerability of Infrastructure} (Lijiang, Yunnan, China: Environment Canada, 2004) at 263.
\textsuperscript{173} Lobel, \textit{supra} note 135 at 395.
\textsuperscript{174} \textit{Ibid} at 396.
\textsuperscript{175} Karkkainen, \textit{supra} note 130 at 474.
\textsuperscript{176} For example, Grainne de Burca suggests that Charles Sabel’s extensive work on “democratic experimentalism” is the most theoretically developed and normatively attractive New Governance model. See de Burca, \textit{supra} note 135 at 228.
omniscience”, experimentalism “discounts the possibility of central, panoramic knowledge.”\textsuperscript{179}

In recognition of the presence of uncertainty and the limits it places our ability to map and devise comprehensive solutions to complex and dynamic social problems, experimentalist approaches adopt a regulatory architecture that embraces provisional, revisable, and experimental policies.\textsuperscript{180}

Experimentalism has a “practical core” of “centrally monitored local experimentation” — that is, it combines the decentralization of operative control with central coordination of the evaluation of results.\textsuperscript{181} Charles Sabel and William Simon suggest that experimentalist approaches share the following basic architecture.\textsuperscript{182} First, a system is set up with a ‘center’ and a set of ‘local units.’ For example, the center may be the national government with states/provinces or municipalities its local units, or alternatively, the center could be a government agency and the local units the private actors it regulates.\textsuperscript{183} Given the importance of infrastructure to society and the risks to health and safety if regulatory ‘experiments’ were to fail, I argue it is not appropriate to adopt an experimentalist model under which local government building enforcement agencies are the ‘center’ and regulated entities are ‘local units’. However, an experimental approach to building regulation that places the provincial government at the ‘center’ and local governments

\textsuperscript{180} Karkkainen, supra note 130 at 484.
\textsuperscript{182} The seminal example of experimentalist approach is the “democratic experimentalism” model developed by Michael Dorf and Charles Sabel. See Michael C Dorf & Charles F Sabel, “A Constitution of Democratic Experimentalism” (1998) 98:2 Colum L Rev 267. Sabel and Simon also suggest that a variety of regulatory structures are best understood in experimentalist terms — for example, management-based regulation. See Sabel & Simon, supra note 178 at 83 (“[Under management-based regulation] the regulator [i.e., the ‘center’] requires each regulated actor [i.e., the ‘local units’] to develop a plan to mitigate specified harms; assesses the adequacy of the plans; monitors their implementation; and, through a combination of tangible penalties, technical assistance, and public shaming, induces the laggards to comply with minimum standards and the frontrunners to improve continuously.”). Also see Cary Coglianese & David Lazer, “Management-Based Regulation: Prescribing Private Management to Achieve Public Goals” (2003) 37:4 Law & Soc’y Rev 691.
\textsuperscript{183} Sabel & Simon, supra note 178 at 79.
as ‘local units’ may be more appropriate, as it would allow local governments to develop more localized, context-appropriate regulatory requirements.\textsuperscript{184}

The goals for the regulatory framework are then established, along with provisional or interim standards, targets, and measures that become ‘benchmarks’ against which local units can evaluate their performance. A monitoring program is also designed and established to generate or gather the information required to measure performance against these benchmarks.\textsuperscript{185} As part of implementation, local units are given autonomy to pursue regulatory goals as they see fit, with their performance monitored and assessed through either a central monitoring framework or reporting obligations placed on local units as a condition of their autonomy. A central monitoring agency then pools and analyzes this information and makes it available to other local units and the public generally. This provides local units with an opportunity to learn from the plans and performance of other local units, and also allows the plans and performance of different local units to be contrasted and compared — referred to as ‘comparative benchmarking.’\textsuperscript{186} Michael Dorf and Charles Sabel assert that such a structure can be used to hold local units accountable to each other and to the public, ideally creating pressures and opportunities for continuous

\textsuperscript{184} Such an approach reflects the principle of subsidiarity. For a discussion of the role currently played by the principle of subsidiarity in the Canadian federative system, see Eugénie Brouillet, “Canadian Federalism and the Principle of Subsidiarity: Should We Open Pandora’s Box?” (2011) 54 Sup Ct L Rev 601 at 605 (“[T]he principle of subsidiarity can be defined as a principle by which the smallest possible social or political entities should have all the rights and powers they need to regulate their own affairs freely and effectively. It also requires that the responsibilities of the larger social and political entities be limited to the things that the smaller entities cannot accomplish alone.”).

\textsuperscript{185} Sabel and Simon note that goals and provisional measures may be established by legislation, administrative action, or through consultation among the center and local units and relevant outside stakeholders.

\textsuperscript{186} Sabel and Simon suggest that this can be achieved through requirements for local units to participate in peer review processes in which their performance is compared with local units employing other means to the same general ends. See Sabel & Simon, supra note 178 at 79.
Finally, analysis of various approaches provides the central agency with an opportunity to learn about the performance of the system and the various approaches adopted by local units, enabling the central agency to periodically reformulate and progressively refine the framework goals, performance measures, and preferred means to achieve them. Given this process of constant revision in response to monitoring, reporting and learning, Bradley Karkkainen, Archon Fung and Charles Sabel refer to experimentalist structures as ‘rolling-rule regimes.’

In short, the key features of an experimentalist regulatory system include: a centrally coordinated structure that promotes ‘local’ regulatory strategies; rigorous monitoring and reporting of plans and performance; assessment of plans and performance against benchmarks; collation and disclosure of information to facilitate learning and accountability; and, the constant reevaluation and revision of regulatory means and ends. Sabel and Simon submit that experimentalist approaches to regulation can generate four advantages: they create pressures for local units to respond to weak signals with self-diagnosis and corrective action; they reduce the information burden on the regulator (in particular, in determining initial levels of acceptable performance); they can accommodate diversity by leaving extensive discretion to local units while making their activities mutually transparent; and, they readily propagate relevant technical improvements.

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187 Dorf & Sabel, supra note 182 at 288 (“Using the novel forms of local participation in service provision as well as the informative performance comparisons that democratic experimentalism provides, citizens of individual jurisdictions can hold their institutions to account.”).
188 Sabel & Simon, supra note 178 at 79.
189 Karkkainen, Fung & Sabel, supra note 181 at 693 (“In this rolling-rule regime, information flows richly and continuously from localities to the centre and back again, forcing continuous improvements in both regulatory standards and environmental performance and heightening the accountability of the actors to each other and to the larger public.”).
and organizational advances that may not otherwise circulate.  These are valuable features for a new regulatory paradigm faced with an uncertain and dynamic future climate.

These core steps in an experimentalist approach — planning, gathering information, assessing, sharing, learning, revising — will prove valuable in guiding a new regulatory paradigm that is capable of responding to the uncertainty and dynamism of climate change. Despite this, experimentalist models will not be sufficient to tackle the challenge of climate change due to the types of uncertainty they are designed to respond to. While Sabel and Simon assert that experimentalist regimes can be characterized as a response to uncertainty, the uncertainties that they seek to address are limited to uncertainty due to our lack of knowledge or understanding — also known as epistemic uncertainty — about the definition of the regulatory problem, the appropriate regulatory response, or both. Although the presence of such uncertainty makes it difficult to comprehensively define regulatory ends and means in advance of implementation, epistemic uncertainties are capable of being reduced or resolved over time by gathering more information or conducting further research. Accordingly, experimentalist models are designed to generate a variety of local regulatory strategies or ‘experiments’, with their effectiveness then compared and evaluated, providing greater clarity about regulatory problems and appropriate responses. Once this uncertainty is resolved, the regulatory framework is adjusted to reflect these improved understandings. In short, experimentalist approaches only acknowledge and seek to address a limited category of uncertainty — epistemic uncertainty.

190 Sabel & Simon, supra note 178 at 88.
191 Warren E Walker et al, “Defining Uncertainty: A Conceptual Basis for Uncertainty Management in Model-Based Decision Support” (2003) 4:1 Integrated Assessment 5 at 13 (“This form of uncertainty is related to many aspects of modelling and policy analysis – e.g., limited and inaccurate data, measurement error, incomplete knowledge, limited understanding, imperfect models, subjective judgement, ambiguities, etc”).
192 Sabel & Simon, supra note 178 at 82.
about the appropriate regulatory strategy — what I refer to as ‘regulatory design uncertainty.’ Experimentalism does not, however, acknowledge or seek to understand other sources of uncertainty — in particular, the underlying causes or sources of regulatory design uncertainty.

While regulatory design uncertainty clearly exists with respect to the adaptation of infrastructure for climate change (as evidenced by the paralysis that is currently gripping regulators), the uncertainties presented by climate change run much deeper and therefore experimentalist models will not suffice. First, it is important to understand that uncertainty is not simply epistemic (i.e., due to the absence of knowledge or understanding). Rather, uncertainty may also be due to the inherent variability or unpredictability of the system under consideration — commonly referred to as ontological uncertainty. Once we appreciate the various ‘natures’ of uncertainty (i.e., epistemic or ontological), it becomes clear that not all uncertainties are reducible, which should be reflected in the design of regulatory responses (i.e., increased research and monitoring will not be a sufficient response where uncertainties are irreducible). In addition to the various ‘natures’ of uncertainty, legislators need to appreciate that there may be multiple ‘locations’ of uncertainty — that is, where uncertainty manifests itself. For example, uncertainties may arise out of the complexity of the system that is the subject of regulation (e.g., how an ecosystem or structure responds to changing circumstances and inputs) — what I refer to

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193 Walker et al, supra note 191 at 8.
194 Walker et al note that, while the terminology used may differ, the above distinction between epistemic and ontological uncertainty is well recognised in the literature about uncertainty. For example, ontological uncertainty, a term derived from philosophy, is also commonly described as aleatory uncertainty (derived from physical science), while Walker et al. prefer the term variability uncertainty.
196 See Ibid at 9–11.
as ‘internal uncertainty.’

197 On the other hand, uncertainties may arise out of the external environment of a system that is outside the control of the regulators (e.g., uncertainty about the stresses that may be imposed on the system) — what I refer to in this thesis as ‘external uncertainty.’

198 While regulatory design uncertainty may simply be a result of lack of information, attempting to design a regulatory strategy for the adaptation of infrastructure for climate change is plagued by both internal and external uncertainties. For example, there is uncertainty about the extent and timing of climatic changes (i.e., external uncertainty) as well as uncertainty about how structures will respond to climate impacts and the efficacy of potential adaptation measures (i.e., internal uncertainty). By only focusing on regulatory design uncertainty, and failing to acknowledge or address the internal and external uncertainties that may lurk beneath (and which are likely to be substantial in the context of climate change), experimentalist approaches do not represent an adequate response. I submit that the design of regulatory frameworks that respond to internal and external uncertainties is an area that requires greater attention in the legal literature. In the following section, I look to a range of ‘adaptive’ concepts from other fields in order to address this gap in the literature.

2.3 The ‘adaptives’

There is growing consensus that climate change adaptation calls for laws and regulations that are themselves adaptive — that is, laws and regulations that adapt in response to changing

197 Walker et al refer to this type of uncertainty as ‘model structure uncertainty.’ See Ibid at 9 (“Model structure uncertainty arises from a lack of sufficient understanding of the system (past, present, or future) that is the subject of the policy analysis, including the behaviour of the system and the interrelationships among its elements.”). I use the term ‘internal uncertainty’ to signify that such uncertainties are contained within the system being regulated.

198 Walker et al refer to this type of uncertainty as ‘input uncertainty.’ See Ibid at 10 (“Uncertainty about the external driving forces that produce changes within the system ... and the magnitude of the forces”).
circumstances and new understandings. However, it is not entirely clear what such adaptive
laws and regulations should look like. A variety of concepts and strategies labeled as
‘adaptive’ have been developed in different fields and are increasingly coming to the fore in
order to comprehend and respond to complex, adaptive change. In this section I review these
‘adaptive’ strategies, identifying how they should guide the development of a new regulatory
paradigm. While there is significant overlap between these ‘adaptive’ concepts and new
governance theory (and in particular ‘experimentalist’ approaches) there is little conversation
between the literatures. In this section, I highlight the similarities and differences between these
literatures, demonstrating the scholarly and practical advances that can be made with respect to
the development of a new regulatory paradigm if these schools of thought were to develop a
common language.

2.3.1 Adaptive management

The need for regulatory responses that increase flexibility and responsiveness in the face of
climate change has led several commentators to suggest that adaptation law can draw from
theories of adaptive management. In this section, I introduce the concept of adaptive
management and the various ways it may be implemented, identifying how it differs from an
experimentalist approach, and explaining why it is valuable in developing a new regulatory
paradigm. C.S. “Buzz” Holling pioneered the concept of ‘adaptive management’ in 1978 in the
fields of ecology and environmental management, and although almost forty years have since


199 See, for example, Jan McDonald, “Creating legislative frameworks for adaptation” in Jean Palutikof et al, eds,
Climate Adaptation Futures (Chichester: Wiley-Blackwell, 2013) 126 at 127; Craig, supra note 16; Ruhl, supra note 8.
Environmental Law Reporter 10426 at 10428.
passed, no work on the topic has improved on his core theory. While the term ‘adaptive management’ is highly malleable, it is generally used to describe an approach to managing ecological resources that applies the methodologies of science to the design, implementation, and evaluation of management strategies with the aim of not only improving the management of complex ecosystems but also understanding the impacts of uncertainty and incomplete knowledge.

Adaptive management sets out principles and approaches to decision-making and management in circumstances where it is not possible reliably to predict the behavior of an ecosystem, including risks of adverse states or outcomes. Robin Kundis Craig and J.B. Ruhl submit that the core of adaptive management is “a multistep, iterative process for adjusting management measures to changing circumstances or new information about the effectiveness of prior measures or the system being managed.” Given this iterative approach, adaptive management can be viewed as a form of experimentalism — that is, policy measures are seen as

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203 Holly Doremus, “Adaptive Management, the Endangered Species Act, and the Institutional Challenges of New Age Environmental Protection” (2001) 41 Washburn LJ 50 at 52 (“[A]daptive management is a highly malleable term. It has been defined and applied in a variety of ways, ranging from highly detailed and rigorous to nearly vacuous.”).


206 Robin Kundis Craig & J B Ruhl, “Designing Administrative Law for Adaptive Management” (2014) 67 Vand L Rev 1 at 1. A white paper prepared by the Center for Progressive Reform — and authored by many of the leading legal scholars on adaptive management — suggests that there is general agreement that adaptive management embraces the following elements: explicitly stated goals and measurable indicators of progress toward those goals; an iterative approach to decision-making, providing the opportunity to adjust decisions in light of subsequent learning; systematic monitoring of outcomes and impacts; feedback loops so that monitoring and assessment produce continuous and systematic learning that in turn is incorporated into subsequent rounds of decision-making; explicit acknowledgement and characterization of risks and uncertainties, identification of key uncertainties for management purposes; and, an overarching goal to reduce uncertainty over time. See Holly Doremus et al, Making Good Use of Adaptive Management, White Paper #1104 (Washington, DC: Center for Progressive Reform, 2011) at 2.
inescapably provisional, subject to subsequent modification in response to new learning and changing conditions.\textsuperscript{207} In addition to a focus on iterative decision-making, Holly Doremus asserts that any adaptive strategy must have a commitment to learning over time.\textsuperscript{208} Doremus goes so far as to suggest that adaptive management \textit{means} “learning while doing.”\textsuperscript{209} On the other hand, J.B. Ruhl and Robert Fischman submit that although the “bumper-sticker sized slogan”\textsuperscript{210} of “learning \textit{while} doing” (or, alternatively, “learning \textit{by} doing”\textsuperscript{211}) may capture the essence of adaptive management, it hardly conveys how to do it.\textsuperscript{212} In this regard, the precise formulation of, and approach to, adaptive management will be a product of context — including the regulatory objectives, the available resources, and the quality of available information.\textsuperscript{213}

Carl Walters — a noted adaptive management scholar — suggests that there are three ways to structure management as an adaptive process: an evolutionary or ‘trial and error’ approach, ‘passive’ adaptive management, and ‘active’ adaptive management.\textsuperscript{214} While

\begin{footnotes}
\footnotetext[207]{Bradley C Karkkainen, “Adaptive Ecosystem Management and Regulatory Penalty Defaults: Toward a Bounded Pragmatism” (2003) 87 Minn L Rev 943 at 943 (“In characteristically Deweyan fashion, this "rolling rule" strategy pragmatically and continuously adjusts both ends and means in light of experience and learning.”).}
\footnotetext[208]{Holly Doremus, “Adaptive Management as an Information Problem” (2010) 89 NC L Rev 1455 at 1464.}
\footnotetext[212]{Ruhl & Fischman, \textit{supra} note 210 at 432.}
\footnotetext[213]{Accordingly, one needs to be explicit about what adaptive management \textit{means} when using the term in a particular context, what is required for it to be successful, and how it is to be applied in practice. As Bradley Karkkainen cautions, “[p]articipants in the debate over its meaning and merits often end up talking past each other, because different people are using the same term to mean very different things.” Bradley C Karkkainen, “Panarchy and Adaptive Change: Around the Loop and Back again” (2005) 7 Minn JL Sci & Tech 59 at 73. Also see Lee Failing, Graham Horn & Paul Higgins, “Using Expert Judgment and Stakeholder Values to Evaluate Adaptive Management Options” (2004) 9:1 Ecology and Society 13 (“[W]idespread use of the term “adaptive management“ has propagated various interpretations of its meaning and, consequently, there are only vague notions about what it is, what is required for it to be successful, or how it is applied in practice.”).}
\footnotetext[214]{Carl J Walters, \textit{Adaptive Management of Renewable Resources} (New York: Macmillan: Macmillan: Collier Macmillan, 1986) at 64, 232.}
\end{footnotes}
significant confusion persists over the distinction between active and passive approaches,\textsuperscript{215} active adaptive management is generally considered to incorporate explicit experimentation, whereas passive adaptive management does not.\textsuperscript{216} That is, under an active adaptive management approach, different interventions are applied simultaneously at different sites in order to test hypotheses about the system and therefore increase understanding, with experimental learning used to guide future decision-making.\textsuperscript{217} Robin Kundis Craig and J.B. Ruhl argue that adaptive management “champion[s] experimentalism”.\textsuperscript{218} However, in contrast with so-called ‘experimentalist’ approaches in new governance theory — where local units are provided with the autonomy to ‘experiment’ with regulatory strategies in a haphazard way — active adaptive management adopts a structured and scientific approach to experimentation.\textsuperscript{219} A passive

\begin{footnotesize}
\textsuperscript{216} Ibid. On the other hand, Byron Williams suggests that passive and active approaches are distinguished primarily by the degree to which they emphasize the reduction of uncertainty. See Byron K Williams, “Adaptive Management of Natural Resources—Framework and Issues” (2011) 92:5 Journal of Environmental Management 1346 at 1350 (“[A]ctive adaptive management actively pursues the reduction of uncertainty through management interventions, whereas passive adaptive management focuses on management objectives, with learning an unintended but useful by-product of decision making.”). I agree with Rist et al that such a distinction is ill-founded, as all management adjusts in response to learning; rather, it is the formalization of the learning process that is the defining characteristic of adaptive management, with active and passive approaches to be distinguished on the basis of whether or not they incorporate explicit experimentation in order to aid learning.
\textsuperscript{217} Carl Walters defines ‘active’ adaptive management as a “deliberate probing for information” through a multistep process involving integrative ecological modeling, conscious generation of testable scientific hypotheses, and field experimentation through carefully tailored management interventions designed to test specific hypotheses. See Walters, supra note 214 at 232. Also see Doremus et al, supra note 206 at 2 (“For example, forest managers uncertain of the effect of post-fire logging on sensitive species might decide to log some areas while leaving others untouched.”). Also see Tracy-Lynn Humby, “Law and Resilience: Mapping the Literature” (2014) 4 Seattle J Envtl L 85 at 118 (“Active adaptive management often refers to conscious efforts to tailor management interventions so as to test scientific hypotheses, involving integrative monitoring, conscious generation of testable scientific hypotheses, and field experimentation.”); Doremus et al, supra note 206 at 2 (“For example, forest managers uncertain of the effect of post-fire logging on sensitive species might decide to log some areas while leaving others untouched.”).
\textsuperscript{218} Craig & Ruhl, supra note 206 at 7.
\textsuperscript{219} See, for example, Kai N Lee, Compass and Gyroscope: Integrating Science and Politics for the Environment (Washington, D.C: Island Press, 1993) at 9 (“Adaptive management ... embodies a simple imperative: policies are experiments .... Its practitioners take special care with information. First they are explicit about what to expect, so that they can design methods and apparatus to make measurements. Second, they collect and analyze information so that expectations can be compared with actuality. Finally, they transform comparison into learning—they correct errors, improve their imperfect understanding, and change action and plans.”).
\end{footnotesize}
adaptive management approach, on the other hand, typically implements a single policy and does not rely on deliberate hypothesis-testing experiments; rather, it has the more modest endeavor of heightened monitoring and evaluation of key indicators and subsequent adjustment of policies in light of what is learned.220 Passive adaptive management is commonly contrasted with ordinary ‘trial and error’ approaches — “a crude and familiar process in which the manager simply tries an approach thought most likely to succeed, and if it fails, moves on to the next most likely successful alternative.”221 While ‘trial and error’ approaches are potentially adaptive, they are not generally considered to be ‘adaptive management.’222 Rather, where ‘trial and error’ is undertaken with no purposeful direction, simply relying on learning that inevitably results from whatever management action is taken, it is reminiscent of Lindblom’s ‘muddling through.’

Similar to experimentalist approaches, adaptive management can be described in terms of two phases. First, a set-up or planning phase during which clear objectives are developed with stakeholders (in order to guide decision-making and measure progress), potential management actions are identified, hypotheses are drawn about the link between management actions and results, and monitoring protocols are designed to enable comparison of hypotheses and observed

220 Humby, supra note 217 at 118. Also see Doremus et al, supra note 206 at 2 (“In a passive adaptive management strategy, forest managers would implement post-fire logging in the locations and to the extent they believe it will promote desired forest conditions. They would intensively monitor the outcome and be prepared to learn that at least some elements of their initial decisions were mistaken.”).
221 Karkkainen, supra note 207 at 950.
222 Arlene Kwasniak notes, however, that there is not always a clear delineation between the passive adaptive management and ‘trial and error’ approaches. See Arlene J Kwasniak, “Use and Abuse of Adaptive Management in Environmental Assessment Law and Practice: A Canadian Example and General Lessons” (2010) 12:4 Journal of Environmental Assessment Policy & Management 425 at 432; Craig R Allen et al, “Adaptive Management for a Turbulent Future” (2011) 92:5 Journal of Environmental Management 1339 at 1339 (“[U]nlke a traditional trial and error approach, adaptive management has explicit structure, including careful elucidation of goals, identification of alternative management objectives and hypotheses of causation, and procedures for the collection of data followed by evaluation and reiteration.”). On the other hand, Holly Doremus suggests that where trial and error approaches are performed systematically (e.g., by taking a best guess at management decisions, monitoring the outcome of those decisions, and revising them as new information is obtained), they can be considered a form of passive adaptive management. See Doremus, supra note 203 at 53.
results. Second, an iterative phase during which an action is chosen from available management alternatives, monitoring protocols are implemented to track changes in the system and responses to management actions over time, the information produced by monitoring is compared with predictions, and improved understanding about the system and the effectiveness of management actions guides the choice of future management actions.223

As Rosie Cooney and Andrew Lang note, the concept and practice of adaptive management have now been developed and elaborated by a range of different writers and practitioners across a range of contexts, and has useful application outside the area of ecological management.224 While J.B. Ruhl notes that “[t]he trend in climate change scholarship is moving in the direction of adaptive management”,225 to date the legal literature has (for the most part) focused on how adaptive management is fundamentally incompatible with administrative law, as well as contemplating the changes that need to made to enable adaptive management approaches to be applied.226 While I do not dispute the importance of this endeavor, the application of adaptive management strategies is likely to be neither practical nor appropriate in the context of the regulatory decision-making about infrastructure for two primary reasons. First, unlike natural resources and ecosystem management — where regulatory decisions do not need to be made once and for all at the ‘front end’, but may be adjusted over time (i.e., at the ‘back end’) in

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224 Cooney & Lang, *supra* note 205 at 531. Also see Byron K Williams & Eleanor D Brown, “Adaptive Management: From More Talk to Real Action” (2014) 53:2 Environmental Management 465 at 476 (“As the urgency of coping with long-term environmental change increases, there is little doubt that the breadth of adaptive management applications will increase as well.”).
225 From Ruhl, *supra* note 8 at 422.
226 See, for example, Craig & Ruhl, *supra* note 206 (arguing that administrative law needs to adapt to adaptive management); Ruhl, *supra* note 202 at 31 (“In short, in order for adaptive management to flourish in administrative agencies, legislatures must empower them to do it, interest groups must let them do it, and the courts must resist the temptation to second-guess when they do in fact do it.”).
response to new information — regulatory decisions approving the design of a particular structure cannot be revisited and revised over time in response to new information and learning, as the structure is likely to have been built and the design decisions locked in. Second, adaptive management focuses on, and is designed to respond to, regulatory design uncertainty (i.e., a lack of knowledge or understanding about the definition of the problem, the appropriate response, or both) and internal uncertainties (i.e., uncertainties arising out of the complexity of the system that is the subject of regulation), yet substantial sources of uncertainty for infrastructure design in a changing climate arise out of the external environment. Given its focus on regulatory design uncertainty and internal uncertainty, feedback loops (i.e., monitoring and assessment of the system itself and how it responds to previous actions is used to inform adjustments to subsequent actions) are considered to be a core component of adaptive management. While climate change certainly poses internal uncertainties that affect infrastructure design (e.g., a lack of knowledge or understanding about whether proposed adaptation measures will be effective in reducing vulnerabilities and building resilience and robustness), feedback regarding the effectiveness of such measures is likely be substantially delayed (i.e., until climatic changes, and the consequent impacts on infrastructure, increase) likely by decades, rendering such feedback of little use in designing adaptation measures. As Robin Kundis Craig and J.B. Ruhl note: “[where] the consequences of a management action...”

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227 Doremus et al, supra note 206 at 7. For a discussion of the challenges that adaptive management poses for administrative law, see, for example, Craig & Ruhl, supra note 206. For a more detailed discussion of the ‘front end’/‘back end’ distinction and the need to be able to adjust policies based on new information, see Sidney A Shapiro & Robert L Glicksman, Risk Regulation at Risk: Restoring a Pragmatic Approach (Stanford: Stanford University Press, 2004) at 177.

228 See, for example, Doremus et al, supra note 206 at 2 (suggesting that feedback loops are one of the core elements of adaptive management); Arnold & Gunderson, supra note 200 at 10440 (“Feedback loops are essential to aiding decision-makers in assessing whether any particular decision or action is adaptive or maladaptive: to monitor, assess, learn from, and adapt to the action’s impacts.”).
cannot be detected for, say, a century, the institutional opportunity to take advantage of adaptive management in realistic policy time horizons is limited.”

In short, the inward orientation of adaptive management makes it ill suited to guide a new regulatory paradigm.

Some scholars have proposed that adaptive management principles be applied to laws and regulations themselves. For example, Daniel Schramm and Akiva Fishman, suggest that “[t]he principles of adaptive management provide a strong conceptual basis for evaluating and strengthening legal frameworks for climate change.” While adaptive management cannot be meaningfully employed in the context of individual structures, I suggest that it may be possible to apply adaptive management to the regulation of all structures — what may be considered an ‘infrastructure ecosystem.’ Holly Doremus argues that adaptive management is principally an information problem, and as such, it only makes sense to implement adaptive management strategies if three prerequisites are satisfied. First, if there is an information gap that is important to management choices; second, if it appears possible to fill that gap on a management-relevant time scale; and third, if there are opportunities to adjust the initial decision over time in response to new information. I suggest that all three prerequisites are satisfied in the context of

229 Craig & Ruhl, supra note 206 at 23.
231 See Doremus, supra note 208 at 1458 (“[Adaptive management] depends on the ability to fill information gaps over time under challenging conditions. It cannot be used appropriately or effectively without confronting that piece of the puzzle.”). While Doremus acknowledges that adaptive management also poses incentives problems, accountability problems, and flexibility problems, she asserts that the information problem is logically prior to the incentives, accountability, and flexibility problems: “[o]nly if learning is feasible does it make sense to worry about whether managers want to learn, can be forced to learn, or can use knowledge they acquire.”
232 Ibid at 1469 (“Although this requirement will rarely turn us away from adaptive management, directly confronting it is an important prerequisite to undertaking effective adaptive management.”).
233 Ibid at 1467.
the regulation that applies to an infrastructure ecosystem. First, the uncertainties surrounding future climate and its impacts on infrastructure represent substantial ‘information gaps’ that are important for setting infrastructure design requirements. Second, ‘external’ information gaps can be (at least partially) filled over time through increased efforts to gather and generate information about climate change and its impacts on infrastructure. That is, monitoring efforts should primarily be directed outwards rather than inwards. While ‘internal’ information about the effectiveness of adaptation strategies would be valuable, as noted above, such feedback will not be available on a ‘management-relevant time scale.’ Third, the regulations that apply to the infrastructure ecosystem can be changed over time in response to this new information. While individual regulatory decisions are typically unable to be revised, the regulatory framework that applies prospectively can be adjusted over time in order to incrementally adapt the infrastructure ecosystem to climate change (i.e., as individual structures are replaced and designed in accordance with the most up to date knowledge and understanding at the time of design).

In summary, adaptive management provides useful guidance for the development of a new regulatory paradigm. It allows action to be taken in the short term despite the existence of uncertainty, and is designed to facilitate learning that reduces those uncertainties over the longer term. It also sets out a structured approach for the adjustment of initial management actions in response to learning in order to improve regulatory outcomes. Active adaptive management — with its emphasis on experimentation and hypothesis testing — is unlikely to be appropriate in the infrastructure context due to the lack of meaningful feedback loops regarding internal uncertainties (i.e., if feedback regarding experimental regulatory strategies cannot be obtained on an appropriately short timeframe in order to improve future actions, then it is of little value) as
well as the potential risks if regulatory experiments were to fail. Nevertheless, I argue that the principles of passive adaptive management (i.e., taking regulatory action now and incrementally adjusting the regulations that apply to the infrastructure ecosystem as more becomes known about climate change and as circumstances and community values change), combined with an outward-looking focus, can take us a long way to developing an adaptive regulatory framework that is flexible but not formless.

2.3.2 Adaptive governance

Despite the promise of adaptive management, it frequently fails to live up to expectations, with shortcomings often attributed (at least in part) to governance issues. This has led to development of the concept of ‘adaptive governance’ in the resilience and environmental governance literature. Thomas Dietz, Elinor Ostrom and Paul Stern first used the term ‘adaptive governance’ in 2003 to expand the focus from adaptive management of ecosystems to address the broader social, human and institutional contexts that enable adaptive management. That is, adaptive governance describes the type of governance that has the potential to mediate the complexity and uncertainty inherent in socio-ecological systems, rather than simply referring

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234 Doremus, supra note 209 at 570. Also see Doremus, supra note 203 at 53 (“Rigorous experimentation is not always possible, however, and even if possible may be impracticable given time and resource constraints.”).
235 Even after 40 years of application, there are relatively few success stories. See, for example, Rebecca J McLain & Robert G Lee, “Adaptive Management: Promises and Pitfalls” (1996) 20:4 Environmental Management 437.
236 See, for example, Craig R Allen & Lance H Gunderson, “Pathology and Failure in the Design and Implementation of Adaptive Management” (2011) 92:5 Journal of Environmental Management 1379 (discussing nine pathologies and challenges that can lead to failure in adaptive management programs); Ruhl & Fischman, supra note 210; Williams & Brown, supra note 224.
to the adaptation of governance. In this section, I argue that adaptive governance’s focus on the broader social and institutional context is valuable when seeking to apply an adaptive approach to regulation of the infrastructure ecosystem. In addition, while there is much overlap between adaptive governance and new governance scholarship, to date there has been little discussion between the two literatures. I argue that scholarly and practical advances could be made if these literatures start to talk to one another. In particular, adaptive governance’s focus on developing formal and informal networks provides a mechanism for the increased participation and collaboration called for in the new governance literature.

In a seminal work in the development of adaptive governance, Carl Folke and his co-authors argued that doing adaptive management well often depends on the social dimension in which it is employed. In order to facilitate successful adaptive management, they suggested that the social context should be explored to identify and avoid barriers to governance transformations at a scale larger than the management of specific resources. Accordingly, in the resilience literature, adaptive governance is viewed as combining more pluralistic, polycentric and collaborative forms of governance that provides sufficient flexibility for adaptive management to be implemented. In particular, there is a focus on multiple, overlapping levels of control; horizontal and vertical transfer of information and coordination of decision-making; meaningful public participation; local capacity building; and authority to respond to a change in

\[ \text{(In a 2009 article, Alejandro Camacho argued that existing governance structures are poorly equipped to deal with the unprecedented uncertainty raised by climate change, and recommended that legislators adopt an “adaptive governance” framework. Camacho used the term adaptive governance to refer to “the systematic evaluation and adaptation of all agency decisions (including rulemaking and planning activities) in furtherance of stated program goals” — that is, the application of adaptive management principles to governance. See Camacho, supra note 59 at 49.} \]


\[ \text{Ibid.} \]
circumstances across a range of scenarios. As may be unsurprising, many of the elements of ‘adaptive governance’ developed in the resilience literature are similar to, or replicate, those developed under the ‘new governance’ moniker in the legal literature. In this regard, Tracy-Lynn Humby submits that “adaptive governance seeks to capitalize on both the reflexive, iterative, scientifically-based learning characteristic of adaptive management, as well as theories of new governance that extend the function of governing to a broader range of actors acting on a wider spatial and temporal scale.” Despite the similarities and the potential for the new governance and adaptive governance literatures to talk to one another, to date adaptive governance has received limited attention in the legal literature and there has been little discussion or collaboration between scholars from the two camps. One exception is the Adaptive Water Governance Project, established in 2013, which brings together ecologists, resilience scholars and legal scholars, and seeks to understand the role of law in adaptive governance (and in particular, in the context of complex, multi-jurisdictional water basins). Barbara Cosens and her co-authors argue that the integration of law and resilience requires identification of legal


243 Humby, supra note 217 at 98. Also see Margot A Hurlbert, “Assessing the Capacity of Law to Facilitate Adaptation to Climate Change” in Walter Leal Filho, ed, Handbook of Climate Change Adaptation (Berlin Heidelberg: Springer-Verlag, 2015) 707 at 710 (“Adaptive governance entails more flexible, participatory, experimental, collaborative, and learning-based designs and approaches to policy making and governance to increase the adaptive capacity of institutions and sustainability of natural resources.”).

244 The Adaptive Water Governance Project is a synthesis project on Social-ecological System Resilience, Climate Change, & Adaptive Water Governance, with the National Socio-Environmental Synthesis Center (SESYNC) under funding from the National Science Foundation. The project’s co-chairs Barbara Cosens, a legal scholar at the University of Idaho, and Lance Gunderson, an environmental scientist at Emory College of Arts and Sciences. For more information, see National Socio-Environmental Synthesis Center, “Social-ecological System Resilience, Climate Change, & Adaptive Water Governance”, online: SESYNC <http://www.sesync.org/project/water-people-ecosystems/adaptive-water-governance>.  

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barriers and opportunities as well as necessary legal tools for implementation of adaptive governance.245

One particular area where I suggest adaptive governance can expand upon new governance approaches is its emphasis on developing and nurturing both formal and informal ‘networks’ of cooperation and collaboration. Hierarchical authority and fragmentation of governance — both geographically and substantively — pose barriers to adaptive management approaches.246 As such, Barbara Cosens argues that two changes are needed to facilitate adaptive responses at multiple scales: (i) an increased role for local knowledge and local action; and (ii) vertical and horizontal networks across jurisdictions and scales.247 While experimentalist new governance approaches emphasize an increased role for local actors, there is limited attention given to the development of networks, and in particular, informal networks. Charles Sabel and William Simon suggest that one potential element of an experimentalist model is a requirement for local units to participate in peer review processes in which their performance is compared with local units in similar circumstances.248 However, such peer review processes are primarily concerned with holding local units accountable, rather than providing opportunities for cooperation and collaboration between local units.249 Conversely, Carl Folke and his co-authors

245 Barbara Cosens et al, “Identifying Legal, Ecological and Governance Obstacles, and Opportunities for Adapting to Climate Change” (2014) 6:4 Sustainability 2338 at 2347.
248 Sabel & Simon, supra note 178 at 79.
249 Ibid (“These reviews require the local units to describe and explain their efforts to peers and superiors; to show that they have considered alternatives; and to demonstrate that they are making progress by some jointly acknowledged measure of success, or are making plausible adjustments if not. The center provides services and inducements that facilitate this disciplined comparison of local performances and mutual learning among local units.”).
submit that adaptive governance requires social networks, and in particular, the formation of informal, multilevel networks that can stimulate collaboration, build trust, provide information, and encourage the development of common perspectives on policy issues. They argue that, in times of rapid change, informal networks can also provide arenas for novelty and innovation and enhance flexibility, all of which tend to be stifled in bureaucracies. They also note that such informal networks are not intended to replace the accountability of existing hierarchical systems, but rather, to operate within and complement them — that is, they advocate a hybrid approach. I argue that the development of, and ongoing support for, both formal and informal networks can further advance new governance principles of increased participation of non-state actors and public–private collaboration, creating the potential for increased cooperation, collaboration and innovation and improving the regulatory framework’s capacity to effectively respond to the challenges posed by climate change.

Even when adaptive governance has been considered in the legal literature, Humby notes that legal scholars have typically been less critical of adaptive governance than they have of adaptive management, assuming that greater decentralization, poly-centrism, openness, and diversity will lead to the enhanced resilience of social-ecological systems. While a focus on creating governance that supports adaptive management is essential, just as there has been criticism in the legal literature of the whole-hearted embrace of new governance theory, one must approach adaptive governance critically, carefully considering the extent to which pluralistic, polycentric and collaborative forms of governance are appropriate in the

250 Folke et al, supra note 240 at 450.
251 Ibid.
252 Ibid.
253 Humby, supra note 217 at 129.
circumstances, as well as the conditions that will be necessary for their success. That is, legislators will need to closely consider how and to what extent adaptive management and adaptive governance should be incorporated into a regulatory framework. In this respect, Barbara Cosens and her co-authors submit that:

translation of adaptive governance into law must strike a balance between a prescriptive approach that unnecessarily constrains innovation and adaptation, and provision of the necessary authority to collaborate and respond adaptively. This requires careful attention to current system structure and adaptive capacity to provide legal authority and processes where lacking, and removing legal barriers that stand in the way of any emergent adaptive response.254

Despite the need for regulatory structures that can balance accountability and the discretion to revise regulatory requirements, to date the legal literature has provided little guidance as to how such a balance can be achieved. In the next section, I argue that the concept of ‘adaptive policies’ can help to produce a regulatory framework that is adaptive yet accountable in the face of climate change.

2.3.3 Adaptive policymaking

While the literature regarding the concept of ‘adaptive policies’ is limited (although growing),255 adaptive policymaking is generally considered to be an approach that recognizes and accepts the inherent uncertainty in the development of policies for a dynamic and unpredictable future, and considers learning, continuous improvement, and adaptation of the policy to be a natural part of the policy life-cycle.256 In the adaptive policymaking literature, a policy is conceived of as “a broad statement of purpose and process for addressing a particular social, economic or

254 Cosens et al, supra note 245 at 2346.
255 International Institute for Sustainable Development & The Energy and Resources Institute, Designing Policies in a World of Uncertainty, Change and Surprise - Adaptive Policymaking for Agriculture and Water Resources in the Face of Climate Change (Winnipeg; New Delhi: IISD; TERI, 2007).
256 See, for example, Swanson & Bhadwal, supra note 106 at 15.
environmental issue”, and regulation is considered to represent one instrument through which a policy is to be implemented.\(^{257}\) Advocates suggest that adaptive policymaking provides a promising and viable means by which to account for climate change uncertainties through the amalgamation of existing practices and greater flexibility and learning mechanisms.\(^{258}\) While adaptive policymaking has not yet been considered in the legal literature, I argue that it represents a valuable source of guidance for a new regulatory paradigm that facilitates and fosters the adaptation of infrastructure to climate change. In particular, I argue that there are three features of adaptive policymaking that can build on the guidance drawn from new governance, adaptive management and adaptive governance. First, the key sources of uncertainty that adaptive policies seek to monitor, learn about, and adjust policies in relation to are external uncertainties (e.g., the future climate that infrastructure will need to be designed to withstand). Second, adaptive policymaking accepts that not all potential future scenarios can be anticipated, and therefore policies are designed to be both robust and adaptive. Third, adaptive policymaking provides a structured process for both the development of robust policies and the adaptation of these policies as a result of monitoring and learning, potentially addressing accountability and transparency concerns and providing greater certainty for stakeholders.

Like ‘experimentalist’ approaches in the new governance literature, adaptive policymaking identifies its genesis in the work of John Dewey.\(^{259}\) As with adaptive management, uncertainty is central to adaptive policymaking, with adaptive policies also taking a

\(^{257}\) Other instruments for implementing policies include economic instruments (e.g., taxes, subsidies); expenditure (e.g., research and development, education and awareness, targeted projects and programmes); and institutional instruments (e.g., sector strategies).

\(^{258}\) Wall et al, supra note 32 at 3.

\(^{259}\) Dewey, supra note 177 (“[P]olicies [should] be treated as experiments, with the aim of promoting continual learning and adaptation in response to experience over time.”).
precautionary approach that combines actions that are time urgent with a framework that allows for adjustments over time in order to protect the policy from failure. While Warren Walker, Vincent Marchau and Jan Kwakkel characterize adaptive management as “[e]arly applications of adaptive policies,” they distinguish adaptive management and adaptive policymaking on the basis of the sources of uncertainty that they seek to address. As discussed above, adaptive management is primarily focused on internal uncertainties. Monitoring efforts are therefore directed inwards at the system itself in order to learn more about the system and how it responds to management actions, and then use that learning to adjust management approaches. Adaptive policymaking, on the other hand, is primarily focused on external uncertainties, and therefore monitoring is directed outwards in order to learn more about external factors, so that policies can be adjusted to be better prepared for the future that they will need to operate in. While climate change presents internal uncertainties (e.g., how structures will cope with increased climate impacts, the effectiveness of adaptation measures, etc), the primary sources of uncertainty that climate change presents for infrastructure design are external uncertainties that are outside the control of policymakers (e.g., uncertainty about the extent and timing of climatic changes, and therefore, the future climate that structures will need to be designed to withstand). Accordingly, the outward orientation of adaptive policymaking represents a better fit than adaptive management when considering how to structure an adaptive regulatory framework for a changing climate.


261 Walker et al note, however, that adaptive policies can also take into account uncertainties in the structure of the system. Ibid.
While there are a variety of approaches to policymaking under uncertainty, I argue that adaptive policymaking represents a substantial improvement over existing, static policymaking approaches. Adaptive policymaking starts from the belief that, in a rapidly changing world, rigid static policies are likely to fail.\textsuperscript{262} Such policies proceed on the assumption that the future can be predicted, and then develop ‘optimal’ regulations for the ‘most likely’ future.\textsuperscript{263} For example, building regulations currently require structures to be built in accordance with static design values (based on probabilistic analyses of historic climate data) that are intended to represent a ‘best guess’ of the future. However, any ‘best guess’ of the future is highly sensitive to assumptions made and, in the presence of uncertainty, is likely to fail.\textsuperscript{264} A more advanced — although still static — approach to regulating in the face of uncertainty is to design robust regulations — that is, regulations that produce acceptable results across a wide range of plausible future scenarios, even if they do not perform optimally in any particular scenario.\textsuperscript{265} While there is no doubt that robust regulations are needed in the face of an uncertain future,\textsuperscript{266} such regulations are still based on the assumption that all potential futures can be anticipated at the

\begin{itemize}
\item See Walker, Marchau & Kwakkel, \textit{supra} note 260 at 232.
\item Warren E Walker, S Adnan Rahman & Jonathan Cave, “Adaptive Policies, Policy Analysis, and Policy-Making” (2001) 128:2 European Journal of Operational Research 282 at 283 (“Fixed policies can fail for particular scenarios because they fail to exploit opportunities that arise, ignore crucial vulnerabilities, or depend for their performance on critical assumptions that fail to hold. Assumptions about the nature of the world can simply prove to be untrue, other actors may take actions in response to the policy that undermine its utility, or exogenous events may critically change the conditions under which the policy must operate.”).
\item Lempert & Collins, \textit{supra} note 54 at 1016. The concept of robustness is well developed in engineering, where it refers to the maintenance of system performance either when subjected to external, unpredictable perturbations, or when there is uncertainty about the values of internal design parameters. See, for example, Carlson & Doyle, \textit{supra} note 54 at 2539 (“By robustness, we mean the maintenance of some desired system characteristics despite fluctuations in the behavior of its component parts or its environment”).
\item Craig, \textit{supra} note 16 at 68 (“Climate change adaptation law should thus encourage or require robust decisionmaking processes that identify adaptation measures that will be helpful under a variety of climate change scenarios for many adaptation decisions. These processes would be especially important for any decisions that involve significant investments in relatively permanent adaptation measures.”).
\end{itemize}
time regulations are designed. Yet we need to accept that even using the most comprehensive scenario analysis, unknown unknowns still exist. As Vincent Marchau, Warren Walker and Bert van Wee caution, “if the actual future world falls outside of the range of future worlds considered, the negative consequences might be larger than if the uncertainties had been totally ignored.”

Adaptive policymaking represents an alternative to these static policy approaches, accepting that for policies to be successful in a complex and dynamic world, policies will need to be adaptive themselves. By explicitly providing for learning and incremental adjustment, adaptive policymaking represents a practical tool to “keep policy yoked to an evolving knowledge base.” It accepts that not all situations can be anticipated in advance, and accordingly, policies are designed to have the capacity to respond and, where necessary, adapt to both anticipated and unanticipated conditions. In short, adaptive policies respond to anticipated conditions through robust up-front design and are structured so that policies will navigate or adapt towards successful outcomes in settings that cannot be anticipated. While strategies have been, and continue to be, developed for building robust policies,

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267 In an unpredictable and rapidly changing world, it will be almost impossible to design fixed static policies that will perform well against all plausible futures. See Warren E Walker & Vincent AWJ Marchau, “Dealing With Uncertainty in Policy Analysis and Policymaking” (2003) 4:1 Integrated Assessment 1 at 3.


271 McCray, Oye & Petersen, supra note 101 at 952.

272 Swanson & Bhadwal, supra note 106 at 15.

273 See, for example, Lempert & Collins, supra note 54; McInerney, Lempert & Keller, supra note 54.
Swanson and his co-authors note that the creation of policies that have the capacity to adapt to unanticipated conditions is “newer territory for policy-making.”

Unsurprisingly, the general structure and many of the features of an adaptive policymaking approach reflect other approaches discussed above. For example, adaptive policymaking calls for multi-stakeholder deliberation in order to strengthen policy design by building recognition of common values, shared commitments and emerging issues, an approach which mirrors the emphasis on participatory processes in the new governance literature. In addition, a focus on decentralizing governance to the lowest effective and accountable jurisdictional level is a focus of both adaptive policymaking and new governance.

Furthermore, similar to the generation of hypotheses in adaptive management, adaptive policymaking requires the use of integrated and forward-looking analysis during the set-up phase in order to identify key factors that are likely to affect policy performance as well as scenarios for how these factors might evolve in the future. Like adaptive governance, adaptive policymaking seeks to create forums that enable social networking, facilitate the sharing of good practices, and strengthen the ability of stakeholders to respond to unanticipated events in a variety of innovative ways.

While many similarities exist, I suggest that there is one particular area where adaptive policies can build on other incremental approaches is its structured approach to both the

276 Ibid at 933–34; Lobel, supra note 135 at 381–85.
277 See Swanson et al, supra note 275 at 928–29.
278 See, for example, Ibid at 932–33; Folke et al, supra note 142.
development and implementation of robust and adaptive policies. In short, the need for adaptation is made explicit at the outset, with inevitable policy changes becoming part of a larger, recognized process rather than occurring on an *ad hoc* basis. The structured approach to the development of robust policies begins with a forward-looking analysis that identifies potential vulnerabilities during the life of the policy (i.e., external developments that could degrade the performance of a policy and jeopardize its success). Where such vulnerabilities are certain to occur, adjustments need to be made to the policy to reduce the likely adverse effects. Where vulnerabilities may potentially — but are not certain to — occur, a decision needs to be made (preferably through multi-stakeholder deliberation) regarding whether action should be taken at the outset to increase the robustness of the policy or whether action can or should be deferred until more information becomes available and more fitting policy actions can be implemented. Where the latter path is chosen, key indicators or ‘signposts’ are developed and tracked, with pre-agreed policy adjustments ‘triggered’ when critical values of signposts are reached. However, it will often be impossible or inappropriate for precise policy adjustments to be designed in advance, and as such, the reaching of critical values of signposts triggers additional analysis and deliberation in order to determine appropriate policy adjustments. In addition, adaptive policymaking acknowledges that unanticipated conditions will arise, and accordingly limits to the validity of the analysis (and its underlying assumptions) are identified and monitored, with the violation of these limits triggering the reassessment of the policy as a

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280 Walker et al refer to these as ‘mitigating actions.’ See Walker, Marchau & Kwakkel, *supra* note 260 at 287.
whole (including objectives, policy actions, monitoring protocols, etc). I argue that adaptive policymaking’s structured approach to policy adjustments, including the development of clear signposts and triggers (and, where appropriate, pre-agreed policy adjustments) through multi-stakeholder deliberation, can generate much greater certainty, transparency and accountability with respect to the adjustment of policies.

Despite the discussion of adaptive policymaking in the literature, it must be acknowledged that adaptive policymaking has seen limited real world application, and accordingly, evidence of the efficacy of these approaches is lacking. In addition, adaptive policymaking is perhaps overly structured and mechanistic, and therefore I do not suggest that a new regulatory paradigm should wholeheartedly embrace an adaptive policymaking approach. Rather, I argue that some of the features of the adaptive policymaking process can provide more rigor and structure to the adaptation of regulation in the response to changing knowledge and circumstances that characterize the challenge of climate change.

2.4 Guiding principles for the development of a new regulatory paradigm

In responding to the dynamism, complexity and uncertainty of climate change, a new paradigm for infrastructure design regulation should draw guidance from the new governance and ‘adaptives’ literatures. In this chapter, I demonstrated that although the scholarship regarding adaptive management, adaptive governance and adaptive policymaking rarely acknowledge or consider the growing field of new governance scholarship, and vice versa, there is considerable overlap between the literatures. There are scholarly advances to be made if these literatures start to talk to one another, and I therefore advocate for increased communication and collaboration

283 See, for example, Jan H Kwakkel & Jan Willem G M van der Pas, “Evaluation of Infrastructure Planning Approaches: An Analogy with Medicine” (2011) 43:9 Futures 934.
across disciplinary boundaries. In this regard, regulation is increasingly being recognized as a multidisciplinary field. For instance, substantial contributions to regulatory debates are being made by lawyers, economists, political scientists, sociologists, and anthropologists, to name a few.\textsuperscript{284} However, without downplaying the benefits of multidisciplinary regulatory research, I argue that that “super wicked” problems\textsuperscript{285} such as climate change demand innovative regulatory solutions. This requires researchers to move beyond a multidisciplinary approach and towards interdisciplinary and, where possible, transdisciplinary approaches. Although the terms interdisciplinarity and transdisciplinarity are often used interchangeably, Robert Lawrence suggests that:

\begin{quote}
[i]nterdisciplinarity can be considered as the mixing together of disciplines, whereas transdisciplinarity implies a fusion of disciplinary knowledge with the know-how of lay-people that creates a new hybrid which is different from any specific constituent part. … Collectively, transdisciplinary contributions enable the cross-fertilisation of ideas and knowledge from different contributors that leads to an enlarged vision of a subject, as well as new explanatory theories. Transdisciplinarity is a way of achieving innovative goals, enriched understanding and a synergy of new methods.\textsuperscript{286}
\end{quote}

The adaptation of infrastructure in the face of uncertainty about the future climate is an undeniably complex problem that is being addressed from various perspectives and domains. As such, I advocate for the adoption of a transdisciplinary approach to the development of a new

\begin{footnotesize}
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  \item Baldwin, Cave & Lodge, supra note 33 at 4.
  \item Kelly Levin et al, “Overcoming the Tragedy of Super Wicked Problems: Constraining our Future Selves to Ameliorate Global Climate Change” (2012) 45:2 Policy Sciences 123 at 124 (“Super wicked problems comprise four key features: time is running out; those who cause the problem also seek to provide a solution; the central authority needed to address them is weak or non-existent; and irrational discounting occurs that pushes responses into the future. Together these features create a tragedy because our governance institutions, and the policies they generate (or fail to generate), largely respond to shortterm time horizons even when the catastrophic implications of doing so are far greater than any real or perceived benefits of inaction.”); Richard J Lazarus, “Super Wicked Problems and Climate Change: Restraining the Present to Liberate the Future” (2008) 94 Cornell L Rev 1153; Horst W J Rittel & Melvin M Webber, “Dilemmas in a General Theory of Planning” (1973) 4:2 Policy Sciences 155.
  \item Roderick J Lawrence, “Housing and Health: From Interdisciplinary Principles to Transdisciplinary Research and Practice” (2004) 36:4 Futures 487 at 488–89 (references removed). Lawrence argues that multidisciplinarity, interdisciplinarity and transdisciplinarity should be viewed as complementary rather than mutually exclusive.
\end{itemize}
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regulatory paradigm: creating spaces and a common language for disciplines to talk to one another, allowing their work to be informed and influenced by these conversations, and hopefully leading to a “fusion” of ideas and knowledge.

In this chapter, I explored some of the commonalities between these various disciplinary approaches that should inform the development of a new regulatory paradigm. First, in the face of a dynamic and unpredictable climate with knowledge and circumstances are ever changing, it is clear that the need for regulation to be adaptive must be made explicit at the outset. While increasing the adaptive capacity of the regulatory framework demands greater flexibility and responsiveness, regulatory adjustments should take place as part of an intentional, structured process, rather than simply ‘muddling through.’ The development of a structured process is vital in order to ensure that the necessary flexibility and responsiveness are balanced with transparency, accountability, and (some degree of) stability for stakeholders. Further, given the geographic variability of climate impacts, local governments should, where possible, be provided with the authority to vary regulatory requirements (within pre-agreed boundaries) to reflect local conditions and concerns.

As is evident from the review of the ‘experimentalist’ and ‘adaptives’ literatures, processes for gathering, analyzing and disseminating information are vitally important for the effective operation of an adaptive approach. However, as Bradley Karkkainen notes, conventional approaches to environmental regulation are nearing a dead end, limited by the capacity of regulators to acquire the information necessary to set regulatory standards and keep pace with rapid changes in knowledge, technology,
and environmental conditions. A pervasive *information bottleneck* constrains the extent, effectiveness, efficiency, and responsiveness of the regulatory system.\(^{287}\)

An adaptive regulatory framework must be designed to ease these information bottlenecks. Accordingly, a new regulatory paradigm needs to establish an information-gathering framework that monitors the development of key vulnerabilities and gathers or generates information that reduces uncertainties, cultivates learning and informs adjustments to the regulatory framework. The new governance and ‘adaptives’ literatures also stress the importance of multi-party, multi-level participation, cooperation and collaboration. As such, it is not enough for information to flow inwards; it also needs to be collated, analyzed and broadly disseminated through formal and informal networks that facilitate learning, sharing, collaboration and innovation.

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\(^{287}\) Bradley C Karkkainen, “Information as Environmental Regulation: TRI and Performance Benchmarking, Precursor to a New Paradigm” (2000) 89 Geo LJ 257 at 263.
Chapter 3: Why the existing regulatory paradigm is in crisis

A proactive shift to a new regulatory paradigm that facilitates, rather than impedes, adaptation involves two distinct but related steps: first, acceptance that the existing paradigm is in ‘crisis’; and second, the search for, articulation of, and conversion to, a new paradigm. I address the first step in the chapter, before addressing the second in Chapter 4. As Thomas Kuhn explains, ‘crisis’ is a necessary precondition to the emergence of a new paradigm.

Because [the conversion to a new paradigm] demands large-scale paradigm destruction and major shifts in the problems and techniques of normal science, the emergence of new theories is generally preceded by a period of pronounced professional insecurity. As one might expect, that insecurity is generated by the persistent failure of the puzzles of normal science to come out as they should. Failure of existing rules is the prelude to search for new ones.

In proposing a template for the systematic adaptation of legal regimes in the face of climate change, Victor Flatt similarly suggests that the first step is to identify the parts of the current regime that will be ‘stress points’ in a changed future (i.e., so that alterations can address these stress points). This chapter identifies four such stress points in the existing regulatory paradigm that render it ill-equipped to respond to the challenges posed by climate change and which a new regulatory paradigm should seek to address. As noted in Chapter 1, I use the example of building regulation, and in particular the National Building Code of Canada (NBCC), as the basis for my analysis of the ‘stress points’ in the existing regulatory paradigm.

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288 Taylor, supra note 114 at 797.
289 Kuhn, supra note 100 at 67–68.
290 Flatt, supra note 95 at 287.
291 It should be noted that this is a non-exhaustive list of the deficiencies in the existing regulatory paradigm, and a more comprehensive analysis of the stress points in the existing paradigm is required.
292 While there are various regulatory requirements aimed at specific building types or at specific services within buildings, building codes are the primary form of building regulation in Canada (and most other jurisdictions) and the NBCC provides an illustrative and compelling example of the challenges that the existing regulatory paradigm faces in responding to climate change, and is therefore the focus of my analysis.
for infrastructure design. First, the NBCC is designed, implemented and enforced through a fragmented regulatory structure that limits the ability for local governments to impose design requirements, thereby impeding the development of adaptation measures that are suited to local experiences, conditions and community expectations. Second, the NBCC lacks the adaptive capacity to keep pace with increasingly rapid natural, scientific and technological developments. Third, existing methods for dealing with uncertainty will be overwhelmed by the uncertainties surrounding climate change. Fourth, the NBCC is poor at facilitating and incentivizing both the development of innovative design solutions and learning through the sharing of information and tools. Some may argue that these stress points are simply ‘anomalies’ — that is, developments that are not fully comprehensible within the terms of the paradigm, but that can nevertheless be bracketed, or the terms of the paradigm can be stretched to cover them. However, as these anomalies accumulate in gravity and number, ignoring them, or ad hoc attempts to stretch the terms of the existing regulatory paradigm to cover them, will gradually undermine the paradigm’s intellectual coherence and precision. I argue that it is no longer be tenable to continue to act and behave as if the existing regulatory paradigm remains valid and relevant, sending the paradigm into a state of ‘crisis.’ 293 This is the starting point for articulating a new regulatory paradigm.

Before exploring the stress points in the existing regulatory paradigm, it is first necessary to briefly discuss the scope and application of the NBCC. The NBCC is not intended to address all aspects of building design and construction, nor is it intended to be a textbook on the design

or construction of buildings. Rather, it sets out minimum requirements in relation to a limited number of regulatory objectives: safety (i.e., limiting the probability of exposure to unacceptable risks of injury); health (i.e., limiting the probability of exposure to unacceptable risks of illness); accessibility (i.e., limiting the probability that a person with a physical or sensory limitation will be unacceptably impeded from accessing or using a building or its facilities); and, fire and structural protection of buildings (i.e., limiting the probability of exposure to unacceptable risks of damage or loss of use due to fire or structural insufficiency). The NBCC does not, for instance, seek to ensure that buildings will be durable (i.e., that a building and its component parts will be capable of performing their intended functions over the entirety of the building’s design life). Instead, the NBCC only considers durability when it supports the fulfilment of an explicit code objective (such as structural safety).

294 Canadian Commission on Building and Fire Codes, supra note 5, Preface (“Designing and building in a technically sound manner depends upon many factors beyond simple compliance with building regulations. Such factors include the availability of knowledgeable practitioners who have received appropriate education, training and experience and have some degree of familiarity with the principles of good practice and experience using textbooks, reference manuals and technical guides.”).

295 Ibid. Provinces and territories can, however, include additional objectives. For example, the British Columbia Building Code contains an additional objective: energy and water efficiency. See Office of Housing and Construction Standards, British Columbia Building Code 2012 (Victoria: Province of British Columbia, 2012), Division A, section 2.2.


297 J. André Potworowski notes that the question of whether durability should be an objective of the code generated a lot of debate during the transition to an objective-based code in the 2005 edition of the NBCC. See J André Potworowski, Making it Happen – The Transition to a Sustainable Society, Case Study - The Transformation of the National Building Code of Canada: from Prescriptions to Objectives (Ottawa: University of Ottawa, 2010) at 12 (“In the end, the discussion helped the Commission reaffirm that the real purpose of the code is to specify ‘minimum practice’ versus ‘best practice.’ It finally decided that the notion of durability would be appropriate for the code only when it supports fulfilling a code objective like structural integrity. However, durability of colour finish for aesthetic reasons was deemed not appropriate for codes.”).
The NBCC also acknowledges that many hazards and undesirable events cannot be prevented, but can only be minimized, retarded or controlled. In this regard, many of the NBCC’s objectives require that a building should be designed “to limit the probability” of (rather than “to prevent”) exposure to unacceptable risks. Such an approach is driven by two factors. First, in many cases, it is not possible to eliminate all risks. For instance, adapting infrastructure to climate change impacts will reduce but not eliminate the risks posed by extreme weather events, which will continue to cause damage and disruption. Nevertheless, proactive measures that reduce vulnerabilities and increase robustness and resilience can help to mitigate or manage these risks. Second, the NBCC seeks to balance the costs of increased risk reduction measures against the perceived benefits that they provide. As such, building codes are generally regarded as “reflect[ing] the collective knowledge and wisdom of the community in the field of engineering and construction and the community consensus as to where the appropriate balance should be struck to reduce risks to the health and safety of members of the community while at the same time allowing for affordable construction.”

298 Canadian Commission on Building and Fire Codes, Supplement to the NBC 2010: Intent Statements (Ottawa: National Research Council of Canada, 2012) (“Many of the hazards and undesirable events the Codes address, such as deterioration, spread of fire and heat loss, can only be minimized, retarded or controlled through compliance; other undesirable events such as the ignition of fire or structural collapse can never be prevented with absolute assurance.”).

299 See Ibid (“Virtually all components of a building will eventually fail in the absence of maintenance, and many will eventually fail even with maintenance. This normal, expected failure cannot be addressed by code provisions.”).

300 Canadian Commission on Building and Fire Codes, supra note 5, Division A, Appendix A. Also see A T Hansen, Applying Building Codes to Existing Buildings, Canadian Building Digest (Ottawa: National Research Council of Canada, 1984) (“The code requirements that establish minimum acceptable levels of health and safety in new construction are developed with an awareness of the cost of the provisions and the constraints they may impose on design. This is balanced by the perceived benefits in terms of safety or health. Although it may be easy in many instances to establish costs with reasonable accuracy, it is not as easy to establish benefits on a quantitative basis. Building code committees must therefore rely on their collective experience and expertise to make such evaluations and judgements.”).

301 Carleton Condominium Corp. No. 21 v Minto Construction Ltd., [2001] OTC 933, 15 CLR (3d) 23 (Ont SCJ); aff'd (2004) 31 CLR (3d) 1 (Ont CA) at para 403.
scenario, requiring all structures to be ‘climate proof’ would be prohibitively costly. As such, more proportionate responses to the potential threats posed by climate change need to be developed.

With respect to the application of the NBCC, the technical provisions set out in the code primarily apply to the design and construction of new buildings.\(^{302}\) Furthermore, new or revised requirements contained in updated versions of the NBCC do not apply retrospectively to existing buildings (unless specifically required by local bylaws). The justification for not applying code requirements to existing buildings is that the costs of reinforcing and/or retrofitting existing structures to comply with new design requirements may be prohibitively expensive when compared with the associated safety benefits.\(^{303}\) While I do not seek to downplay the importance of assessing the risks that climate impacts will pose for existing infrastructure, reducing the vulnerabilities they face, and ensuring their regular maintenance, this thesis focuses on the existing regulatory framework — that is, the regulatory framework that applies to the design and construction of new buildings. That is, I do not consider how the existing regime could be expanded, or a new regulatory regime developed, to promote the adaptation of existing infrastructure. While this may appear to discount a large portion of structures, Heather Auld, Don Maclver and Joan Klassen note that within the next 50 years (and assuming a replacement rate of 1% to 1.5% for buildings), it is likely that roughly half of existing buildings will need to

\(^{302}\) Note that the NBCC also applies to the alteration, change of use or occupancy, and demolition of existing buildings. See Canadian Commission on Building and Fire Codes, supra note 5, Division A, section 1.1.1.2 (“Where a building is altered, rehabilitated, renovated or repaired, or there is a change in occupancy, the level of life safety and building performance shall not be decreased below a level that already exists.”).

\(^{303}\) Hansen, supra note 300 (“[I]n the case of new construction, applying building codes is relatively straightforward. Design loads and design procedures are well established and codes make provision for unusual structures that may require special consideration. In most cases it is possible not only to assign costs accurately, but benefits as well. For an existing building, however, the cost of increasing the strength of an existing structure may exceed the potential benefits. As a result, some compromise may have to be sought, such as restrictions on future use.”).
be demolished and replaced. Accordingly, over the timeframe that climate change impacts are expected to intensify, new buildings will cumulatively account for an equal or greater proportion of structures. Designing and building structures that are prepared for climate change will therefore play an increasingly important role in the adaptation of infrastructure, with continued regulatory paralysis resulting in more and more structures being built that are unprepared for the impacts of climate change. In the remainder of this chapter, I explore four ‘stress points’ in the existing regulatory paradigm that render it ill-equipped to handle a dynamic and uncertain future climate.

3.1 Stress point #1: A fragmented regulatory structure that restricts the development of local adaptation measures

While all levels of government will be called upon to play a role in dealing with the impacts of climate change, commentators commonly stress the importance of matching the institutional scale with the scale of implementation. In this regard, there are often calls in the literature for more adaptation governance at the local level, as a local focus allows responses to be tailored to the specific harms that are either occurring or anticipated. Moreover, local governments have...
demonstrated far more leadership to date with respect to adaptation than other levels of government. However, as I discuss in this section, the existing regulatory framework provides local governments with little scope to design and implement local adaptation responses.

In Canada, each level of government has a role in the regulatory regime for building design and construction. While legislative responsibility for building regulation rests with the provinces and territories, a centralized system for model code development and maintenance has been developed in order to generate economies of scale and to harmonize building design across the country. Under this system, the Canadian Commission on Building and Fire Codes (CCBFC) — an independent committee of volunteers established by the National Research Council of Canada — is primarily responsible for developing new editions of the NBCC. As discussed further in section 3.2 below, the code development process seeks to minimize the differences between the national model code (i.e., the NBCC) and the provincial and territorial


309 Canada’s constitution gives the ten provinces and three territories jurisdiction over construction: Constitution Act, 1867 (UK), 30 & 31 Vict, c 3, reprinted in RSC 1985, App II, No 5, s 92(13). In some circumstances, provincial governments devolve the power to make building regulations to local government. For example, under the Vancouver Charter, SBC 1953, c 55, s 306, the City of Vancouver is enabled to adopt bylaws to regulate the design and construction of buildings, although this power is unique to Vancouver in British Columbia. Nevertheless, legislative power predominantly rests with provincial and territorial governments, and therefore, for the sake of simplicity I treat this as a solely provincial power in this thesis.


311 The National Research Council of Canada is an agency of the Government of Canada that reports to Parliament through the Minister of Industry. Also see Meacham, supra note 47 at 49. (“The CCBFC is a committee of 40 +/- volunteers from across Canada and from all segments of the community affected by the National Code Documents—consumer representatives, architects, engineers, building officials, fire officials, plumbing officials, material suppliers, builders, etc. The CCBFC makes all the decisions regarding the content of the National Code Documents.”)
building codes (e.g., the British Columbia Building Code). In order to increase harmonization, provinces and territories are provided several opportunities to participate in the development of new code requirements: first, they have an opportunity to review (and potentially veto) proposed changes prior to them being released for public review; second, following the public review process, they have an opportunity to review the final version of proposed changes and identify their concerns before they are submitted to the CCBFC for final approval. Local governments, on the other hand, are not explicitly involved in the NBCC development process, with their ability to submit or comment on proposed changes effectively the same as members of the general public.

It must not be forgotten, however, that the NBCC is a model code that only gains legal force if and when the provinces and territories adopt it. In this regard, provincial and territorial governments have the discretion to adopt the NBCC ‘as is,’ to adopt it with amendments to the model provisions to suit regional needs or concerns, or not to adopt it. By way of example, Saskatchewan has adopted the 2010 NBCC by regulation with few amendments. British Columbia, on the other hand, adopts its own provincial code — for example, the 2012 British Columbia Building Code (BCBC) was adopted as a regulation under the Local Government

313 For an overview of how each province and territory has adopted or adapted the NBCC, see National Research Council Canada, “Model Code Adoption Across Canada”, (1 June 2015), online: <http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/codes_centre/code_adoption.html>.
314 See The Uniform Building and Accessibility Standards Act, SS 1983-84, c U-1.2; The Uniform Building and Accessibility Standards Regulations, RRS c U-1.2 Reg 5, reg 3(1) (“The National Building Code of Canada 2010, with the amendments set out in the Appendix to these regulations incorporated into it, is declared to be in force...”). Manitoba, Nova Scotia and Newfoundland and Labrador have also adopted the 2010 NBCC as a regulation under provincial legislation, while Northwest Territories, Nunavut and Yukon all have legislation enforcing the then current version of the NBCC. See, for example, Building Standards Act, RSY 2002, c 19, s 2(2) (“Except as otherwise prescribed pursuant to this Act, the National Building Code [defined as the the 1980 NBCC, as amended or replaced from time to time] is hereby adopted as the building code to apply throughout the Yukon as if enacted by the Legislative Assembly.”).
Act— which has been adapted from the NBCC, with variations that are primarily additions. For instance, in addition to the NBCC’s four objectives (safety, health, accessibility, fire and structural protection of buildings), the 2012 BCBC contains a fifth regulatory objective: water and energy efficiency. Finally, Ontario maintains its own code development system in parallel with the national system, although the Ontario Building Code is still largely based on the model NBCC (with significant variations in content and scope).

Local governments, on the other hand, are not typically given much scope to impose building requirements customized to their particular local communities. In Ontario, for example, municipalities are unable to pass bylaws that require different or higher standards to those found in the provincial building code. In British Columbia, while local governments are granted concurrent authority to impose requirements relating to the design and construction of buildings, this power is generally limited to structures that are not subject to the requirements of the provincial building code. Where local governments want to establish standards that are

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315 RSBC 1996, c 323, s 692(1). The BCBC applies throughout the province, except in the City of Vancouver, Indian Reserves and federal lands. For example, the City of Vancouver has authority under the Vancouver Charter, SBC 1953, c 55, s 306 to adopt bylaws to regulate the design and construction of buildings. It does this through the Vancouver Building By-law, which implements a modified version of the 2012 BCBC that includes design and construction requirements unique to the City of Vancouver. See City of Vancouver, by-law No 10908, Building By-law (1 April 2014). Alberta and Quebec have taken the same approach as British Columbia (i.e., adopting a Province-wide building code that is substantially the same as NBCC, with variations that are primarily additions).

316 See Office of Housing and Construction Standards, supra note 295, Division A, section 2.2.1.1 (“An objective of this Code is to limit the probability that, as a result of design, construction or renovation of a building, the use of energy or water will be inefficient, or the production of greenhouse gases will be excessive.”).


318 Building Code Act, 1992, SO 1992, c 23, s 35(1) (“This Act and the building code supersede all municipal by-laws respecting the construction or demolition of buildings.”).

319 Local Government Act, RSBC 1996, c 323, s 8(3)(l) (“A council may, by bylaw, regulate, prohibit and impose requirements in relation to … buildings and other structures.”) Local governments are granted concurrent authority to pass bylaws with respect to buildings and other structures under the Community Charter, SBC 2006, c 26, s 9(1)(d). The Buildings and Other Structures Bylaws Regulation, BC Reg 86/2004 is significant in relation to which municipalities and regional districts may adopt bylaws without further ministerial approval. Generally, the Regulation preserves a ministerial veto over all matters of substance in the field of building regulation.
“additional to or different from” the standards established by the provincial building code, they require approval from the provincial Minister. However, the regulation-making power of British Columbia local governments will be further restricted under the recently passed Building Act — which will come into effect over a period of time that has yet to be defined — which provides that local governments will no longer have authority to establish building requirements. Making the provincial government the sole regulation-making authority not only limits local governments’ ability to respond to specific community goals or needs, but it also means that new regulatory requirements will not be implemented unless and until the provincial government is able to find a solution that can be applied uniformly across the province. While the policy justification for not allowing local governments to impose local building regulations (i.e., to increase consistency across communities in order to reduce complexity and costs for the construction industry) is understandable, an unfortunate byproduct — in the context of climate change adaptation — is that it severely curtails the ability of local governments to develop and implement localized design requirements.

320 I note that local governments are able to impose requirements relating to the design and construction of buildings that are not subject to the provincial building code. See Buildings and Other Structures Bylaws Regulation, BC Reg 86/2004, s 2(2).

321 Building Act, SBC 2015, c 2 (assented to March 25, 2015). It has been suggested that there will be a two- to four-year transition period before the major changes take effect, to give local governments, building officials and the construction industry time to adapt. See Office of Housing and Construction Standards, Understanding B.C.’s Building Regulatory System (Vancouver: Office of Housing and Construction Standards, 2015).

322 Building Act, SBC 2015, c 2, s 5(3) (“[A] local building requirement has no effect to the extent that it relates to a matter that is (a) subject to a requirement, in respect of building activities, of a building regulation, or (b) prescribed by regulation as a restricted matter.”) I note, however, that local authorities will have the ability to request that the Minister make a variation to the BC Building Code or other provincial building regulations with respect to that local authority’s area of jurisdiction. See Ibid, s 7(1). In addition, the City of Vancouver will continue to have jurisdiction to create and enforce its own building regulations. See Ibid, s 2(1).


324 I note, however, that the NBCC provides local governments — as the ‘authority having jurisdiction’ (i.e., the governmental body responsible for the enforcement of the code) — with the ability to set climatic values for the design of buildings in their local jurisdiction. Where they do not set climatic values, Article 1.1.3(1) provides that
role in the existing regulatory framework is largely limited to implementation. Local governments are typically vested with the authority, but not the obligation, to enforce the provincial and territorial building codes.\footnote{325}{In essence, local governments have the discretion to decide if they want to administer and enforce the code, and if so, how and to what extent, with such decisions influenced to a large degree by the resources that a particular local government has available for enforcement activities. For example, in British Columbia, local governments are authorized to enforce the BC Building Code through the \textit{Local Government Act} and the \textit{Community Charter}, with most local governments passing bylaws regarding the administration of the building code (specifying, for example, when building permits are required, the roles and responsibilities of the owner and the local government entity, etc).\footnote{326}{See, for example, the \textit{Building Code Act}, SO 1992, c 23, s 3(1) (“The council of each municipality is responsible for the enforcement of this Act in the municipality, except where otherwise provided by this Act.”).}\footnote{327}{Community Charter SBC 2006, c 26, s 9(1)(d).}\footnote{328}{Office of Housing and Construction Standards, \textit{supra} note 321 at 10.} }

In essence, local governments have the discretion to decide if they want to administer and enforce the code, and if so, how and to what extent, with such decisions influenced to a large degree by the resources that a particular local government has available for enforcement activities. For example, in British Columbia, local governments are authorized to enforce the BC Building Code through the \textit{Local Government Act} and the \textit{Community Charter}, with most local governments passing bylaws regarding the administration of the building code (specifying, for example, when building permits are required, the roles and responsibilities of the owner and the local government entity, etc).\footnote{326}{See, for example, the \textit{Building Code Act}, SO 1992, c 23, s 3(1) (“The council of each municipality is responsible for the enforcement of this Act in the municipality, except where otherwise provided by this Act.”).}\footnote{327}{Community Charter SBC 2006, c 26, s 9(1)(d).}\footnote{328}{Office of Housing and Construction Standards, \textit{supra} note 321 at 10.}

Local governments’ awareness of local community needs and objectives combined with their familiarity with the challenges that are faced when implementing building code requirements suggests that they should have a prominent role in developing regulatory requirements for the adaptation of infrastructure. While local governments have already shown buildings must be designed using the default climate values set out in in Appendix C of the NBCC. As such, local governments who wish to take proactive adaptation measures could potentially set climate design values that are based on climate projections rather than historic values, or where reliable localized projections are not available, design values that include a safety factor in order to accommodate the substantial uncertainty about future climate. However, in my research I was unable to locate any instances of local governments specifying climate values greater than those specified in the provincial building code.\footnote{325}{For example, in British Columbia, local governments are empowered to regulate buildings and other structures. See \textit{Local Government Act}, RSBC 1996, c 323, s 8(3)(l) (“A council may, by bylaw, regulate, prohibit and impose requirements in relation to … buildings and other structures”). Note, however, that section 9(1)(d) of the \textit{Community Charter} SBC 2006, c 26 makes this a concurrent authority with the provincial government. I note, however, that in other provinces, such as Ontario, municipalities are under a duty to enforce the building code. See the \textit{Building Code Act}, SO 1992, c 23, s 3(1) (“The council of each municipality is responsible for the enforcement of this Act in the municipality, except where otherwise provided by this Act.”).}
leadership on both climate change mitigation and adaptation,\textsuperscript{329} few municipalities have moved beyond problem diagnosis and planning and into the implementation phase due to various barriers and challenges.\textsuperscript{330} This is particularly true in the context of infrastructure regulation, as the fragmented way in which the existing regulatory framework develops, implements and enforces regulatory requirements severely constrains local governments’ ability to make any meaningful contribution. Moreover, the recent legislative changes in British Columbia suggest that the provincial government is moving backwards, not forwards, in its support of local governments’ ability to facilitate the adaptation of infrastructure.

3.2 Stress point #2: Poor adaptive capacity

In a dynamic world characterized by rapid and often nonlinear transformations, regulation can be brittle and maladaptive\textsuperscript{331} if it cannot keep up with the pace, scale, and direction of these changes.\textsuperscript{332} In this regard, I argue that a second ‘stress point’ is the poor adaptive capacity — what the IPCC defines as “the ability … to adjust to potential damage, to take advantage of opportunities, or to respond to consequences”\textsuperscript{333} — of the existing regulatory paradigm. While


\textsuperscript{330} See, for example, Intergovernmental Panel on Climate Change, \textit{supra} note 55 at 1473 (“Leadership in adaptation is far more evident locally than at other tiers of government in North America. Few municipalities have moved into the implementation stage, however; most programs are in the process of problem diagnosis and planning. … Surveys of municipal leaders showed adaptation is rarely incorporated into planning, due to lack of resources, information, and expertise, and the prevalence of other issues considered higher priority, suggesting the need for subnational and federal-level facilitation in the form of resources and enabling regulations.”) (references removed); Gremillion, \textit{supra} note 307; Measham et al, \textit{supra} note 43.

\textsuperscript{331} See footnote 55 for an overview of how the term ‘maladaptation’ is used in this thesis.

\textsuperscript{332} Arnold & Gunderson, \textit{supra} note 200 at 10427.

\textsuperscript{333} The IPCC notes that the term ‘adaptive capacity’ can be used in the context of systems, institutions, humans, and/or other organisms. See Intergovernmental Panel on Climate Change, \textit{supra} note 55 at 1758.
increasing attention is being paid to assessing and, where necessary, increasing the adaptive capacity of the systems that are the subject of regulation (e.g., ecosystems, natural resources etc), I submit that attention must also be paid to building the adaptive capacity of the regulatory framework itself.\textsuperscript{334} In this section, I argue that the adaptive capacity of the existing framework is limited by two factors. First, the current code development process means that the regulatory framework is typically slow to respond to changed circumstances or new information.\textsuperscript{335} Second, the consensus-based process used to develop new or revised design requirements means that changes are typically conservative.\textsuperscript{336}

The slow pace of change in regulatory design requirements in the NBCC is a combination of several factors. First, revision of the NBCC currently takes place on a 5-year cycle, with the current cycle running from 2010 (when the last edition was released) to 2015 (with a new edition is anticipated before the end of the year).\textsuperscript{337} This 5-year cycle is extended at both the front- and back-end. At the front-end, changes to code requirements are proposed, and the subsequent technical and public review of these proposed changes takes place, in the years leading up to

\textsuperscript{334} In this regard, Daniel Schramm and Avika Fishman suggest that laws themselves should also undergo an ‘adaptive capacity’ analysis, which would identify the features of the existing regulatory framework that pose barriers to the incorporation of measures that respond to the impacts of climate change and drive adaptation measures. They suggest that such barriers can stem from both rigidity in the administrative procedures of the law and the absence of mandates to achieve long-term tangible objectives. See Schramm & Fishman, supra note 230 at 496–97.

\textsuperscript{335} Auld, supra note 9 at 285.

\textsuperscript{336} For an overview of how the consensus-based process operates, see National Research Council Canada, “Making Code Changes”, (27 May 2015), online: <http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/codes_centre/faq/code_changes.html> (“Consensus is the substantial agreement of members and includes the resolution of all significant concerns and technical disagreements. It implies much more than the concept of a simple majority, but it does not necessarily imply unanimity. Consensus requires that all opinions be considered and weighed and that any statement of committee agreement should be reached only after full and fair discussion of the issues involved. When consensus on a proposed change has not been achieved, additional development is undertaken, or the proposed change is rejected and the proponent of the requested change is informed. Committee decisions are based on this principle, whenever possible.”).

\textsuperscript{337} National Research Council Canada, ”About the Canadian Codes Centre”, (1 June 2015), online: <http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/codes_centre/about_codes.html>.
publication of a new edition. At the back-end, there is often a substantial delay between the model code being published and the provincial and territorial governments passing it into law (if at all). By way of example, the 2010 NBCC was not adopted in New Brunswick and Alberta until 2015. In addition, where diverse stakeholder priorities and concerns exist about a new regulatory problem, the consensus-based process through which new code requirements are developed can result in substantial delay before agreement on appropriate regulatory measures is reached, and those measures are implemented. Finally, existing processes currently require proposed code changes to be supported by ‘sound scientific knowledge’ (in order to provide confidence that the NBCC’s objectives will continue to be met), yet the resources required to conduct such research are often lacking. The combination of these factors can result in substantial delays in regulatory requirements being adjusted to reflect changing circumstances and new information (not only about potential risks, but also about technological developments and opportunities). While this slow pace of regulatory evolution may have been satisfactory in the past (e.g., with respect to the incorporation of requirements regarding improved building

338 For example, the public review process for the yet-to-be-released 2015 editions of the National Model Construction Codes was held in fall 2014.
339 See National Research Council Canada, supra note 313. Also see National Research Council Canada, “Evaluation of NRC Construction Portfolio”, (24 February 2014), online: <http://www.nrc-cnrc.gc.ca/eng/about/planning_reporting/evaluation/2013_2014/eep.html> (“[C]ode adoption is strongly influenced by the P/T’s political processes (i.e., legislative process). In fact, because codes are laws, the adoption of the code is required to follow the legislative process. Like all laws, code adoption can be delayed by provincial elections, which was the case in Quebec and Alberta.”).
340 National Research Council Canada, supra note 339, sec 3.1.4 (“[M]any stakeholders, including politicians in [provinces and territories (P/Ts)], have large stakes in the code content. Under these conditions, national priorities do not always reflect provincial priorities. For example, while British Columbia placed priority on changing the height of mid-rise wood frame buildings in their building code (i.e., the number of stories allowed), this was not the case for other P/Ts. British Colombia placed priority on this issue given the importance of the wood industry to that province. Only when sufficient support was identified across other P/Ts did this issue become a national priority for the [National Model Codes].”).
341 Ibid.
materials or design practices etc), I submit that a more responsive process for adjustments will be necessary in the face of climate change.

In addition to the slow pace of change, I argue that the consensus-based approach to development of the NBCC, combined with the requirement for changes to be supported by ‘sound scientific knowledge,’ results in conservative adjustments to regulatory requirements. While anyone is able to propose changes to code requirements, there are multiple opportunities throughout the lengthy review process for innovative or proactive changes to be abandoned or watered-down. The process starts with the CCBFC (i.e., the national body responsible for developing and updating the NBCC) conducting a preliminary review of each proposed code change, at which point they decide whether or not to move a proposed change forward. If the CCBFC elects to proceed, a detailed review of the code change request is then undertaken, at which point the proposal may be rejected, amended, deferred (pending further information or research), or approved. Provincial and territorial governments are then given an opportunity to review the proposed change, and if any of them has serious policy or administrative concerns, the proposed change can be withdrawn or deferred for further discussion. A public review is then undertaken — in which code users are invited to review and comment on the proposed change — after which the comments are reviewed by the CCBFC and the proposed change may once again be withdrawn, revised or deferred. The provinces and

342 National Research Council Canada, supra note 312 (“Code change requests can be submitted by regulatory officials, design and safety professionals, manufacturers and suppliers, contractors, building managers or owners, consumers, and other public and private sector stakeholders – in fact, by anyone with an interest in the Codes.”). Also see National Research Council Canada, “Guidelines for Requesting Changes”, (8 September 2014), online: <http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/codes_centre/code_change_guidelines.html>.

343 National Research Council Canada, supra note 310 (“Work plan approval and priority setting by the CCBFC ensures that code development work focuses on issues of importance to the provinces and territories as well as to stakeholders.”).
territories then have an opportunity to review the final version of the proposed change and to identify any concerns.\textsuperscript{344} Only then is a code change submitted to the CCBFCC for final approval and inclusion in the next edition of the NBCC.\textsuperscript{345} Given the multiple opportunities for changes to be amended, withdrawn or deferred, without the political support necessary to generate consensus among stakeholders and provincial and territorial governments, it is very unlikely that bold changes will be approved.

In addition, the combination of a consensus-based process and the need for code changes to be supported by sound scientific knowledge provides opportunities for powerful stakeholders to exploit the uncertainties associated with climate change in order to delay the inclusion of adaptation requirements.\textsuperscript{346} This is particularly likely to be the case with respect to substantial changes that will add to the cost or complexity of construction.\textsuperscript{347} Furthermore, governments are often subject to temporal myopia — or ‘short-termism’ — that erodes their willingness to introduce regulations that adequately consider and respond to long-term risks.\textsuperscript{348} Accordingly, despite (or perhaps, because of) having “one of the most extensive — and involved — public

\begin{footnotesize}
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\item National Research Council Canada, “Roles and Responsibilities”, (27 May 2015), online: <http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/codes_centre/faq/roles.html> (“If a large majority of jurisdictions support a proposed change, it normally proceeds through all considerations. If, from an administrative or policy point of view, some jurisdictions are concerned about a proposal that has received support through public review, the CCBFC will try to further address the concerns through an ad hoc committee. The committee will attempt to find a solution that may procure a greater consensus. Consensus, however, does not imply unanimity. If a strong consensus is not possible, the proposal will normally be withdrawn so as not to create disharmony. If the concern relates to a technical issue, the proposal has a good chance of surviving but may be revised to address the concern.”).
\item National Research Council Canada, supra note 310.
\item Joel Tickner & David Kriebel, “The Role of Science and Precaution in Environmental and Public Health Policy” in Elizabeth Fisher, Judith Jones & René von Schomberg, eds, Implementing the Precautionary Principle: Perspectives and Prospects (Northampton, Mass: Edward Elgar Publishing, 2006) 42 at 54 (“[U]nder uncertainty it is in the interest of those fighting regulation to convert political questions (should we act or not) into technical/scientific ones so as to delay regulation. Thus uncertainty is used strategically by the regulated community as reason to justify inaction.”); J Rolf Olsen, Adapting Infrastructure and Civil Engineering Practice to a Changing Climate (Reston: American Society of Civil Engineers, 2015) at 17.
\item Auld, MacIver & Klassen, supra note 304 at 7.
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review procedures in the world,” I argue that the current code-development process typically only produces revisions that are insubstantial and/or unobjectionable, further limiting the NBCC’s adaptive capacity in the face of changing circumstances and improved knowledge.350

3.3 Stress point #3: Ill-equipped to handle the uncertainties posed by climate change

Uncertainty is not a new challenge for engineers. As William Bulleit notes, “engineering design is replete with uncertainties, some of which are obvious and some of which many engineers may never have considered.”351 One source of uncertainty that engineers will always encounter during the design process is uncertainty about the future (e.g., “how much snow load will the structure I am designing experience during its lifetime?”).352 Despite the existence of uncertainty, structures must continue be built, and the traditional approach has been to either ignore the uncertainties that exist or to develop methods that attempt to account for uncertainty.353 A third ‘stress point’ in the existing regulatory paradigm is that the deep and evolving uncertainties surrounding climate change can no longer be downplayed or dismissed and that current methods for dealing with uncertainty are unlikely to be sufficient.

Infrastructure design codes and standards typically seek to ‘account’ for the uncertainty about future weather conditions (and the loads they will impose on infrastructure) through a

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349 National Research Council Canada, supra note 337.
350 National Research Council Canada, Developing Canada’s National Construction Codes, online:<http://www.nrc-cnrc.gc.ca/ci-ic/article/v19n2-5>. Individuals from all segments of the Canadian construction community have the opportunity to contribute to the development of the codes, either directly, through committee membership, or indirectly, by submitting or commenting on proposed changes.
352 William Bulleit identifies five broad sources of uncertainty that an engineer encounters during the design process: time, randomness, statistical limits, model limits, and human error. See Bulleit, supra note 351.
353 See, Kwakkel & van der Pas, supra note 283; Walker & Marchau, supra note 267 at 2 (“The first (and most common) [to deal with uncertainty] is to ignore it – to overlook it or act as if it is not there. An implicit assumption is made that the future world will be structurally more or less the same as the current world .... Of course, this does not solve the uncertainty problem. It merely sweeps it under the rug, and can have serious consequences.”).
combination of climatic design values and factors (or margins) of safety.\textsuperscript{354} For example, the NBCC specifies design values for snow and wind, rain intensities, cold and hot temperatures, relative humidity, and ice loads.\textsuperscript{355} These climate design values include simple information, like average annual temperature and precipitation, as well as sophisticated probabilistic analyses of historical meteorological extremes (e.g., heavy-precipitation probabilities).\textsuperscript{356} In short, design values seek to represent a ‘best estimate’ of the climate impacts that will be experienced over the lifetime of the structure.\textsuperscript{357} Safety factors are then applied to ‘account’ for the inherent randomness in future conditions (i.e., so that structures can cope with larger-than-expected extreme events), as well as uncertainties in other loads and variability in material properties.\textsuperscript{358} Safety factors are typically set on the basis of engineering experience and also to reflect the levels of risk that have been deemed acceptable during the code development process. In this regard, the extent of safety factors is often dependent on the intended occupancy or use of the structure (i.e., the greater the number of people expected to use or be impacted by the structure, the lower the risk that is acceptable, and the greater the safety factor to be applied). By way of example, when selecting design wind loads for a building, the NBCC assigns an ‘importance category’ — low, normal, high or post-disaster — to buildings depending on their intended use.

\textsuperscript{354} With safety factors, design values are multiplied by the relevant safety factor, with the design then checked to ensure that it is safe at the larger value. Margins of safety, on the other hand, add a specified amount to the design value — that is, they are additive, not multiplicative. Safety factors represent a classic example of a ‘heuristic’ — what Billy Koen defines as “anything that provides a plausible aid or direction in the solution of a problem but is in the final analysis unjustified, incapable of justification, and potentially fallible.” See Billy V Koen, \textit{Discussion of the Method: Conducting the Engineer’s Approach to Problem Solving} (Oxford: Oxford University Press, 2003); Bulleit, \textit{supra} note 351 at 29 (“Heuristics are absolutely vital to our ability to design structures. We use them every day without thinking about them, and that is okay as long as we recognize the limits of our heuristics.”).

\textsuperscript{355} Institute for Catastrophic Loss Reduction, \textit{supra} note 70 at 13.

\textsuperscript{356} Stéphane Hallegatte, “Strategies to Adapt to an Uncertain Climate Change” (2009) 19:2 Global Environmental Change 240 at 241.

\textsuperscript{357} Auld et al, \textit{supra} note 5 at 2.

\textsuperscript{358} Bulleit, \textit{supra} note 62 at 321 (“Uncertainties due to randomness are a large part of the uncertainties dealt with in codes of practice by using various types of safety factors.”).
and occupancy. A higher ‘importance factor’ (i.e., a greater safety factor) is then applied to structures with a more sensitive or important use. For example, the importance factor applied to wind loadings for buildings of ‘low’ importance — that is, buildings that represent a low direct or indirect hazard to human life in the event of failure — is 0.8 (i.e., the design value is reduced by 20%). At the other end of the spectrum, a factor of 1.25 (i.e., a 25% increase from the design value) is applied to ‘post-disaster’ buildings — that is, buildings that are essential to the provision of services in the event of a disaster (e.g., hospitals, utilities, control centers etc).

Existing safety factors are applied as a contingency against the randomness and unpredictability in the climate system; they are not intended to account for gradual changes in baseline climate conditions over time. Accordingly, while existing safety factors may be sufficient to protect against climate impacts in the short term, increasing changes in climate over time will likely absorb any remaining tolerances and render structure vulnerable to failure. In this regard, Heather Auld and Don MacIver note that even small increases in weather and climate extremes may potentially result in large increases in infrastructure damage. In short, existing methods are likely to fall short in the face of deep and evolving uncertainties posed by climate change.

Before exploring why current methods used to ‘account’ for uncertainty in the regulatory framework are likely to be ill-equipped to handle the uncertainties that surround the effects of

\[359\] See Canadian Commission on Building and Fire Codes, *supra* note 5, Division B, section 4.1.7 (Wind Load).

\[360\] In fact, some existing climatic design values may already be at risk under current climate conditions and not be able to accommodate any further increases in loads. See Auld & MacIver, *supra* note 172 at 268.

\[361\] *Ibid* at 258. For example, an investigation of claims by the Insurance Australia Group (IAG) indicated that a 25% increase in peak wind gust strength can result in a 650% increase in building damage. See Tony Coleman, *The Impact of Climate Change on Insurance against Catastrophes* (Coolum, Australia, 2003) at 4–5 (“IAG claims data also shows that once wind gusts reach a certain level, entire roof sections are blown off, or additional damages are caused by falling trees. Yet below this level damage may be minimal.”).
climate change over long time-horizons, I first examine what is meant by the term ‘uncertainty’ and also the nature of the uncertainties surrounding climate change. The concept of uncertainty has taken on different meanings and emphases in different domains and disciplines. The IPCC, for example, defines uncertainty as “[a] state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable.” While it is generally accepted that ‘uncertainty’ exists in practically all policymaking situations, Warren Walker and his co-authors note that “there is little appreciation for the fact that there are many different dimensions of uncertainty, and there is a lack of understanding about their different characteristics, relative magnitudes, and available means of dealing with them.” In this regard, they identify three dimensions of uncertainty: the location of uncertainty (i.e., what we are uncertain about); the level of uncertainty (i.e., how uncertain we are “along the spectrum between deterministic knowledge and total ignorance”); and the nature of uncertainty (i.e., why we are uncertain).

A focus on the third dimension — the nature of the uncertainty — is particularly important when designing regulatory frameworks as it can help to understand how specific uncertainties should be addressed. As noted in Chapter 2, it is important to understand that uncertainty is not simply the absence of knowledge. Rather, a distinction is often drawn

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362 For an overview, see Walker et al, supra note 191.
363 Intergovernmental Panel on Climate Change, supra note 55 at 1774.
364 Walker et al, supra note 191 at 5.
365 Walker et al, supra note 191.
366 Ibid at 13.
367 Ibid at 8.
between *epistemic* uncertainty — that is, uncertainty due to lack of knowledge\(^\text{368}\) — and *ontological* uncertainty — that is, uncertainty due to the inherent variability or unpredictability of the system under consideration.\(^\text{369}\) However, it must also be acknowledged that uncertainty does not exist ‘out there,’ even if some of its sources do.\(^\text{370}\) That is, assessments of uncertainty are subjective. They are related to satisfaction with existing knowledge (i.e., ‘uncertainty’ arises when people think that there are shortcomings in their understanding of a system), which is understandably coloured by stakeholders’ underlying values and viewpoints.\(^\text{371}\) In this regard, Marcela Brugnach and her co-authors suggest that the different, and sometimes conflicting, views about how to understand a system — what they refer to as ‘frames’ — represents a third ‘nature’ of uncertainty.\(^\text{372}\)

We are increasingly expanding our knowledge and understanding about the expected impacts of climate change, which drives an expectation that the development of more accurate models will reduce the uncertainty regarding climate predictions, thus allowing society to successfully adapt to a changing climate.\(^\text{373}\) However, while continued improvements in

\(^{368}\) *Ibid* at 13 (“This form of uncertainty is related to many aspects of modelling and policy analysis – e.g., limited and inaccurate data, measurement error, incomplete knowledge, limited understanding, imperfect models, subjective judgement, ambiguities, etc”).

\(^{369}\) Walker et al note that, while the terminology used may differ, the above distinction between epistemic and ontological uncertainty is well recognised in the literature about uncertainty. For example, ontological uncertainty, a term derived from philosophy, is also commonly described as *aleatory* uncertainty (derived from physical science), while Walker et al. prefer the term *variability* uncertainty.


\(^{371}\) Walker, Marchau & Kwakkel, *supra* note 260 at 220.

\(^{372}\) Marcela Brugnach et al, “Toward a Relational Concept of Uncertainty: About Knowing too Little, Knowing too Differently, and Accepting not to Know” (2008) 13:2 Ecology and Society 30 (“In our definition of uncertainty, we incorporate the concept of multiple frames, in order to capture the difference among multiple forms of knowledge. We consider each frame to represent a potentially valid view of a situation, reflecting the viewpoint of a particular community of practice.”).

\(^{373}\) See, for example, Andrew J Ash & Mark Stafford Smith, “Adaptation Research: Community, Science or Discipline?” in Jean Palutikof et al, eds, *Climate Adaptation Futures* (Chichester: Wiley-Blackwell, 2013) 47 at 50; Suraje Dessai et al, “Do We Need Better Predictions to Adapt to a Changing Climate?” (2009) 90:13 Eos,
knowledge and understanding will undoubtedly be beneficial, climate change presents various uncertainties that differ with respect to their location, level and nature (and not all of which can be overcome through improved knowledge). First, fundamental, irreducible uncertainties limit the accuracy of climate predictions, with further uncertainty added when the projections are ‘downscaled’ (e.g., from the hundreds of kilometers used in global climate models to the few 10s of kilometers used in the regional climate models). Second, there is uncertainty about the extent of mitigation efforts that will be taken, which will impact the extent of change to which we will need to adapt. Third, uncertainty exists with respect to the efficacy of potential adaptation strategies. Fourth, there is uncertainty about a range of non-climate drivers — for example, demographic change, technological developments, economic priorities, and the future financial and/or political support for adaptation measures — that interact to reduce or increase the risks associated with climate change. In short, the continued treatment of ‘uncertainty’ as a

Transactions American Geophysical Union 111 at 111 (“Many climate scientists, science funding agencies, and decision makers now argue that further quantification of prediction uncertainties and more accuracy and precision in assessments of future climate change are necessary to develop effective adaptation strategies.”).

Intergovernmental Panel on Climate Change, supra note 13 at 93 (“As the WGII AR5 demonstrates, we know a great deal about the impacts of climate change that have already occurred, and we understand a great deal about expected impacts in the future. But many uncertainties remain, and will persist. In particular, future greenhouse gas emissions depend on societal choices, policies, and technology advancements not yet made, and climate-change impacts depend on both the amount of climate change that occurs and the effectiveness of development in reducing exposure and vulnerability.”).

Dessai et al, supra note 373 at 111 (“For climate prediction, uncertainties can arise from limitations in knowledge (e.g., cloud physics), from randomness (e.g., due to the chaotic nature of the climate system), and from human actions (e.g., future greenhouse gas emissions). Some of these uncertainties can be quantified, but many simply cannot, leaving some level of irreducible ignorance in our understanding of future climate.”).


Camacho, supra note 59 at 14 (“[M]itigation activities raise their own uncertainties because they will be carried out by a host of regulatory actors and are likely to change over time.”).


Ash & Smith, supra note 373 at 50 (.references removed).
homogeneous concept — despite the variety of uncertainties surrounding climate change — makes it impossible for the regulatory framework to appropriately respond to these uncertainties.

The deep and evolving uncertainties that climate change presents also calls for a more sophisticated response than current methods that simply seek to ‘account’ for uncertainty. Some have suggested that uncertainty over the future climate is simply one more source of uncertainty, and that “[s]ince uncertainty is well accepted as a part of construction codes and standards and the regulatory process, it should be possible to deal with the growing uncertainty of future climate design values through measures such as increasing safety factors.” Such an increase in safety factors would not be unheard of; in the past, codes and standards have sometimes adjusted their safety factors in order to address increasing risks and uncertainties. In some circumstances, it may be possible to add extra safety margins at null or low costs, often referred to as ‘no-regret’ or ‘low-regret’ measures. However, increasing safety factors will generally entail not insubstantial increases in construction costs. In addition, I suggest that using increased safety factors to respond to the complex challenge of climate change represents an inappropriately imprecise regulatory response. While a risk-based approach could potentially be

380 Auld & MacIver, supra note 12 at 11.
381 Ibid.
382 See, for example, Hallegatte, supra note 356 at 244 (“For instance, to calibrate drainage infrastructure, water managers in Copenhagen now use run-off figures that are 70% larger than their current level. Some of this increase is meant to deal with population growth and the rest is to cope with climate change, which may lead to an increase in heavy precipitation over Denmark. This 70% increase has not been precisely calibrated, because such a calibration is made impossible by climate change uncertainty. But this increase is thought to be large enough to cope with almost any possible climate change during this century, considering the information provided by all climate models. This move is justified by the fact that, in the design phase, it is inexpensive to implement a drainage system able to cope with increased precipitation. On the other hand, modifying the system after it has been built is difficult and expensive. It is wise, therefore, to be over-pessimistic in the design phase.”).
383 See, for example, Rasmus Heltberg, Paul Bennett Siegel & Steen Lau Jorgensen, “Addressing Human Vulnerability to Climate Change: Toward a ‘No-Regrets’ Approach” (2009) 19:1 Global Environmental Change 89 (“[N]o-regret interventions ... [are] strategies that yield benefits regardless of future trends in greenhouse gas emissions and climate scenarios. No-regrets interventions are useful for hedging climate exposure because of the uncertainty over climate scenarios.”).
used to assign different safety factors based on, for example, the type or location of certain infrastructure (e.g., higher safety factors to be applied in regions that are more vulnerable to climate impacts),\textsuperscript{384} the use of risk regulation is not without its own challenges.\textsuperscript{385} Furthermore, the risks that climate change creates are likely to increase over time, and therefore safety factors would also need to vary depending on the intended service life of a structure (i.e., to reflect the range of potential future climate impacts over that period). For instance, there is greater uncertainty about the range of climate impacts that a structure designed for a service life of 100 years will face as compared to a structure designed for a 20-year service life, and as such, the former would require greater safety factors to make the structure robust against a wider range of possible future climate impacts. Yet, given the deep uncertainty about the climate futures that structures with long service lives will encounter, it will likely be difficult to agree on what safety factor would be reasonable in the circumstances, or even if any safety factor could appropriately account for the uncertainties.\textsuperscript{386}

Lastly, increasing safety factors avoids the crux of the issue. Safety factors account for uncertainty implicitly, rather than requiring explicit analysis of uncertainties. That is, safety factors give the appearance that data gaps and other uncertainties have been ‘taken care of’ in an objective fashion whereas, in reality, substantial uncertainty remains. Contestable value

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\textsuperscript{384} See, for example, Heather Auld, Don C Maclver & Joan Klaassen, \textit{Adaptation Options for Infrastructure under Changing Climate Conditions} (Downsview, ON, CAN: Adaptation and Impacts Research Division, Environment Canada, 2007) at 7 (suggesting that regionally specific “Climate Change Adaptation Factors” could be applied in localities and regions that have been identified as being at risk to current climate variability and future change).

\textsuperscript{385} Meacham, \textit{supra} note 51 at 5 (“Who or what is at risk, how is the risk calculated, how is the risk perceived, what should we do to mitigate risk and how much will that cost are just a handful of considerations that need to be addressed.”).

\textsuperscript{386} See, for example, Olsen, \textit{supra} note 346 at 17; Intergovernmental Panel on Climate Change, \textit{supra} note 13 at 917; Trisolini, \textit{supra} note 15 at 629 (“Although the broad outlines of future changes can be discerned, many details remain hazy.”).
}
judgments simply become embedded within design values and safety factors rather than being analyzed and questioned during the design process.387 In this regard, despite the fact that engineering design is “replete with uncertainties,” the NBCC makes no mention of uncertainty.388 This failure to explicitly acknowledge and assess the location, level and nature of the various uncertainties that exist can lead to some uncertainties going unrecognized, incorrectly discounted or ignored. And as Daniel Farber cautions, “[i]gning major problems because of uncertainty is an invitation to disaster.”389

3.4 Stress point #4: Poor at facilitating innovation, sharing, learning and collaboration

Adapting infrastructure to the impacts of climate change is unlikely to simply be a matter of increasing design loads to account for the worst plausible future scenario (and thereby reducing the chance of damage occurring), as this ‘extra’ design would be accompanied by substantial cost increases (i.e., as more material, or more expensive and stronger materials, will need to be used) and would therefore likely be resisted by industry participants.390 The NBCC’s focus on the cost-effectiveness of new regulatory requirements suggests that greater regulatory attention should be paid to the development of innovative and cost-effective design solutions that either

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387 Peel, supra note 77 at 148.
388 A search of the NBCC for the word ‘uncertain’ returned zero results (i.e., the NBCC makes no acknowledgement of the uncertainty that is present when designing infrastructure, nor does it articulate how the code provisions seek to respond to that uncertainty).
390 For example, in a series of 2012 workshops with stakeholders to discuss challenges faced by homebuilders in constructing homes to withstand extreme weather, the ICLR noted that reluctance to alter established building practices was evidenced. Institute for Catastrophic Loss Reduction, supra note 70 at 7 (“Resistance to change by individual homebuilders may reflect a lack of perceived benefit with buyers coupled with greater potential cost. Homebuyers will benefit from more durable homes, insurers will reduce their damage claims costs, and regulators will improve public safety without making significant public investments. There is no obvious downside risk for insurers or regulators. Homebuyers may expect somewhat higher prices, homebuilders likely face the possibility of having to absorb at least some of the additional costs. Homebuilders question their capacity to absorb the risk of added construction costs that may not be entirely transferable to consumers and the implications for their competitive positioning and ultimately profitability.”).

reduce the vulnerability, or increase the resilience and robustness, of structures in the face of climate change. In this regard, I argue that a fourth ‘stress point’ in the existing regulatory framework is that it is poor at promoting both the development of innovative design solutions and that it does not provide any means for these solutions to be shared between stakeholders, thereby missing opportunities for learning and collaboration.

While building regulations historically contained prescriptive specifications that dictated how a building must be built (e.g., what materials may be used, how they may be used, when they may be accepted by approval authorities, etc), Canada transitioned to an *objective-based* building code in 2005. Compliance with the objective-based NBCC can be achieved in one of two ways. The most straightforward way is to conform with ‘acceptable solutions’ — a mix of prescriptive and performance requirements (i.e., requirements that state the performance level or result that must be achieved, e.g., ventilation requirements, fire resistance rating requirements etc.). Acceptable solutions are deemed to satisfy the NBCC’s objectives, and are generally considered to reflect what engineers and industry stakeholders consider represent the boundary between ‘acceptable’ and ‘unacceptable’ risks.

The other way of complying with the NBCC is through the development of ‘alternative solutions’ that provide an equivalent or higher level of protection or performance than the

391 See Meacham, *supra* note 47 at 19 (“Empirically developed over many decades, and often the result of a building failure or loss of some type, most of the prescriptive requirements speak to what is needed and when … rather than why and for what purpose…”).
392 *Ibid* at 50.
393 That is, once an acceptable solution (or an equivalent ‘alternative solution’) has been implemented, the residual level of risk is deemed to be acceptable. See Canadian Commission on Building and Fire Codes, *supra* note 5, Division A, Appendix A, section A-1.2.1.1.(1)(b) (Code Compliance via Alternative Solutions).
corresponding acceptable solution. In order to facilitate the evaluation of alternative solutions against the benchmark set by the equivalent acceptable solution, each acceptable solution is linked to at least one explicitly-stated ‘objective’ (i.e., the underlying objective that the acceptable solution is intended to achieve) as well as one or more ‘functional statements’, which translate the objectives into operational terms (i.e., they describe the outcome required, but not how it should be achieved). For example, the acceptable solution contained in Article 4.1.7.1 of the NBCC sets out a formula that must be used to calculate the wind forces that will be imposed on a building. This acceptable solution is linked to three code objectives; for example, compliance with Article 4.1.7.1 is intended “to limit the probability that … a person in or adjacent to the building will be exposed to an unacceptable risk of injury due to structural failure.” The associated functional statement provides that compliance with Article 4.1.7.1 should ensure that a building “support[s] and withstand[s] expected loads and forces.” Accordingly, an alternative solution that seeks to replace the formula in article 4.1.7.1 with an alternative way of calculating wind forces must demonstrate to satisfaction of the ‘authority having jurisdiction’ — typically the relevant local government building department — that the alternative solution will also “support and withstand expected loads and forces” and thereby

394 Evaluation of alternative solutions is facilitated by the additional information provided in the NBCC regarding each acceptable solution, such as the intent and application statements, functional statements and objectives. See Ibid, Division A, section 1.2.1.1 (Compliance with this Code).
395 Ibid, Division A, section 2.2.1.1, objective OS2 (Structural Safety). The other two objectives are: OP2 – Structural Sufficiency of the Building (“to limit the probability that … the building or part thereof will be exposed to an unacceptable risk of damage or loss of use due to structural failure or lack of structural serviceability”; and OH4 – Vibration and Deflection Limitation (“to limit the probability that a person in the building will be exposed to an unacceptable risk of illness due to high levels of vibration or deflection of building elements.”)).
396 Ibid, Division A, section 3.2.1.1, functional statement F20.
“limit[ing] the probability that … [people] will be exposed to an unacceptable risk of injury due to structural failure.”  

While the transition to an objective-based code promised to “foster a spirit of innovation” through the increased use of alternative solutions, this promise has yet to be realized, with structures still largely being designed using acceptable solutions. There are several reasons for this. First, greater expertise is required for engineers to develop, and building officials to evaluate, alternative solutions, yet such expertise is often lacking. In addition, the objectives and functional statements set out in the NBCC — and against which alternative solutions are assessed — are typically framed in vague terms. For example, the objective cited above seeks “to limit the probability that … a person in or adjacent to the building will be exposed to an unacceptable risk of injury due to structural failure.” But perceptions of what constitutes an ‘unacceptable risk of injury’ will understandably vary between engineers and building officials, and also between local governments, resulting in inconsistent evaluation processes for alternative solutions. When combined with insufficient training and expertise, such vaguely worded objectives and functional statement can create a fear of liability among building officials (i.e., concern that they will be held liable if they approve an alternative solution.

397 Ibid, Division A, section 2.2.1.1, objective OS2 (Structural Safety).
398 National Research Council Canada, supra note 337.
399 See National Research Council Canada, supra note 339, sec 4.3 (“While instances of increased innovation resulting from object-based codes were identified, an intended outcome of the new regulatory framework, widespread adoption of innovative products and design in the built environment has not yet occurred.”); Potworowski, supra note 297 at 18.
400 National Research Council Canada, supra note 339, sec 4.3.2 (“[A] lack of training of building officials was [recognized as] a main barrier to the adoption of innovative products and designs.”); Mario Levesque, “‘Build it …if you can!’: Discretion, Building Inspectors and Part 8 of Ontario’s 2006 Building Code” (2011) 20:1 Canadian Journal of Urban Research 103 at 119–20.
that subsequently fails), resulting in the continued application of narrow code interpretations.\textsuperscript{402} A final reason that the existing regulatory framework is poor at promoting the development of innovative design solutions is that the process for obtaining approval of alternative solutions has proven to be time-consuming, burdensome, complex, and unfamiliar to the parties involved.\textsuperscript{403}

Notwithstanding these hurdles, alternative solutions \textit{are} being developed by engineers and assessed by building officials. However, the existing regulatory framework does not contain any mechanisms for the sharing of alternative solutions that have been developed and approved. For example, when a local government approves an alternative solution, there is no requirement for the details of that alternative solution to be communicated to the provincial or federal level (which could, for example, provide ideas for changes to the next edition of the NBCC or the relevant provincial building code). Nor are there any mechanisms for local governments to share details of alternative solutions, or tools and techniques for assessing alternative solutions, with other local governments. Perhaps unsurprisingly then, there is no repository of alternative solutions at either the provincial or national level.\textsuperscript{404} Therefore, even where industry leaders develop innovative adaptation measures, there are no mechanisms for such measures to be shared with other engineers and stakeholders and adopted (and potentially improved upon) in subsequent projects. Without such sharing, there are limited opportunities for the systemic and collaborative learning that is likely to prove invaluable in developing innovative adaptation

\textsuperscript{402} Levesque, supra note 400 at 123, 125 (“Moving forward, it appears innovation may remain stunted until liability issues are resolved.”).

\textsuperscript{403} Potworowski, supra note 297 at 18. For example, the City of Surrey requires that alternative solutions proposals “include adequate technical analysis and sufficient evidence to justify and validate achievement of the minimum level of performance required by the 2012 BCBC.” See City of Surrey, Planning and Development, Alternative Solutions (Surrey: City of Surrey, 2013).

\textsuperscript{404} National Research Council Canada, supra note 339, sec 4.3.2 (Impacts of Objective-based Codes on Adoption of Innovative Technologies and Designs).
measures. Under the current regulatory paradigm, the widespread adoption of innovative measures is therefore unlikely to occur unless and until they are incorporated into the subsequent edition of the NBCC.405

3.5 Conclusion

When viewed together, the four ‘stress points’ identified in this chapter — a fragmented structure that restricts the development of local adaptation measures; poor adaptive capacity; a framework that is ill-equipped to handle the uncertainties posed by climate change; and, a structure that fails to foster sharing, learning, collaboration, and innovation — undermine the existing regulatory paradigm and its ability to achieve its objectives, representing a ‘crisis.’406 However, while the existence of a crisis in the existing paradigm is a necessary prerequisite to a paradigm shift, it will not be sufficient to trigger the conversion to a new paradigm.407 Rather, as Thomas Kuhn explains, “[t]he decision to reject one paradigm is always simultaneously the decision to accept another.”408 In short, notwithstanding the deficiencies of the existing regulatory paradigm in the face of a changing climate, it will only be abandoned if an alternative is available to take its place. Accordingly, in the following chapter I examine some key features of a new, adaptive regulatory paradigm that addresses the stress points identified in this chapter and draws on guidance from the new governance and ‘adaptives’ literatures.

405 However, as noted in section 3.2, any innovative measures are likely be watered-down through the consensus-based code development process.
406 Kuhn, supra note 100 at 66–76.
407 Ibid at 158 (“[C]risis alone is not enough. There must also be a basis … for faith in the particular candidate chose. Something must make at least a few scientists feel that the new proposal is on the right track.”).
408 Ibid at 77 (“[T]he judgment leading to that decision involves the comparison of both paradigms with nature and with each other.”).
Chapter 4: Constructing a new, adaptive regulatory paradigm

The shift to a new, adaptive regulatory paradigm demands a critical reassessment of the assumptions and understandings that underpin and inform the regulation of infrastructure design. First and foremost, it is clear that a new regulatory paradigm must accept the “death” of stationarity.\(^{409}\) However, while abandoning stationarity may not be difficult, it is not so easy to articulate the basis upon which infrastructure should be designed going forward. Given the deep and evolving uncertainties about the future climate that infrastructure needs to be designed for, a new regulatory paradigm needs to be open and honest about the existence of uncertainty and the implications it has for regulatory decision-making.\(^{410}\) rather than uncertainty being dismissed, ignored or downplayed — for instance, the NBCC does not currently make any mention of uncertainty.\(^{411}\) However, a simple acknowledgement that ‘uncertainty’ exists will not suffice. A new regulatory paradigm needs to embrace a more sophisticated approach to characterizing, assessing, and understanding uncertainty before it can develop regulatory tools and techniques that appropriately and effectively respond to the various uncertainties that exist. Such an approach should, as a minimum, identify the regulatory provisions that are affected by uncertainty, and then evaluate the location (what we are uncertain about), the level (how uncertain we are) and the nature (why we are uncertain) of each of these uncertainties.\(^{412}\) A detailed analysis that identifies and characterizes the multiple dimensions of the various uncertainties that exist would provide several benefits: decreasing the chance that key

\(^{409}\) See Milly et al, supra note 27; Craig, supra note 16.

\(^{410}\) Jordan & O’Riordan, supra note 20 at 19.

\(^{411}\) See supra footnote 388.

\(^{412}\) With respect to the nature of uncertainty, Warren Walker et al note that it is not always easy to clearly distinguish between epistemic and ontological uncertainty: “it often remains a matter of convenience and judgement linked up to features of the problem under study as well as to the current state of knowledge or ignorance”. See Walker et al, supra note 191 at 13.
uncertainties will be overlooked; providing an appreciation that ‘uncertainty’ is not homogeneous and that different uncertainties will require different regulatory responses;\(^\text{413}\) facilitating better communication and understanding among regulators, stakeholders and the public about the limitations in our knowledge (potentially generating greater political and public support for the adoption of proactive, precautionary measures); and providing an opportunity to critically evaluate the scope and effectiveness of existing methods for dealing with uncertainty.\(^\text{414}\) Only once the regulatory paradigm changes how it addresses and understands the deep and evolving uncertainties surrounding climate change, and understands that they differ along various dimensions (with some uncertainties being reducible and others not), can new regulatory methods and structures be developed that appropriately respond to this challenge rather than uncertainty continuing to paralyze efforts to develop proactive regulatory measures.

\(^{413}\) Judith Jones, “Regulatory Design for Scientific Uncertainty: Acknowledging the Diversity of Approaches in Environmental Regulation and Public Administration” (2007) 19:3 J Envtl L 347 at 354. For example, where uncertainty is characterized as epistemic (i.e., due to incomplete knowledge), regulatory efforts are likely to be directed at remedying the deficiencies in the available knowledge by either gathering more information or conducting more research. In this regard, it must be acknowledged that while new information will typically decrease uncertainty, it may also have the opposite effect (i.e., new knowledge may reveal the presence of uncertainties that were previously understated or unknown). As Warren Walker et al note, “more knowledge illuminates that our understanding is more limited or that the processes are more complex than we previously thought.” See Walker, Marchau & Kwakkel, supra note 260 at 220. On the other hand, where uncertainty is characterized as ontological uncertainty (i.e., due to inherent variability or unpredictability), it is likely to be more appropriate for regulatory strategies to be aimed at increasing the robustness and adaptive capacity of both infrastructure and the regulatory framework itself so that they can effectively withstand and respond to changing and unknown conditions. Lastly, where uncertainty arises out of conflicting views or understandings of a situation — all of which may be plausible and legitimate — strategies may need to focus on reframing the problem through deliberative approaches in order to resolve conflicting views. See, for example, René Bouwen, Art Dewulf & Marc Craps, “Participatory Development of Technology Innovation Projects: Collaborative Learning among Different Communities of Practice” (2006) 49 Anales de la Universidad de Cuenca 127 (outlining relevant strategies for dealing with multiple knowledge frame); Brugnach et al, supra note 372 (“Ways of understanding the system can differ in where to put the boundaries of the system or what and whom to put as the focus of attention. Differences can also emerge from the way in which the information about the system is interpreted. Different decision makers can give different meanings to this information (e.g., about what the most urgent problems are).”).

\(^{414}\) For example, with respect to safety factors, it would enable consideration of the uncertainties that existing safety factors are seeking to ‘account for’ (and perhaps more importantly, the uncertainties that are downplayed or dismissed). In addition, it would also facilitate an evaluation of the degree of uncertainty that existing safety factors are designed to tolerate (i.e., at what point safety factors need to be reconsidered).
This is not to suggest that the search for new regulatory methods and structures that respond to uncertainty will be straightforward. In Chapter 2, I introduced three different approaches to regulating under uncertainty: static rigid regulations; static robust regulations; and adaptive robust regulations.415 Some consider that the continued development of higher-resolution climate models will produce regional climate projections with greater accuracy, precision, and reliability, and that these projections can then form the basis for static climate design values.416 However, as Suraje Dessai and his co-authors note, there are limits to the predictability that climate models can provide; in particular, when regulators seek to downscale projections to a local level, there is an “explosion of uncertainty.”417 In short, any ‘best guess’ of the future based on downscaled climate projections is likely to be wrong and is therefore likely to perform poorly if (and more likely when) the future turns out to be different from the one assumed. As such, simply shifting to a new set of static design values based on climate projections (rather than historic climate values) is unlikely to represent a satisfactory solution.418

Static robust regulations — while an improvement on static rigid regulations — are also likely to be inadequate. For example, one method for creating robust regulatory responses is scenario planning, under which potential regulations are evaluated based on their performance in the context of all plausible ‘climate scenarios’, not on their performance in any single scenario.419 While there is no doubt that regulations need to be robust across a range of climate

415 Adapted from Kwakkel & van der Pas, supra note 283 at 935.
416 Dessai et al, supra note 373 at 111.
417 Ibid.
418 Craig, supra note 16 at 30.
419 Climate scenarios are stories or images that describes a potential future, developed to inform decision making under uncertainty. They are not predictions of what the future will be but rather a plausible and often simplified representation of how the future might unfold. See Intergovernmental Panel on Climate Change, supra note 55 at
scenarios, it is unlikely that all plausible futures can be specified well enough at the time regulations are designed in order to produce a static regulatory framework that will generate acceptable outcomes in most (and preferably all) future scenarios. Accordingly, legislators will need to develop regulations that are not only robust, but that will also evolve as our understanding of the future develops and circumstances inevitably change in unpredictable ways. While the periodic review and adjustment of static robust regulations can go some way to achieving this evolution, I submit that the regulatory framework requires greater responsiveness given the frequent changes in understanding about climate change and the development of potential responses. Accordingly, in this chapter I consider how the adaptive capacity of the regulatory framework can be increased, beginning the task of mapping the contours of a new, adaptive paradigm for infrastructure design regulation.

In particular, I explore two key regulatory mechanisms that have the potential to facilitate the adaptation of infrastructure. Given that the climate is changing along dynamic and unpredictable pathways, it is commonly argued that regulatory tools and techniques will need to be flexible and responsive. But it is not entirely clear what it means for regulation to be ‘flexible’ and ‘responsive.’ Rather than these terms degenerating into buzzwords, how can the rhetoric of flexibility and responsiveness be turned into reality? I argue that buttressing an iterative

1761, 1772 (“Note that scenarios are neither predictions nor forecasts, but are useful to provide a view of the implications of developments and actions.”).
420 In this unpredictable and rapidly changing world, it will be almost impossible to design fixed static policies that will perform well against all plausible futures. Walker & Marchau, supra note 267 at 3.
421 Wall et al, supra note 32 at 3.
422 When thinking about increasing adaptive capacity, Derek Armitage notes that it is important to disentangle two related objects of analysis: the governing system (e.g., building regulation) and the system to be governed (e.g., buildings). This distinction is important because the adaptive capacity of the governing system will not necessarily be positively correlated with the adaptive capacity of the system to be governed. That is, while there may be only limited capacity to create flexible and adaptive buildings, legislators can and should be seeking to design regulatory frameworks that are themselves robust and adaptive. See Derek Armitage, “Resilience and Administrative Law” (2013) 18:2 Ecology and Society 11.
regulatory framework with some structure — through the use of ‘triggers’ that prompt regulatory adjustments and constraints on how much regulatory requirements can be adjusted to reflect changing knowledge and conditions — can deliver the necessary flexibility and responsiveness while at the same time maintaining accountability, transparency and a certain level of stability for stakeholders. However, a structured adaptive regulatory framework will not operate effectively unless it is supported by: explicit regulatory objectives that guide regulatory adjustments in the right direction (i.e., towards effective adaptation); a monitoring and information-gathering framework that facilitates learning and reduces uncertainty over time in ways that are relevant to subsequent regulatory adjustments;423 the right level and timing of public and stakeholder participation so that regulations remain agile and responsive but are also yoked to community values and concerns; and, sufficient resources, legislative mandates and incentives to ensure adjustments take place when called for and the regulatory framework’s adaptive capacity is utilized. In addition to an adaptive regulatory framework that iteratively adapts to reflect changing knowledge and circumstances, a new regulatory paradigm should seek to foster the adaptation of infrastructure through the increased development and adoption of innovative design solutions. In this regard, drawing on adaptive governance scholarship, I recommend that the NBCC’s ‘alternative solutions’ process be augmented with multi-level networks of cooperation and collaboration that enable the dissemination and sharing of information that can facilitate learning and collaboration and spur innovation.

423 Doremus, supra note 209 at 549 (“From that perspective, the most important challenge of uncertainty is not always how it should be accounted for in an initial decision. How to reduce uncertainty through learning, in order to improve later rounds of decisionmaking, may be more important.”).
4.1 Developing an adaptive regulatory framework

While there is increasing recognition among scholars and policymakers that laws and regulations must be flexible and responsive as science evolves and more becomes known about the actual and projected impacts of climate change, these calls are generally framed in vague and general terms. In addition, while tools and techniques for developing robust regulatory tools have received increasing attention, comparatively little attention has been paid to how to design adaptive regulations. In this section, I seek to address this gap in the literature, exploring how legislators can create an intentional, structured adaptive strategy. While adaptive strategies will obviously need to be tailored to fit the regulatory context, I focus on some of the key design decisions for provincial and territorial legislators that can make or break an adaptive regulatory framework. First and foremost, the adaptation of regulatory requirements cannot occur in the “shadows” of the regulatory framework. Rather, the need for regulation to be constantly and iteratively revised to reflect scientific and technical developments must be explicit from the outset. Second, a clear, structured approach to adaptation must be developed in order to ensure that an adaptive strategy does not “descend into a vague promise of future adjustments without

427 While a model adaptive framework could be developed at the national level (i.e., in the NBCC), as noted in section 3.1, legislative responsibility for building regulation rests with the provinces and territories, and therefore it would still need to be adopted (and adapted) by provincial and territorial legislatures.
429 Adaptive policymaking, for example, makes adaptation explicit at the outset of policy formulation, with inevitable policy changes becoming part of a larger, recognized process rather than occurring on an ad hoc basis. See Walker, Rahman & Cave, supra note 264 at 283.
clear standards.” A key challenge will be providing the flexibility required to adaptively manage regulatory requirements, while at the same time ensuring adequate regulatory accountability and providing the stability sought in laws and regulations. I argue that this requires consideration of what elements of the regulatory framework can be iteratively adjusted, who will be responsible for making such adjustments, and whether any precommitments should be made with respect to, or restrictions placed on, when and how much regulatory requirements can be adjusted.

In this section, I also argue that the adaptation of regulation cannot, and will not, happen on its own, and that close attention needs to be paid to the following three aspects of an adaptive regulatory framework. First, legislators, in conjunction with public and stakeholders, need to think carefully about what information is required to facilitate learning and improve the operation of the regulatory framework, as well as the challenges and costs of obtaining that information. Second, legislators need to decide when, how much and with respect to what matters public and stakeholder participation is sought in order to ensure that iterative adjustments head in the right direction. Third, legislators need to ensure that there are sufficient human and financial resources for the set up and ongoing operation and maintenance of an adaptive regulatory framework, that regulators have legislative authority and/or obligations to adaptively manage regulation, and that there are incentives for both regulators and regulated entities to ensure the effective operation of the regulatory framework.

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430 Ruhl & Fischman, supra note 210 at 434.
431 Ruhl, supra note 202 at 54; Doremus, supra note 203 at 55.
4.1.1 A structured approach: designing regulation that is flexible but not formless

Given the rapid pace at which climate knowledge is developing, an adaptive regulatory framework needs to be designed to permit rapid and appropriate responses to new information and changing conditions.\(^{432}\) However, as demonstrated in Chapter 3, the NBCC has poor adaptive capacity, with the introduction of new requirements, or the adjustment of existing requirements, typically significantly delayed and conservative. While more flexible regulatory frameworks will be required in order to respond to evolving uncertainties and changing circumstances,\(^{433}\) there is a danger that increased regulatory flexibility can lead to reduced accountability and transparency, opening the door to regulatory capture and potential abuse.\(^{434}\)

Richard Lazarus neatly describes the challenge as follows:

> for climate change legislation to be successful, the new legal framework must simultaneously be flexible in certain respects and steadfast in others. Flexibility is necessary to allow for the modification of legal requirements over time in light of new information. Steadfastness or “stickiness” is important to maintain the stability of a law’s requirements over time. The need for both is particularly great for climate change legislation. … [T]he law will need to include institutional design features that allow for such flexibility but insulate programmatic implementation to a significant extent from powerful political and economic interests propelled by short-term concerns.\(^{435}\)

\(^{432}\) Sussman et al, supra note 424 at 91.

\(^{433}\) Doremus, supra note 203 at 55 (“A management program cannot be adaptive unless decisions are always subject to re-evaluation in light of new information.”).

\(^{434}\) Craig, supra note 16 at 64; Arnold & Gunderson, supra note 200 at 10441 (“The legal system serves to hold people and entities accountable for their actions and accountable to boundaries on their actions.”); Craig, supra note 16 at 17 (“Given the societal importance of climate change adaptation, … increased legal flexibility should not become a mechanism for avoiding effective environmental regulation … the specific means of adaptation can reflect local circumstances and needs, but the fact of adaptation and the general goals and policies climate change adaptation law seeks to effectuate should not be subject to local veto or avoidance.”); Doremus et al, supra note 206 at 11 (“One of the most significant weaknesses of adaptive management to date has been that agencies have promised future adaptation but not delivered it.”).

\(^{435}\) Lazarus, supra note 285 at 1157–58. Also see, Bradley C Karkkainen, “Collaborative Ecosystem Governance: Scale, Complexity, and Dynamism” (2002) 21 Va Environ Law J 189 at 236–37 (“[T]here is a place for law, for example, in defining and policing procedural regularity, so as to reduce opportunities for interest-group capture,
As Bradley Karkkainen notes, careful and thoughtful attention needs to be paid to the design of regulatory structures and processes if an adaptive regulatory framework is to become “something more than a disparate series of slapped-together, ad hoc arrangements, and more than the fashionable buzzwords into which it could easily degenerate.”\textsuperscript{436} As discussed further below, not only does a regulatory framework need to provide some constraints on excessive regulatory discretion, but it must also limit a regulator’s discretion to do nothing (i.e., ensure that changes actually take place when new information shows them to be necessary).\textsuperscript{437} In addition to accountability concerns, regulatory flexibility does not mesh well with the desire for regulatory certainty and stability.\textsuperscript{438} However, as Holly Doremus notes, at some point “there is no choice but to sacrifice some rigidity. Rigid standards based on the past can no longer stand. Perhaps the best we can do is to adopt standards that are flexible but not formless, … and combine them with procedures that will encourage their robust implementation.”\textsuperscript{439} In this section, I identify some potential tools and techniques for creating regulations that are ‘flexible but not formless.’ In order to ensure that an appropriate balance is struck between flexibility on the one hand and accountability, transparency and certainty on the other, in this section I explore four aspects that require close consideration and should be clearly set out in an adaptive regulatory framework: (i)

\textsuperscript{436} Karkkainen, supra note 435 at 237.
\textsuperscript{437} Doremus et al, supra note 206 at 11.
\textsuperscript{438} Joseph Raz suggests that the stability of laws is one of the core principles underlying the rule of law. See Joseph Raz, “The rule of law and its virtue” in Auth. Law Essays Law Moral (Oxford: Clarendon Press, 1979) 210 at 214–15 (“[Laws] should not be changed too often. If they are frequently changed people will find it difficult to find out what the law is at any given moment and will be constantly in fear that the law has been changed since they last learnt what it was.”). Also see Martin A Nie & Courtney A Schultz, “Decision-Making Triggers in Adaptive Management” (2012) 26:6 Conservation Biology 1137 at 1139 (“A key tension in the politics of adaptive management is the widespread search for managerial and economic certainty by political actors, whereas adaptive management plans necessarily include flexibility to respond to the uncertainty inherent in resource management.”).
\textsuperscript{439} Doremus, supra note 209 at 79–80.
which aspects of the regulatory framework may be adjusted in response to new information or changing circumstances; (ii) when regulatory requirements may be, or are required to be, adjusted; (iii) whether there are any constraints on how or how much regulatory requirements may be adjusted; and (iv) who has the authority to make regulatory adjustments.⁴⁴⁰

With respect to which aspects of the regulatory framework that are subject to adjustment, allowing all aspects of the regulatory framework to be adjusted is likely to bring substantial instability and complexity to the regulatory framework, and is therefore unlikely to be appropriate. Limiting the scope of regulatory framework that is subject to potential adjustment can reduce the consequences of too many changes being made, providing greater stability but also reducing the risk of multiple adjustments being made that do not support one another, or worse, that undermine each other. Accordingly, as part of the design of an adaptive regulatory framework, legislators should identify those regulatory requirements that are particularly affected by uncertainty and are most likely to require adjustment as knowledge improves. For instance, the climate design data in the NBCC is an aspect that will most likely be subject to frequent revision or updating as our understanding of future climate improves over time. It may also be appropriate for the various safety factors in the building code to be subject to adjustment as understanding improves, with safety factors to be adjusted where uncertainties are shown to have previously been under- or over-estimated. However, as noted above, it is not appropriate for regulatory objectives to be adjusted or redefined iteratively; rather, these should be reevaluated and revised through participatory, deliberative processes. In short, by limiting the scope of the

⁴⁴⁰ Camacho & Glicksman, supra note 426 at 82 (“For example, a governing authority may compel stakeholder participation, use of adaptive management, or the integration of clear triggers within an adaptive management process, rather than make them optional.”).
potential adjustments, it can reduce the instability that such adjustments may otherwise produce in the regulatory system.

Next, with respect to *when* regulatory requirements may be, or are required to be, adjusted, I suggest that legislators should seriously consider the use of ‘precommitment’ strategies. 441 Richard Lazarus notes that such strategies can, for example, “deliberately make it hard (but never impossible) to change the law in response to some kinds of concerns. At the same time, the legislation should also include contrasting precommitment strategies that deliberately make it easier to change the law in response to other longer-term concerns that are in harmony with the law’s central purpose.” 442 Adaptive policymaking embraces the use of precommitment strategies in the form of built-in policy adjustments. 443 The pre-agreement of triggers and adjustments to policies also resembles an ‘adaptation pathways’ approach 444 — an approach which requires the explicit consideration of the timing and sequencing of possible ‘pathways’ of adaptation measures over time under different scenarios, each of which is triggered by a change in knowledge or circumstances. 445 In the regulatory context, for example, as certain tipping points are surpassed, regulators may be required to take additional regulatory

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441 As Holly Doremus explains, ‘precommitment’ simply means doing something now in order to increase the likelihood of taking (or not taking) another action later, and that “[l]aw itself can be the subject of collective precommitment.” See Doremus, *supra* note 209 at 48–49. Also see, Samuel Freeman, “Reason and Agreement in Social Contract Views” (1990) 19:2 Philosophy & Public Affairs 122 at 143; Thomas C Schelling, “Enforcing Rules on Oneself” (1985) 1:2 Journal of Law, Economics & Organization 357.


443 See, for example, Suruchi Bhadwal, Stephan Barg & Darren A Swanson, “Automatic Policy Adjustment” in Darren A Swanson & Suruchi Bhadwal, eds, *Creating Adaptive Policies: A Guide for Policy-making in an Uncertain World* (New Delhi, India: SAGE, International Institute for Sustainable Development, 2009) 56 at 57 (“Automatic policy adjustment mechanisms help policies respond well in variety of plausible and clearly identified future circumstances. They can speed up the process of response to conditions that are more or less anticipated. They can be used in complicated policy environments by separating the various policy issues into units wherein the understanding of the system is high, allowing for fine-tuning of the system and making adjustments that help reduce risks and maintain performance.”).

444 See, for example, Ranger, Reeder & Lowe, *supra* note 48.

action (e.g., increasing safety factors) or potentially switch to an alternative pathway (e.g., where the speed of climatic change is greater than anticipated, more fundamental changes may be required). The use of triggers and pre-agreed policy responses can provide greater stability for industry stakeholders (as they can plan for adaptation measures that have not yet, but may soon, be triggered) and also hold regulators accountable (i.e., to ensure that regulatory adjustments are made when a pre-agreed tipping point is triggered).

An adaptive regulatory framework should seriously consider setting out clear, pre-negotiated decision-making triggers or ‘adaptation tipping points’ — that is, scales of change under which the current regulatory requirements will likely cease to be effective in meeting regulatory objectives — that will either trigger future regulatory adjustments or put in motion specific procedures for making such adjustments. The establishment of triggers and associated adjustments (or processes for making adjustments) requires careful consideration as they can vary substantially in terms of their design, specificity and enforceability — in some cases, they are detailed, legally binding commitments; in others, they are more discretionary and simply activate a range of possible actions. Courtney Schultz and Martin Nie suggest that the “trick” is to include triggers and monitoring that are meaningful so that they result in adjustments in a relevant timeframe, and are enforceable. Schultz and Nie also note that one of the most

446 As Nicola Ranger et al. note, an adaptation pathways approach also encourages regulators to consider up front the conditions under which a strategy will fail and to design actions to guard against this, including preparing for actions that might be triggered later. Ranger, Reeder & Lowe, supra note 48 at 250.
447 The underlying question when setting triggers or tipping points is: ‘how much climate change can the current regulatory requirements cope with?’ See Kwadijk et al, supra note 48 at 730; Barnett et al, supra note 445 at 1103.
449 Ibid.
contentious issues when establishing triggers is who sets the trigger points and where. While expert input will clearly be required, I submit that triggers should ultimately be developed through participatory processes that are transparent and explicit about the choices made with respect to acceptable levels of risk, how triggers are to be used, and how they will be monitored. Lastly, given the delayed nature of climate impacts, it is likely that such triggers will need to be framed around climate projections (e.g., projected increases in extreme events over the lifetime of a structure) rather than observed climate impacts; if we wait until changes are observed, it is likely to be too late.

Next, the question of how or how much the regulatory framework may be adjusted. In some circumstances, it may be possible to agree on both triggers and the corresponding regulatory adjustment or course of action. Also, given the range of possible futures, it may be appropriate to incorporate a continuum of trigger points (rather than a single trigger) with associated adjustments. Such pre-agreed triggers and adjustments can then form one or more ‘adaptation pathways.’ However, given the uncertainties that exist with respect to climate change, in many cases it is likely to be impossible, impractical or inappropriate to pre-define the precise nature of the adjustment that will be required when a trigger is reached. Rather, it is likely to be more appropriate for pre-defined triggers to initiate a structured process for

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450 Ibid at 521 (“This determination is a heavily loaded choice involving determinations about how risk-prone or risk-averse a program or project is in its approach to resource management.”).
451 Ibid at 517–18.
452 For example, such triggers may specify what actions will be taken if monitoring information shows x or y Schultz & Nie, supra note 99 at 455.
453 For example, where projected wind speeds are less than 10% greater than current design values, no change is required; if projected wind speeds are between 10% and 20% greater than current design values, change x is required to be made; if projected wind speeds are more than 20% greater than current design values, change y is required to be made; etc.
454 In other words, ‘fully automatic’ regulatory adaptations are unlikely to be appropriate in these circumstances. See Swanson et al, supra note 275 at 929–30.
determining suitable regulatory adjustments, along with specified timeframes for such adjustments to be implemented. In addition, a framework that contains transparent processes for making adjustments is more likely to carry credibility with stakeholders and the public.\textsuperscript{455} In this regard, I suggest that such an adaptive regulatory framework should contain some objective boundaries or constraints on how or how much the regulatory system may be adjusted.\textsuperscript{456} For example, J.B. Ruhl proposes that a regulator’s adaptive mandate should be subject to limitations on ‘volatility’ and ‘drift’. A limit on ‘volatility’ entails a constraint on the extent of each individual incremental change, in order to ensure that a regulatory agency does not deviate from its initial position too dramatically over the short-term.\textsuperscript{457} A limit on ‘drift’, on the other hand, is intended to protect against an accumulation of small adjustments over time that leads to a position that is substantially different from the initial position. By predefining limits on volatility and, in particular, drift, it allows stakeholders to agree on clear limitations on regulators’ discretion to adjust regulatory framework.\textsuperscript{458} Where pre-agreed limits are exceeded, or a regulator considers that an adjustment which exceeds these limits is appropriate in the circumstances, I suggest that participatory, deliberative processes should be used to reevaluate and revise the regulatory framework — and, in particular, the objectives, triggers, and limits on volatility and drift.

\textsuperscript{455} Doremus et al, supra note 206 at 11 (“Merely including a requirement for reconsideration of management direction—in other words, a mandatory process without mandatory results—is not sufficient.”).
\textsuperscript{456} Ruhl, supra note 202 at 55.
\textsuperscript{457} Ibid (“A small adjustment made soon after the initial position is implemented is understandable, but a radical departure made quickly after the initial position suggests that the agency’s operational model is faulty, its monitoring is defective, or something else about the agency’s approach is fundamentally flawed, and that the agency needs to go back to the drawing board.”).
\textsuperscript{458} Nie & Schultz, supra note 438.
While the use of pre-identified triggers may potentially run counter to the theory and spirit of adaptive management, I argue that triggers, combined with objective constraints on the extent of adjustments, can provide the level of transparency, accountability and stability required to ensure sufficient public and political support while still providing the regulatory framework with sufficient flexibility to respond to changing circumstances. In addition, by building such triggers and constraints into the regulatory framework from the beginning of the process, regulatory adjustments can be insulated (to a significant extent) from powerful political and economic interests propelled by short-term concerns, as there will be less opportunity for adjustments to be delayed once the triggers have been satisfied. As Nie and Schultz explain, triggers can help provide structure and “regulatory sideboards” to an adaptive framework by limiting the amount of discretion afforded to agencies that might otherwise fail to follow through on their commitments. This is not to deny that challenges would be encountered in setting up triggers and constraints on adjustments. Different stakeholders and the public will undoubtedly have different opinions about what to do in the face of uncertainty, and these opinions will need to be managed or reconciled. In particular, there are likely to be disagreements about where triggers and thresholds should be set, as such decisions are full of value judgments — for instance, how precautionary they should be. In short, “[p]eople often like the idea of using triggers in theory but disagree on how they are used in practice.” Despite these challenges, the

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459 As adaptive approaches are adopted in circumstances involving widespread uncertainty, therefore making it difficult to determine appropriate triggers at the outset. Ibid.
460 Lazarus, supra note 285 at 1258. Also see Ibid at 1153 (“Climate change legislation is especially vulnerable to being unraveled over time for a variety of reasons, but especially because of the extent to which it imposes costs on the short term for the realization of benefits many decades and sometimes centuries later.”).
461 Nie & Schultz, supra note 438 at 1143.
462 Questions also arise as to what exactly is triggered, over what time frame, and how such requirements might be enforced if not undertaken. See Schultz & Nie, supra note 448 at 457.
463 Ibid at 513.
use of triggers as precommitment strategies can go a long way to creating a more structured adaptive regulatory framework.

A final issue that provincial legislators will need to grapple with is who should have the authority to make regulatory adjustments. Given the focus in the adaptation literature on providing more governance at the local level, local governments would ideally be granted the authority to iteratively adjust regulatory requirements (subject to triggers and constraints discussed above) to reflect local conditions and community expectations. Such an approach would reflect ‘experimentalist’ models developed in the new governance literature (i.e., with the provincial government at the ‘center’ and local governments as ‘local units’). However, before making local governments responsible for adjustments, legislators would need to ensure that they local governments have sufficient resources, expertise and accountability mechanisms to effectively and appropriately adjust regulatory requirements.\(^{464}\) Legislators should also assess the value that local input and local control of regulatory adjustments is likely to bring. In this regard, Cristie Ford suggests that we should be cautious of “an unreflective over-embrace of localism and local knowledge.”\(^{465}\) For example, while local adjustments may be more reflective of community expectations, they may not be supported by scientific developments, and local governments may be more susceptible to regulatory capture.\(^{466}\) In summary, while decisions about who is responsible for making adjustments will depend on various factors, I submit that unless there is a substantial restructuring of local government funding arrangements and the

\(^{464}\) Lobel, supra note 135 at 454 (noting that the capacity of stakeholders to utilize newly available information effectively is critical to their ability to contribute to governance processes in a meaningful way).

\(^{465}\) Ford, supra note 130 at 473 (“The assumption that local actors possess the best information seems to have been accepted too uncritically, and applied too sweepingly.”).

\(^{466}\) See, for example, Karkkainen, supra note 207 at 961 (“The playing field may not be level in local arenas; concentrated local interests with an interest in the outcome will often be in a stronger position to influence the decision-making process in their favor.”).
development of expertise among local government building officials, it would likely be more appropriate for a new provincial agency, which has the expertise and resources to gather and synthesize relevant information, to be granted the authority to make regulatory adjustments (as and when required).

### 4.1.2 Getting the right objectives to guide regulatory adjustments

As Annecoos Wiersema notes, “[s]o much focus has been put onto the flexible and adaptive aspects of these new forms of management that the tracks that would guide them have not yet been fully addressed.” As such, clearly identifying and explicitly articulating at the outset what the new regulatory paradigm is trying to achieve will play a critical role in guiding regulatory adjustments and assessing regulatory performance over time. Yet the articulation of regulatory objectives is not a simple task — the challenge is to generate goals that are sufficiently specific so that they can meaningfully guide regulatory adjustments, yet sufficiently broad that they can be generated at the outset in circumstances of incomplete knowledge and information. As a starting point, the transition to a new regulatory paradigm demands a reevaluation of the existing regulatory objectives in order to determine whether the climate will be so changed over the lifetime of infrastructure that existing goals either cannot be achieved or are no longer appropriate, and also whether they may potentially hinder adaptation or be

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468 For example, Holly Doremus et al submit that one of the core elements of an adaptive management approach is explicitly stated goals and measurable indicators of progress toward those goals. Doremus et al, supra note 206 at 2, 8 (“To the extent that statutory goals are, as is so often the case, vague or conflicting, they should be clarified at the outset. In other words, an agency planning or considering undertaking adaptive management should identify what it views as its management goals as well as the metrics it believes will indicate achievement of those goals.”). Also see Williams, supra note 216 at 1348.

469 Wiersema also notes that where regulatory goals no longer reflect the political will of those being governed, they can always be changed through the same process that has generated them, arguing that such change should occur in an open, transparent process allowing for accountability. Wiersema, supra note 467 at 1296.
maladaptive.\textsuperscript{470} Decisions about what the regulatory framework should seek to achieve are fundamentally normative questions, and therefore strong public and stakeholder participation will be critical in setting regulatory objectives and priorities.\textsuperscript{471} In the context of increasing climate impacts, I suggest that the NBCC’s four primary objectives — safety, health, accessibility, and fire and structural protection of buildings\textsuperscript{472} — are likely to remain appropriate, with some likely to take on greater prominence. For example, the objectives of structural safety (which seeks to limit \textit{peoples’} exposure to unacceptable risks of injury due to structural failure)\textsuperscript{473} and structural sufficiency (which seeks to limit \textit{buildings’} exposure to unacceptable risks of damage or loss of use due to structural failure)\textsuperscript{474} are likely to become even more important given the increasing climate impacts that structures are likely to experience over their lifetimes.

Legislators will also need to canvass whether any additional regulatory objectives are required to guide regulatory adjustments that support the adaptation of infrastructure. I suggest that regulatory adjustments should seek to create more resilient, robust and adaptive structures, and therefore these should be made explicit objectives of the regulatory framework. The

\begin{footnotesize}
\textsuperscript{470} That is, whether they may result in actions, or inaction, that may lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future. See Intergovernmental Panel on Climate Change, \textit{supra} note 13 at 857.
\textsuperscript{471} For example, ‘experimentalist’ new governance models typically establish regulatory goals through consultation among the ‘center,’ ‘local units’ and relevant outside stakeholders. See Sabel & Simon, \textit{supra} note 178 at 79.
\textsuperscript{472} Canadian Commission on Building and Fire Codes, \textit{supra} note 5, Preface.
\textsuperscript{473} \textit{Ibid}, Division A, section 2.2, objective OS2 (“The risks of injury due to structural failure addressed in this Code are those caused by: loads bearing on the building elements that exceed their loadbearing capacity; loads bearing on the building that exceed the loadbearing properties of the supporting medium; damage to or deterioration of building elements; vibration or deflection of building elements; instability of the building or part thereof; and collapse of the excavation.”).
\textsuperscript{474} \textit{Ibid}, objective OP2 Structural Sufficiency of the Building (“The risks of damage and of loss of use due to structural failure or lack of structural serviceability addressed in this Code are those caused by: loads bearing on the building elements that exceed their loadbearing capacity; loads bearing on the building that exceed the loadbearing properties of the supporting medium; damage to or deterioration of building elements; vibration or deflection of building elements; instability of the building or part thereof; and instability or movement of the supporting medium.”).
\end{footnotesize}
regulatory framework should seek to produce structures that are resilient; that is, structures that are able to absorb the impacts of climate change and continue to function.\textsuperscript{475} In addition, given that we are unable to confidently predict the range of climate futures that infrastructure will need to withstand during their service lives (i.e., any ‘best guess’ of the future is likely be wrong), the regulatory framework should seek create robust structures (i.e., structures that are able to perform adequately in all — or at least a range of — plausible futures). Given that our understanding about the future is likely to improve over time, I suggest that, where possible, the regulatory framework should seek to produce structures that are flexible and adaptive (e.g., structures that are able to be easily adjusted or enhanced in the future at minimal additional cost).\textsuperscript{476} Finally, these regulatory objectives should be revisited and reviewed over time in order to ensure that they reflect changing values and priorities (e.g., the level of risk that is acceptable to the society).\textsuperscript{477} However, given the importance of regulatory objectives in guiding the development of the regulatory framework, they should not be subject to iterative adjustment by regulators. Rather, they should be developed and revised through participatory, deliberative processes, allowing proposed adjustments to be opened up for debate.

\textsuperscript{475} de Haan, supra note 53 at 921 (“[R]ather than designing our infrastructure systems to function optimally for a forecasted – within error margins – future, we should equip our systems with an ability to keep on functioning when unexpected things happen.”). I note that this conception of resilience is often referred to as ‘engineering resilience,’ and is a narrower concept than ‘ecological resilience.’ For a discussion of the two terms, see supra footnote 53.

\textsuperscript{476} Olsen, supra note 346 at 23. While most structures, by their very nature, are inflexible, the regulatory framework could, for example, support the design of infrastructure in modular units (thus allowing structures to built in phases as conditions change) where possible and appropriate. See de Haan, supra note 53 at 921; Richard De Neufville & Stefan Scholtes, \textit{Flexibility in Engineering Design} (Cambridge: MIT Press, 2011) at 9 (noting that flexible designs fall into three major categories: those that enable changes in size, those that enable changes in function or capability, and those that protect against particular failures or accidents).

\textsuperscript{477} While some may argue that regulatory objectives themselves should be evaluated and reconsidered as part of the iterative cycle, I submit that the adjustment of regulatory objectives should not occur without significant input from the public and stakeholders. Daniel Schramm et al, \textit{Legal and Policy Tools to Adapt Biodiversity Management to Climate Change} (Washington, D.C.: Environmental Law Institute, 2011) at 73–74.
4.1.3 Getting the right information to support regulatory adjustments

Incremental adjustments to regulatory requirements can only occur where learning has taken place, and such learning depends on the information that is available. As such, monitoring is often considered to be the keystone of adaptive approaches, as “without monitoring, there can be no improved understanding of conditions or responses to management actions, and therefore, no informed adjustment of on-the-ground practices.” In particular, the use of triggers and constraints on adjustments are inextricably linked to monitoring. In short, where a framework for monitoring, gathering and generating information — what I refer to as an ‘information-gathering framework’ — is under-funded, ineffective, unreliable or produces information that lacks credibility, it may not be possible to determine whether adjustments are required (including, for example, whether a trigger condition has been met or a constraint has been exceeded) and to facilitate evaluation and learning after decisions are made.

In setting up an information-gathering framework that enables an adaptive regulatory framework to fulfill its potential, the first step will be to identify and acknowledge the information gaps and uncertainties that exist. As Holly Doremus and her co-authors note, “[e]xplicitly identifying information gaps focuses attention on areas where learning would be most helpful. It is also the first step in identifying why information is missing, and how it might be obtained.” While legislators may be inclined to design an extensive information-gathering framework, they need to be conscious of the implications that may follow from a regulatory framework that has intensive information demands. As Bradley Karkkainen notes, doing

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478 Schultz & Nie, supra note 448 at 447, 505 (“The importance of monitoring, and learning from what is found, is what fundamentally differentiates adaptive management from other approaches.”).
479 Ibid at 457.
480 Williams & Brown, supra note 224 at 474.
481 Doremus et al, supra note 206 at 7.
regulation well — or in some cases, regulating at all — requires a good deal of information, and the generation of required information is neither costless nor abundant. Moreover, the burden of acquiring or producing information, and then managing, analyzing, and evaluating that information, typically falls on regulators rather than regulated entities. Accordingly, the availability, accuracy, cost, and timeliness of gathering information can represent a critical constraint on the capacity of regulators to respond effectively. In fact, Karkkainen suggests that these information burdens can sometimes be “crushing, debilitating, or broadly distorting of policy outcomes.” In short, legislators need to be conscious that there is such a thing as too much information, both with respect to requiring substantial information to justify regulatory action, and also with respect gathering too much information that overwhelms regulatory capacity.

In particular, legislators also need to acknowledge that uncertain and inadequate funding can exacerbate these information burdens. As Courtney Schultz and Martin Nie note, “[m]onitoring dollars are often the first to be cut or reshuffled in agency budgets.” Accordingly, legislators should also consider how to reduce information burdens. For example, after considering what funds are likely to be available, legislators should assess the value and

483 Rather, scientific research and data gathering require substantial human and financial resources.
485 Karkkainen, supra note 287 at 270.
486 Karkkainen, supra note 484 at 1412. Also see Lobel, supra note 135 at 454 (“[T]oo much information can be debilitating and counterproductive.”).
487 Uncertain and inadequate funding is one of the most widely acknowledged challenges to monitoring. Schultz & Nie, supra note 448 at 509.
488 Ibid at 510 (“This is partly because monitoring can be expensive. ... Dollars for monitoring must also compete with other agency priorities.”).
feasibility of gathering or producing specific types of information, which should in turn
determine information priorities. Assessments of the value of certain types of information turn
not only on that information’s effectiveness in reducing uncertainties and information gaps, but
also on whether it is necessary to inform regulatory adjustments. As Holly Doremus suggests,
“efforts to gather, distribute, and use scientific information should be tailored to the value that
information has to the decisions being made.”489 Some key questions for legislators to consider
when designing an information-gathering framework include: is full use being made of existing
information? What additional information would lead to learning and improved regulatory
outcomes? What would it take to get that information? For example, while monitoring the
relevant developments in climate science will be essential, research regarding building and
design practices that could improve the resilience, robustness and adaptive capacity of new
infrastructure may also be valuable in improving regulatory outcomes, yet such research is not
currently widely accessible or available.490

While public and stakeholder involvement in the design of an information-gathering
framework is important, legislators and regulators also need to be conscious of the power
dynamics potentially at play.491 In particular, regulatory structures and processes can determine
the quantity, quality, and completeness of information that is available to inform adjustments (as

489 Holly Doremus, “Data Gaps in Natural Resource Management: Sniffing for Leaks along the Information
Pipeline” (2008) 83 Ind LJ 407 at 447. I suggest that in some circumstances it may also be appropriate to approach
this issue from the opposite angle. That is, to first assess what information can be gathered most efficiently and
effectively, which will then determine which aspects of the regulatory framework are subject to adjustment.
490 Institute for Catastrophic Loss Reduction, supra note 70 at 5.
491 John S Applegate & Robert L Fischman, “Missing Information: The Scientific Data Gap in Conservation and
Chemical Regulation” (2008) 83 Ind LJ 399 at 404 (“[P]olitical actors quite deliberately exploit procedural
requirements to assure or frustrate particular decisions by regulatory agencies”).
well as the extent to which regulatory adjustments must be supported by this information), and therefore unless care is taken powerful stakeholders can quite deliberately exploit procedural requirements to frustrate the adaptive capacity of the regulatory framework. In addition, it must be acknowledged that the design of an information-gathering framework is unlikely to be perfect at the outset, and therefore the framework itself should be monitored and adjusted where necessary to improve its effectiveness (although I suggest that it may be more appropriate for such adjustments to take place as part of a participatory, deliberative review on a periodic basis rather than through an iterative process). For example, new sources of information may appear that will facilitate learning, or the cost and/or difficulty of obtaining valuable information may substantially decrease, in which case careful consideration should be given to whether the information-gathering framework should be adjusted to reflect these changes.

Finally, it must be acknowledged that gathering the required information is only the first step in an adaptive regulatory framework. That is, gathering the right information is essential, but having the right information will not, in and of itself, make the regulatory framework ‘adaptive.’ Regulators need to ensure that information is compiled, analyzed and used to improve the operation of the regulation. Without these further steps, even substantial investment in an

492 Matthew D McCubbins, Roger G Noll & Barry R Weingast, “Structure and Process, Politics and Policy: Administrative Arrangements and the Political Control of Agencies” (1989) 75:2 Va L Rev 431 at 440–41 (“An agency that has sufficient resources to generate its own information about the consequences of its decisions, available funds to subsidize the participation in its processes of various poorly organized interests, and a relatively lenient standard for judicial review of its actions (for example, arbitrary and capricious), will be far less dependent on highly organized, well-represented interests than an agency that lacks resources and faces a high standard for upholding its decisions in Court.”).
493 Applegate & Fischman, supra note 491 at 404.
495 Doremus et al, supra note 206 at 12 (“Systematic monitoring to collect … data is essential to adaptive management, but monitoring should not be treated as an end in itself. Data must not sit on a shelf. The learning
information-gathering framework will be of limited utility.\textsuperscript{496} As Holly Doremus notes, “[f]ailure to get useful information to the right people can undermine decisions just as surely as failure to generate information. The same is true for failure to make effective use of available information.”\textsuperscript{497}

\textbf{4.1.4 Getting the right level and timing of public and stakeholder\textsuperscript{498} participation}

In Chapter 2, I demonstrated that the engagement of appropriate stakeholders and ensuring their involvement is considered to be a key step in adaptive processes.\textsuperscript{499} A focus on participation and collaboration is also emphasized in the new governance scholarship, which advocates a move away from hierarchical, top-down regulatory structures to a more collaborative model that seeks to promote mutual accountability among regulators and regulated entities, increasing the need for parties to work together to realize their interests and goals in a mutually respectful way.\textsuperscript{500}

Finding the right level and timing of public and stakeholder participation in the development and implementation of adaptive regulations will be a key challenge.

An adaptive regulatory framework should demand both public and industry stakeholder participation at various stages of the regulatory process, and in particular, when setting up the regulatory framework. Firstly, public and stakeholder participation will be important in setting effort must include systematic and ongoing data interpretation and evaluation, as well as data sharing within and between agencies so that learning diffuses from one action to others.”.\textsuperscript{496} Applegate, \textit{supra} note 482 at 272.\textsuperscript{497} Doremus, \textit{supra} note 489 at 413; Lobel, \textit{supra} note 135 at 454 (“[I]nformation is not worth much if there are insufficient means to use it, sort it, make sense of it, apply it, and upgrade it.”).\textsuperscript{498} While there is no uniform definition of ‘stakeholder,’ the term is often defined in the literature as individuals or groups that have a stake, or an interest, in a particular issue, either because they can affect a decision or policy, or because they will be affected. See Karin André et al, “Method Development for Identifying and Analysing Stakeholders in Climate Change Adaptation Processes” (2012) 14:3 Journal of Environmental Policy & Planning 243 at 245.\textsuperscript{499} See, for example, Williams, \textit{supra} note 216 at 1348.\textsuperscript{500} Lobel, \textit{supra} note 135 at 378–79.
regulatory objectives and priorities. In addition, risk appetites understandably vary, and participatory processes should therefore be used to determine the levels of risk that the community deems to be acceptable in the face of uncertainty, as this will heavily influence the design of the regulatory framework. 501 For instance, precommitment strategies (e.g., triggers, automatic policy adjustments etc) and constraints on iterative adjustments (e.g., limits on volatility and drift) should be developed through participatory, deliberative processes. The use of participatory processes that seek to understand and address public and stakeholder expectations from the outset can help to flesh out the normative aspects of the regulatory framework, bring some legitimacy to the process and empower stakeholders to influence adaptation measures and take appropriate actions themselves. 502 Without such support, there is a danger that an adaptive approach may be used as an “empty symbol” 503 or may become a “smokescreen to cover politically adaptive evasion of agency responsibilities.” 504

While participatory processes can provide a number of benefits during the design of an adaptive regulatory framework, legislators should also be conscious of the potential for powerful stakeholders to dominate and for disenfranchised groups to be shut out or disadvantaged by potential changes. 505 Legislators should therefore think carefully about the criteria that are used to select the stakeholders to be involved in participatory processes (e.g., through an analysis of

502 Fisher, supra note 77 at 320; Lebel, Grothmann & Siebenhüner, supra note 501 at 335–36 (“Empowerment should expand the options, opportunities and quality of local adaptation.”).
503 Doremus, supra note 203 at 53.
504 Ibid at 52–53 (“Agencies can use claims of adaptive management as a ploy to placate demands for environmental protection without actually imposing any enforceable constraints on themselves.”); Doremus, supra note 209 at 80 (“[A]daptive management can be the flimsiest of reeds when the political winds come up.”).
stakeholder influence and interests), as this can have a significant impact on the structure and
success of the framework. Also, in order to help correct political power asymmetries, I suggest
that legislators should consider putting a “thumb on the scales” in favor of more precautionary
adjustments. In addition, legislators will need to closely consider whether participatory,
deliberative processes are appropriate during the implementation phase. As Jan McDonald notes,
choices made in the design and implementation of an adaptive regulatory framework will
necessarily involve tradeoffs between competing interests and values, and therefore “[a] level of
contestation must be expected.” In this regard, resistance from powerful industry stakeholders
is likely to be particularly strong when adaptation measures will be costly or require significant
changes to design or construction practices. As such, while public and stakeholder
participation have the potential to substantially improve the design of an adaptive regulatory
framework (as discussed above), deliberative processes are less likely to be a good mix during
the implementation phase, as they can add a potentially insurmountable barrier to making quick
adjustments in response to new information. This is particularly true of consensus-based
decision-making processes, as parties may not be able to agree on what has been learned or what
adjustments should be made. In short, requiring consensus (or near consensus) with respect to
each iterative adjustment will likely nullify the benefits of an adaptive regulatory framework.

506 André et al, supra note 498 at 252.
30 Harv Envtl L Rev 99.
508 McDonald, supra note 43 at 288.
509 Craig, supra note 16 at 42–43.
510 Doremus et al, supra note 206 at 3; Doremus, supra note 203 at 82–83.
511 Doremus et al, supra note 206 at 3 (noting that even though adaptive management is frequently coupled with
collaborative or consensus-based decision-making, the two are conceptually distinct); Barnett et al, supra note 445
at 1103 (“Local consensus on adaptation decisions is difficult, because within communities there are differences
among people with respect to their awareness of the risks of climate change, preferences for the distribution of
benefits and costs of action and inaction, associations and attachments to places, and hopes for the future.”).
4.1.5 Providing the resources, legislative support and incentives for success

Even where an adaptive regulatory framework is well designed — that is, where it finds an appropriate balance between flexibility and accountability, transparency, and stability; is guided by clear objectives; gathers the information required to facilitate learning and inform adjustments; and adopts participatory, deliberative processes in order to ensure regulations reflect a variety of viewpoints and expertise — it will be unable to make effective adjustments and achieve its regulatory objectives unless it is supported by sufficient human and financial resources, and provides regulators with the authority and incentives to regulate adaptively. First, legislators need to ensure that there is sufficient funding and resources to make learning and regulatory adaptation possible. It must be acknowledged that adaptive approaches will typically require more resources than traditional approaches, as doing it right requires taking the time to carefully set up the system at the outset, ensure that the information-gathering framework provides valuable new information, and periodically reassess and adjust regulatory requirements. As Alejandro Camacho notes, “without sufficient resources directed toward information gathering, monitoring, and adaptation, a regulatory agency is unable to implement adaptive regulatory management.” It must also be acknowledged that learning and adjustment will take time, with the effectiveness of the framework likely to be adversely impacted where regulators need to constantly struggle for funding. Therefore, legislators need to ensure that an adaptive regulatory framework is supported by stable and specifically dedicated funds over the long-term.

512 Doremus et al, supra note 206 at 5.
513 Camacho, supra note 494 at 347. Also see Lobel, supra note 135 at 454 (“[A]bundance in information demands an equivalent abundance in resources and knowledge to apprehend it. … [I]nformation is not worth much if there are insufficient means to use it, sort it, make sense of it, apply it, and upgrade it.”).
514 Doremus et al, supra note 206 at 13.
Regulators also need to be explicitly empowered to make iterative regulatory adjustments, particularly given that an adaptive approach is a substantial departure from existing practices for regulatory development and implementation. As R Edward Grumbine notes, regulatory agencies “have not often been rewarded for flexibility, openness, and their willingness to experiment, monitor, and adapt”, and therefore vague legislative guidance to promote participation and an adaptive framework is unlikely to be sufficient. Instead, legislators should incorporate comprehensive requirements and procedures with respect to gathering information and determining appropriate adjustments to the regulatory framework. Furthermore, the effectiveness of adaptive regulatory framework will likely vary depending on whether it is framed in mandatory or permissive terms.

As Alejandro Camacho and Robert Glicksman note, “if a statute requires an agency to use its adaptive capacity, it is less likely that the agency will respond to budgetary constraints by deferring or giving short shrift to efforts to adapt to change than if the agency has unconstrained discretion to take advantage of its adaptive capacity or leave it lying dormant.” In short, in order to ensure that a regulatory framework actually adapts (rather than simply having adaptive capacity that goes unexercised), legislators should closely consider whether it is appropriate for regulators to have not only the authority, but also the obligation, to manage regulation adaptively.

515 For example, the current 5-year code development cycle and the consensus-based approach to code development are likely to be incompatible with an adaptive approach, as discussed above.
517 Craig, supra note 16 at 65.
518 Camacho & Glicksman, supra note 426 at 82 (“In one sense, requiring compliance with a flexible substantive goal reduces agency discretion, but in a way that minimizes the potential for other factors to derail effective adaptation to change.”).
519 Ibid.
Even when an adaptive approach is possible, regulators may not engage in it fully or effectively, for example, by failing to build in opportunities for learning or making adaptive adjustments.\textsuperscript{520} In this regard, Holly Doremus notes that regulatory agencies do not naturally adopt a learning focus, and therefore, “[u]nless learning is systematically rewarded by the legislature or the highest levels of the executive branch — which is rare — there is little external incentive for agency leaders to buck [a tradition of perpetuating ignorance].”\textsuperscript{521} As such, legislators may need to create incentives for regulators to adopt a learning focus, and also to ensure that any learning translates to appropriate regulatory changes.\textsuperscript{522} In addition, in order to cultivate a truly adaptive and participatory regulatory program, legislators should also consider providing incentives for regulated entities to actively assist in the adaptive process and to contribute to the generation of required information.\textsuperscript{523} By way of example, regulated entities could be incentivized to engage in an adaptive regulatory framework (e.g., participating in deliberative processes, providing information that leads to valuable learning and/or informs regulatory adjustments incentives, etc) through the use of grants or tax credits.\textsuperscript{524}

In summary, turning vague calls for regulations to be ‘flexible’ and ‘responsive’ into reality will not be easy. Nevertheless, I argue that a new regulatory paradigm needs to develop an intentional, structured regulatory framework that is flexible but not formless, and that is supported by clear and explicit regulatory objectives that guide regulatory adjustments, an information-gathering framework that facilitates learning and informs iterative adjustments, 

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\textsuperscript{520} Arnold & Gunderson, supra note 200 at 10437.
\textsuperscript{521} Doremus, supra note 209 at 571.
\textsuperscript{522} Doremus et al note that effective adaptive management requires political courage, and suggest, by way of example, that career advancement should be tied to learning, not solely to ‘bean-counting’ measures of success nor reduction of political controversy. See Doremus et al, supra note 206 at 12.
\textsuperscript{523} Camacho, supra note 494 at 355.
\textsuperscript{524} Ibid at 355–56.
\end{footnotesize}
public and stakeholder participation at multiple stage of the regulatory process that ensure the regulatory framework remains yoked to community values and concerns, and sufficient resources, authority and incentives to optimally implement the adaptive framework.

4.2 Creating networks that encourage learning, sharing and collaboration

While the iterative adjustment of regulatory requirements will play a key role in an adaptive regulatory framework, I suggest that design of resilient, robust and adaptive infrastructure can also be facilitated through a regulatory framework that enables and encourages the development, and widespread adoption, of innovative design solutions. In this section, I argue that this can be stimulated through the development of both formal and informal networks across multiple scales that augment the NBCC’s ‘alternative solutions’ process (i.e., the process whereby engineers and industry stakeholders may develop alternative solutions that provide an equivalent or higher level of protection or performance than the corresponding acceptable solution). As discussed in Chapter 2, in order to facilitate adaptive responses at multiple scales, adaptive governance calls for the development of vertical and horizontal networks across jurisdictions and scales.\textsuperscript{525} In this section, I explore how such networks could potentially be structured to facilitate the diffusion of information, experiences and innovations, and to encourage collaboration in order to increase the development and replication of innovative adaptation solutions. I suggest that networks which support the increased development and use of alternative solutions can be viewed as a form of cooperative and collaborative governance, with industry stakeholders expected and encouraged to participate in the development and diffusion of innovative solutions rather than simply

\textsuperscript{525} Cosens, \textit{supra} note 247.
asserting their narrow economic or political interests. Nevertheless, while I believe that greater stakeholder cooperation and collaboration can facilitate increased development and adoption of innovative adaptation measures, I do not consider that responsibility for approval of alternative solutions should be devolved to industry (e.g., a self-regulatory approach). Rather, government oversight remains necessary to protect public safety and maintain public confidence in the regulatory system.

First, I suggest that an adaptive regulatory framework should develop formal, horizontal networks that provide those responsible for evaluating and approving alternative solutions (e.g., local government building officials) with opportunities to learn from the knowledge and experiences of similarly situated enforcement agencies. As discussed in Chapter 3, at present enforcement officials are given neither sufficient opportunities nor incentives to learn from one another, with information about alternative solutions, and tools and processes for analyzing alternative solutions, rarely gathered or shared. This leads to inconsistent evaluation processes for alternative solutions (i.e., an alternative solution approved in one jurisdiction may not be approved elsewhere), resulting in increased costs and uncertainty for stakeholders and thereby hampering the uptake of innovative solutions. One simple solution would be the development of a centralized repository or clearinghouse of alternative solutions that would provide building officials with the ability to compare and assess proposed alternative solutions against others that have previously been proposed or approved in similar locations and/or contexts. While I do not

526 See Lobel, supra note 135 at 376–79; Freeman, supra note 160 at 2 (“Collaborative governance requires problem solving, broad participation, provisional solutions, the sharing of regulatory responsibility across the public-private divide, and a flexible, engaged agency.”).
527 Camacho, supra note 59 at 7.
consider that previous determinations should be binding (as designs must always be appropriate for the context and location in which a particular structure is located), this would simplify the evaluation process for building officials as building officials could refer to previous determinations as to whether a proposed alternative solution provides an equivalent or higher level of protection or performance than the equivalent acceptable solution. In addition, the systematic collection and analysis of alternative solutions could enable a streamlined process for the approval of alternative solutions that have previously been accepted. For example, the substantial requirements for documentation supporting a proposed alternative solution could be reduced, as the equivalency of the alternative solution has already been demonstrated. In short, the development of horizontal networks between enforcement officials could lead to reduced inconsistency and a less burdensome approval processes, with such changes likely to encourage the increased adoption of alternative solutions.

Second, I advocate the development of vertical networks that collect, analyze and then disseminate details of alternative solutions to stakeholders, hopefully enabling and encouraging innovations developed in one location and context to be adopted and adapted elsewhere. In this regard, the systemic failure to collect and synthesize alternative solutions has adverse implications not only for the evaluation of alternative solutions by regulatory officials, but also for the adoption and development of alternative solutions by engineers and other industry stakeholders. I suggest that this represents a major leak in what Holly Doremus refers to as the

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529 Ronald D Brunner & Toddi A Steelman, “Toward Adaptive Governance” in Adaptive governance: integrating science, policy, and decision making (New York: Columbia University Press, 2005) 268 at 283 (“[A]ppraisals of innovations in one or more decision processes provide inputs to the planning (or more generally, the intelligence) function in other decision processes. Each local community is independent of the others, but as information flows between them, the people involved tend to clarify their common interests at higher levels and to advocate higher-level working solutions accordingly.”).
“information supply pipeline” — that is, it allows useful information to “spill out” before it reaches those who might make use of it. Without that information, engineers are forced to repeatedly re-invent the wheel when developing alternative solutions, unnecessarily wasting time and resources. Conversely, formal vertical networks can help to harvest the experience of successful innovations for others to use in similar circumstances. For instance, an on-line database of alternative solutions could enable engineers to search for and filter alternative solutions on the basis of, for example, location, design component, complexity, etc. While the establishment of such a database should be relatively straightforward given modern information management and distribution tools, it must be acknowledged that simply making details of alternative solutions available does not guarantee that such information will be used, particularly where alternative solutions are likely to result in increased design and/or construction costs. Accordingly, as discussed in section 4.1.5, legislators may need to consider whether incentives should be built into an adaptive regulatory framework in order to encourage the adoption of alternative solutions that will increase the resilience and adaptive capacity of infrastructure.

Third, not only are details of alternative solutions not currently gathered or shared, there is also a prevailing sentiment that additional information is required in order for engineers to fully account for the impacts of a changing climate in infrastructure design. For example, in a 2012 survey of Canadian infrastructure engineers, the majority (74%) responded that they feel

530 Doremus, supra note 489 at 438.
531 Brunner & Steelman, supra note 529 at 281 (“With that experience, such people can proceed on a more informed basis. This is important because the rate of progress in a quasi-evolutionary process depends on the quality of trials. If people are informed, the quality of trials tends to be maintained in adaptive governance because no one knowingly copies a failed alternative without modification. ... At the same time these problems stimulate the demand to be informed about successful innovations. The diversity of trials can be maintained because the communities differ in important respects and because these differences tend to be taken into account in both the innovation and the adaptation of working solutions. The diffusion and adaptation of successful innovations tend to arise spontaneously, without central planning or control.”).
they need more information to address the impacts of a changing climate in their practice.\textsuperscript{532} In this respect, engineers do not typically have time, resources or incentives to seek out up-to-date information about projected climatic changes, the anticipated impacts on infrastructure, or research about innovative design and building practices that could improve the resilience, robustness and adaptive capacity of structures. However, given the wealth of information that is likely to be generated through an information-gathering framework, I suggest that vertical networks (e.g., an on-line database or information clearinghouse) should also be designed to disseminate information that will enable engineers to fully account for the impacts of a changing climate in their designs. However, this information must not only be available in a form that is easily accessible and comprehensible, it must also be used.\textsuperscript{533} Accordingly, while making information easily available may lead to greater numbers of engineers using that information, legislators may also need to consider how to structure networks to incentivize the use of information they provide.

Fourth, in addition to formal vertical networks that facilitate the dissemination of alternative solutions and other valuable information, I suggest that an adaptive regulatory framework should also support the development of informal networks that provide opportunities and incentives for collaborative learning among regulators, engineers and climate scientists.\textsuperscript{534}

\textsuperscript{532} CSA Group, supra note 21 at 12. In fact, 13\% of engineers surveyed identified a lack of information and resources as the \textit{main} reason preventing them from addressing the impacts of a changing climate on infrastructure.\textsuperscript{533} In the 2012 survey of Canadian infrastructure engineers, while 70\% of respondents indicated that a changing climate has already affected or will affect their engineering decisions, only 47\% indicated that they would be likely to seek specific information on a changing climate as it relates to their engineering practice in the next 12 months. \textit{Ibid.}\textsuperscript{534} Camacho, supra note 378 at 1823. Professional bodies often identify a need for greater dialogue and collaboration between the engineering profession, meteorologists and climate scientists. See, for example, Engineers Canada, supra note 46 at 67. Also see Engineers Canada, supra note 4 at 18 (“Professional engineers should work with climate and meteorological specialists/experts to ensure that interpretations of climatic and weather
Few mechanisms presently exist for such learning and collaboration to take place on a large scale. I suggest, for example, that an online database developed to disseminate details of alternative solutions and other valuable information could also be designed to enable the submission of comments and suggestions for further development or adaptation, allowing feedback and collaboration. Further, in order to truly promote regulatory learning, such a database should also include information on both successes and failures. For example, by sharing examples of rejected alternative solutions (and in particular, proposals that were rejected on the basis that there was insufficient evidence to demonstrate that the alternative solution would provide at least the level of performance required by the corresponding acceptable solution), it can allow engineers to collaborate and build on earlier proposals. In addition to providing opportunities for collaboration, making such information publicly available would increase the transparency and accountability of regulatory decision-making with respect to alternative solutions.

It must be acknowledged that the creation and on-going maintenance of such networks would undoubtedly be a challenging and resource-intensive undertaking. Given the limited resources that are likely to be available, I suggest that participatory processes should be used to determine what types of information will be most valuable for regulators and stakeholders and lead to the greatest improvement in regulatory outcomes, with networks then structured so that

considerations used in professional practice reasonably reflect the most current scientific consensus regarding the climate and/or weather information.

As Alejandro Camacho notes, this is information that is rarely shared today. See Camacho, supra note 59 at 66.

Ibid.

Ibid at 69 ("Others have recommended analogous data repositories for environmental assessment data, where the potential to apply modern information technology has been similarly underutilized, but existing databases are far from complete. An administering agency would have to balance the need for an interface and databases that are publicly accessible and easily searchable with the need to ensure that such tools are also comprehensive and adaptable.").
the right information reaches the right people in a form that they can understand and use. Also, as noted above, for networks to operate optimally, regulators and engineers may need to be provided with incentives to actively seek out the information that is available and to generate alternative solutions. Lastly, as with other aspects of the adaptive regulatory framework, the operation and effectiveness of networks should be monitored and periodically adjusted to improve their usage, functionality and utility.\textsuperscript{538}

4.3 Conclusion

In this chapter, I mapped the contours of two regulatory mechanisms that I consider should form the core of a new regulatory paradigm that fosters the adaptation of infrastructure to climate change: an adaptive regulatory framework that is flexible but not formless, and multi-party, multi-level networks that support learning, collaboration and innovation. So, where to from here? Thomas Kuhn notes that while the proponents of a new paradigm may claim that they can solve the problems that have led the old one to a crisis, such claims will rarely be sufficient on their own.\textsuperscript{539} Rather, Kuhn suggests that the transfer of allegiance from one paradigm to another is a “conversion experience”, and “first supporters” of a new paradigm therefore need to “develop it to the point where hardheaded arguments can be produced and multiplied.”\textsuperscript{540} While Kuhn notes that a new candidate for paradigm may have few supporters at first, he submits that:

\begin{quote}
if [the supporters] are competent, they will improve [the new paradigm], explore its possibilities, and show what it would be like to belong to the community guided by it. And as that goes on, if the paradigm is one destined to win its fight, the number and strength of the persuasive arguments in its favour will increase.
\end{quote}

\begin{flushright}
\textsuperscript{538} \textit{Ibid.}
\textsuperscript{539} Kuhn, \textit{supra} note 100 at 154.
\textsuperscript{540} \textit{Ibid} at 158.
\end{flushright}
More scientists will then be converted, and the exploration of the new paradigm will go on.\textsuperscript{541}

In this chapter I have made an initial attempt at defining the contours of a new, adaptive regulatory paradigm in the hope that it will provide a springboard for further exploration and the development of persuasive arguments by other ‘first supporters,’ ultimately, leading to widespread acceptance of the new paradigm and conversion.

\textsuperscript{541} Ibid at 159.
Chapter 5: Conclusion

As Thomas Kuhn explained, paradigm shifts do not occur through some “mystical aesthetic;” they are “conversion experience[s].”\footnote{Ibid at 158. For a further discussion, see footnote 122.} Furthermore, rather than a single group conversion, the transition to a new paradigm is realized through an increasing shift in the distribution of professional allegiances, and will therefore take time and committed effort. The first step in the conversion process is to identify and articulate the serious anomalies that plague the existing paradigm and explain why they constitute a ‘crisis’ demanding a paradigm shift.\footnote{For a discussion of the Kuhnian conception of ‘crisis,’ see footnote 118.} Accordingly, in Chapter 3 I analyzed four ‘stress points’ in the existing regulatory paradigm — a fragmented regulatory structure that constrains the development and implementation of local adaptation measures; inadequate adaptive capacity to keep pace with increasingly rapid natural, scientific and technological change; the inability of existing regulatory methods for dealing with uncertainty to handle the deep uncertainties posed by climate change; and a regulatory structure that fails to foster innovation, sharing, learning and collaboration. I argued that, when viewed together, these stress points represent a ‘crisis’ in the existing regulatory paradigm. Continuing to act as if this paradigm remains valid will lead to more and more structures being designed and built that are vulnerable to failure in the face of a changing climate, which, in turn, increases risks to public health and safety and jeopardizes substantial public and private investments in infrastructure.

While acceptance that the existing regulatory paradigm is in crisis is a necessary precondition for the conversion to a new paradigm, it will not be sufficient to trigger such a shift;
as Kuhn elucidated, a viable alternative must also be articulated and developed.\(^{544}\) In particular, conversion requires the community to have faith that the new paradigm will succeed where the old paradigm has failed.\(^{545}\) In Chapter 2, I reviewed various literatures that should provide the basis for the development of a regulatory paradigm that is capable of responding quickly and appropriately to new knowledge and unfolding realities and that fosters collaboration and innovation. I argued that a new regulatory paradigm should draw guidance from new governance scholarship in the legal literature, and in particular, ‘experimentalist’ approaches, which are intended to enable local variation and adaptation to changing circumstances. While existing new governance approaches do provide valuable guidance, they are not adequate to address the deep uncertainties surrounding climate change, nor do they have a sufficiently structured process for the adaptation of regulation. I suggested that a new regulatory paradigm should be developed through a transdisciplinary approach in which spaces and a common language are created for disciplines to talk to one another, allowing their work to be informed and influenced by these conversations. This can hopefully result in a “fusion” of knowledge and ideas, leading to “an enlarged vision of a subject, as well as new explanatory theories.”\(^{546}\) In this light, I looked to a range of ‘adaptive’ approaches from other disciplines — adaptive management, adaptive governance and adaptive policymaking — that can, and should, inform the design of an adaptive regulatory framework. While I am not, nor do I purport to be, an expert in adaptive management, adaptive governance or adaptive policymaking, this thesis demonstrates that there are advances to be made when ideas and knowledge from these different perspectives are brought together. In

\(^{544}\) Kuhn, supra note 100 at 158.

\(^{545}\) Ibid at 157.

\(^{546}\) Lawrence, supra note 286 at 488–89.
particular, these ‘adaptive’ approaches acknowledge, and seek to respond to, the challenges of
decision-making in the face of a dynamic and uncertain future.

In Chapter 4, I attempted an initial ‘fusion’ of the ideas and knowledge drawn from
various literatures reviewed in Chapter 2. In particular, I mapped the contours of two regulatory
mechanisms that should form the core of a new, adaptive regulatory paradigm that recognizes
and seeks to confront, rather than ignore, the multiple and deep uncertainties presented by
climate change. First, I advocated the development of an adaptive regulatory framework that
adopts a structured, iterative process. In particular, I suggested that such an approach should
adopt precommitments or tipping points that trigger regulatory adjustments, combined with
constraints on which regulatory requirements can be adjusted, and how much they can or should
be adjusted, to reflect changing knowledge and conditions. I argued that an iterative approach
could provide regulatory frameworks with the agility required to respond to, and keep pace with,
increasingly rapid natural, scientific and technological changes, while at the same time providing
some structure in order to maintain accountability, transparency and stability. Second, drawing
on adaptive governance scholarship, I argued that multi-party, multi-level networks should be
developed that facilitate learning, cooperation and collaboration among various regulatory actors
and foster the development of innovative design solutions.

In summary, this thesis sought to explore how one should design a regulatory framework
for infrastructure design that responds proactively and appropriately to the challenges of climate
change. In answering this question, I first demonstrated that tinkering with existing regulatory
techniques and methods will not be sufficient. Rather, appropriately responding to climate
change requires both researchers and regulators to completely revamp the way we think about
regulation — it requires us to reevaluate what we are trying to achieve through regulation, the assumptions on which regulation is based, and the structure and tools of the regulatory framework. Second, in order to combat the anxiety that many researchers and regulators may experience about the wholesale abandonment of conventional approaches and adoption of a new regulatory paradigm, traditional regulation and new approaches should be yoked together in a hybrid approach. In this light, I argued that a proactive response to climate change demands a conversion to a new, adaptive regulatory paradigm with two key features: a structured, iterative process that enables regulation to adapt in response to dynamic and uncertain change; and formal and informal networks of cooperation and collaboration that support the development of innovative regulatory solutions. This thesis has made some first attempts at mapping the contours of a new regulatory paradigm in the hope that it will provide a springboard for further theoretical development. One potential avenue for such future development is the exploration of more sophisticated approaches to characterizing, assessing, and understanding the various dimensions of uncertainty that impact infrastructure design and infrastructure design regulation. This will enable regulators to determine which aspects of an adaptive regulatory framework are likely to be most impacted by uncertainty and should therefore be subject to iterative adjustment and/or increased research and monitoring efforts. In addition, much more work is required to determine how the general ideas I have outlined in this thesis about the structure of an adaptive regulatory framework could be applied in specific regulatory context of the NBCC. Finally, researchers need to consider whether the theoretical development of an adaptive regulatory framework can and should be expanded beyond the context of infrastructure design, and in particular the NBCC.

547 For a discussion of this “new governance anxiety,” see footnote 143.
to other regulatory contexts involving long-term decision-making in the face of a dynamic and uncertain future.

While the design of any regulatory instrument is important, effective implementation is also vital. Accordingly, when designing a new regulatory paradigm, researchers and regulators need to consider the realistic prospects for effective implementation. Given the importance of infrastructure to society, there is a need to understand and appreciate the real world constraints that may affect the implementation of a complex, adaptive regulatory framework and the conditions under which it may fail to operate effectively. In particular, close consideration must be given to whether there are sufficient resources and regulatory commitment to implementation to ensure that an adaptive approach will actually result in improved regulatory outcomes. Holly Doremus and her co-authors submit, for example, that in order to ensure that an adaptive management approach is not applied inappropriately or indiscriminately, an explicit, formalized analysis of the prospects for learning and its expected value for future management actions should be undertaken before deciding to implement an adaptive strategy. They argue that an adaptive approach should only be adopted in circumstances where the improvements it promises over time justify the trade-offs it imposes. When conducting such an analysis, we

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548 McDonald, supra note 199 at 131–32 (“Legislative frameworks may be necessary for some adaptation goals, but they will not be sufficient. Implementing agencies require appropriate resourcing to give effect to statutory mandates, and in some cases a change in institutional culture and management priorities may be required.”).
549 Ford, supra note 130 at 480.
550 See, for example, NeJaime, supra note 133; Kwakkel & van der Pas, supra note 283 at 935.
551 Doremus et al, supra note 206 at 6. Also see J B Ruhl & Robert L Fischman, “Adaptive Management in the Courts” (2010) 95 Minn Law Rev 424 at 442 (“Our concern is whether the agency-implemented a/m-lite is enough of an improvement over the comprehensive rationality assumption of front-end decisionmaking to justify the loss of certainty and transparency. This concern is particularly important because adaptive management is most often invoked as a tool to handle decisionmaking in the face of uncertainty.”).
552 Doremus et al, supra note 206 at 6.
need to be realistic about regulatory capacity. In particular, advocates need to avoid designing a regulatory system that is too complex for actual regulators to implement, as an adaptive regulatory framework that is adaptive in name only is simply an “empty symbol.” By giving the appearance of doing something without actually making any real change, it may be worse than the status quo, as it can diminish political will to take action.

Given that climate change presents an unprecedented challenge, it will often be difficult for researchers and regulators to determine the prospects for the successful implementation of an adaptive regulatory framework. I suggest that there are two empirical sources that may provide support for such determinations. First, one can look to the real-world experiences of other ‘adaptive’ approaches. For example, there has been substantial empirical research regarding adaptive management, although this research has demonstrated that the implementation of adaptive management approaches has failed more often than not. While adaptive governance seeks to address some of the perceived shortcomings in the implementation of adaptive management approaches, further empirical research regarding the successes and failures of adaptive governance approaches in practice is still required. In addition, while the adaptive policymaking scholarship is growing, adaptive policies have seen little practical application to

553 Ford, supra note 130 at 484 (“It may not be possible in all environments, given existing incentives and available resources, to create and maintain meaningful and not just cosmetic new governance initiatives. In other words, we need to consider that new governance will not work everywhere.”).
554 Cristie Ford, “Principles-Based Securities Regulation in the Wake of the Global Financial Crisis” (2010) 55:2 McGill LJ 257 at 299; Ford, supra note 130 at 480 (“[E]ven an optimal regulatory model will not work if it is too complex for regulators to implement.”).
555 Doremus, supra note 203 at 53 (“Agencies can use claims of adaptive management as a ploy to placate demands for environmental protection without actually imposing any enforceable constraints on themselves.”).
556 See, for example, Allen & Gunderson, supra note 236 (articulating nine pathologies and challenges that can lead to failure in adaptive management programs).
557 See, for example, Chaffin, Gosnell & Cosens, supra note 238 (noting that an increased effort to explore case studies of both successful and unsuccessful transformations toward adaptive governance is required).
date,\textsuperscript{558} with the efficacy of these approaches typically argued on theoretical, rather than empirical, grounds.\textsuperscript{559} In short, further empirical, transdisciplinary research is needed in order to understand the challenges that must be overcome in implementing such ‘adaptive’ approaches.

A second potential source of empirical support for the implementation of an adaptive regulatory framework could be through the use of small-scale adaptive regulatory prototypes. Given the importance of infrastructure to society and the fact that design decisions are typically locked in for decades, it is often appropriate for innovative approaches to infrastructure design to be tested and evaluated prior to their wide scale implementation. In this regard, R. John Hansman and his co-authors argue that new approaches to the development of infrastructure systems should be tested through controlled real-world application, such as in the form of research-oriented pilot projects or experiments.\textsuperscript{560} In determining the appropriate scope of such regulatory prototypes, they suggest that “[t]he selection should emphasize situations that will push the methodologies; can be executed, documented, and carefully evaluated; and have high potential payoff from the overall infrastructure viewpoint.”\textsuperscript{561} The implementation of an adaptive regulatory framework as a regulatory prototype could, for instance, be limited to a local government area or to a specific type of infrastructure. The implementation of such a regulatory prototype could be closely monitored, thereby providing opportunities for researchers to discern

\begin{itemize}
\item \textsuperscript{558} Jan Willem GM van der Pas, Jan H Kwakkel & Bert Van Wee, “Evaluating Adaptive Policymaking using Expert Opinions” (2012) 79:2 Technological Forecasting and Social Change 311 at 312 (noting that, to date, adaptive policymaking has been carried out almost exclusively by researchers not by the real-world policymakers or domain experts).
\item \textsuperscript{559} See, for example, R John Hansman et al, “Research Agenda for an Integrated Approach to Infrastructure Planning, Design and Management” (2006) 2:2-3 International Journal of Critical Infrastructures 146; Walker, Marchau & Swanson, \textit{supra} note 281; Kwakkel & van der Pas, \textit{supra} note 283 at 936; van der Pas, Kwakkel & Van Wee, \textit{supra} note 558 at 312 (noting that, to date, adaptive policymaking has been carried out almost exclusively by researchers not by the real-world policymakers or domain experts).
\item \textsuperscript{560} Hansman et al, \textit{supra} note 559 at 157.
\item \textsuperscript{561} \textit{Ibid.}
\end{itemize}
whether the components of the adaptive regulatory framework are operating effectively (e.g., whether the monitoring framework is functioning well, whether the ‘triggers’ are set appropriately to ensure that regulatory adjustments are made when required etc) and are achieving their intended outcomes (e.g., creating more robust and adaptive structures). If they are, it can provide persuasive empirical support for its wide scale implementation; if not, it can help to highlight the implementation challenges, and to guide future adjustments to the framework. While this thesis has demonstrated the common ground between a variety of adaptive disciplines and new governance scholarship, and the benefits that could be realized if these disciplines begin to speak to one another, a truly transdisciplinary approach demands that such conversations also engage with empirical research into the operation of regulatory frameworks and the implementation challenges that they face.

On a final note, it must be acknowledged that the theoretical and empirical development of a new regulatory paradigm will take time, as will the generation of sufficient political and public support and regulatory capacity for the conversion to a new regulatory paradigm. Yet, given the potential consequences of continued inaction, it is not appropriate to simply maintain the status quo (i.e., continuing to design on the basis of historic climate data) until sufficient theoretical and empirical support for the conversion to an adaptive regulatory framework has amassed. While deep uncertainty persists around the future climate that infrastructure needs to be designed for and the actions that should be taken, continuing to design infrastructure on the basis of historic design data is no longer tenable — the precautionary principle urges us to take proactive, proportionate action. Although not ideal, maybe the best that we can do for the time
being is to adopt a less sophisticated approach.\textsuperscript{562} For instance, default or ‘prophylactic’ rules\textsuperscript{563} — “clear and generally overdrawn requirements … which serve as placeholders to protect an important interest until and unless a better, more tailored method for achieving the same end can be implemented”\textsuperscript{564} — could require increased safety factors to be adopted in relation to certain infrastructure loads or locations that are subject to higher climate risks. Although such an approach is crude in its application and inevitably imperfect, it may represent a viable stopgap measure until a new regulatory paradigm can be developed and effectively implemented.\textsuperscript{565} Nevertheless, it must be acknowledged that in complex, dynamic, uncertain environments, prophylactic rules such as increased safety factors do not represent an appropriate long-term response: they simply “paper over uncertainty, forcing difficult interpretations underground—or alternatively forcing rule revisions through legislative processes that are far too cumbersome to be serviceable in “live,” fast-moving systems.”\textsuperscript{566} The effective adaptation of infrastructure to climate change ultimately demands a transition to a new regulatory paradigm.

\textsuperscript{562} See, for example, John C Coffee Jr & Hillary A Sale, “Redesigning the SEC: Does the Treasury Have a Better Idea?” (2009) 95:4 Va L Rev 707 at 782 (arguing that “simple rules typically work better than complex ones.”).
\textsuperscript{563} Christopher H Schroeder, “Rights against Risks” (1986) 86:3 Colum L Rev 495 at 558 (“So long as precise information on risks and their effects remains unavailable or available only at substantial expense (in terms of both cost and regulatory delay), prophylactic rules will continue to be important regulatory tools, though the appropriate precision and detail of such rules for risks need further elucidation.”). While Schroeder uses the term ‘prophylaxis’ or ‘prophylactic rule’ in the context of risk regulation, the term ‘prophylactic rule’ is most commonly used in the (American) legal literature to refer to a subset of constitutional decision rules made by the judiciary — that is, relatively specific, often bright-line rules meant principally to guide lower courts in implementing less determinate constitutional principles. See, for example, Mitchell N Berman, “Constitutional Decision Rules” (2004) 90:1 Va L Rev 1.
\textsuperscript{564} Ford, \textit{supra} note 554 at 298.
\textsuperscript{565} See also, Coffee & Sale, \textit{supra} note 562 at 782 (“Although a prophylactic rule ... has its costs, it is capable of effective implementation, while a more optimal rule (in terms of its theoretical design) may not be.”).
\textsuperscript{566} Ford, \textit{supra} note 553 at 298.
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