MODELLING **RELEVANCE AND VALUE**

Energy Modelling Initiative

Bringing the Tools to Support Canada's Energy Transition

Initiative de modélisation énergétique

Outiller le Canada pour réussir la transition

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Natural Resources Canada / Ressources naturelles Canada
Canada

INSTITUT DE L'ÉNERGIE TROTTIER

POLYTECHNIQUE MONTRÉAL

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Modelling Relevance and Value

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About the Institut de l'énergie Trottier (IET)

The IET was created in 2013 thanks to a generous donation from the Trottier Family Foundation. Its mission is to train a new generation of engineers and scientists with a systemic and trans-disciplinary understanding of energy issues, to support the search for sustainable solutions to help achieve the necessary transition, to disseminate knowledge, and to contribute to societal dialogue on energy issues. Based at Polytechnique Montréal, the IET team includes professor-researchers from HEC, Polytechnique and Université de Montréal. This diversity of expertise allows IET to assemble work teams that are trans-disciplinary, an aspect that is vital to a systemic understanding of energy issues in the context of combating climate change.

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CONTEXT

The mandate for the Energy Modelling Initiative (EMI) has been given by Natural Resources Canada (NRCan) to the Institut de l'énergie Trottier at Polytechnique Montréal (IET), under the leadership of Louis Beaumier (IET), Madeleine McPherson (Institute for Integrated Energy Systems, University of Victoria)and Normand Mousseau (IET/Université de Montréal). Following a workshop organized by NRCan about the "Development of an Open Modelling Platform for Electrification and Deep Decarbonization Studies," in February 2019, NRCan sought to facilitate the adoption of federal and provincial policies that foster the electrification and deep decarbonisation of Canadian energy systems through a nationally coordinated

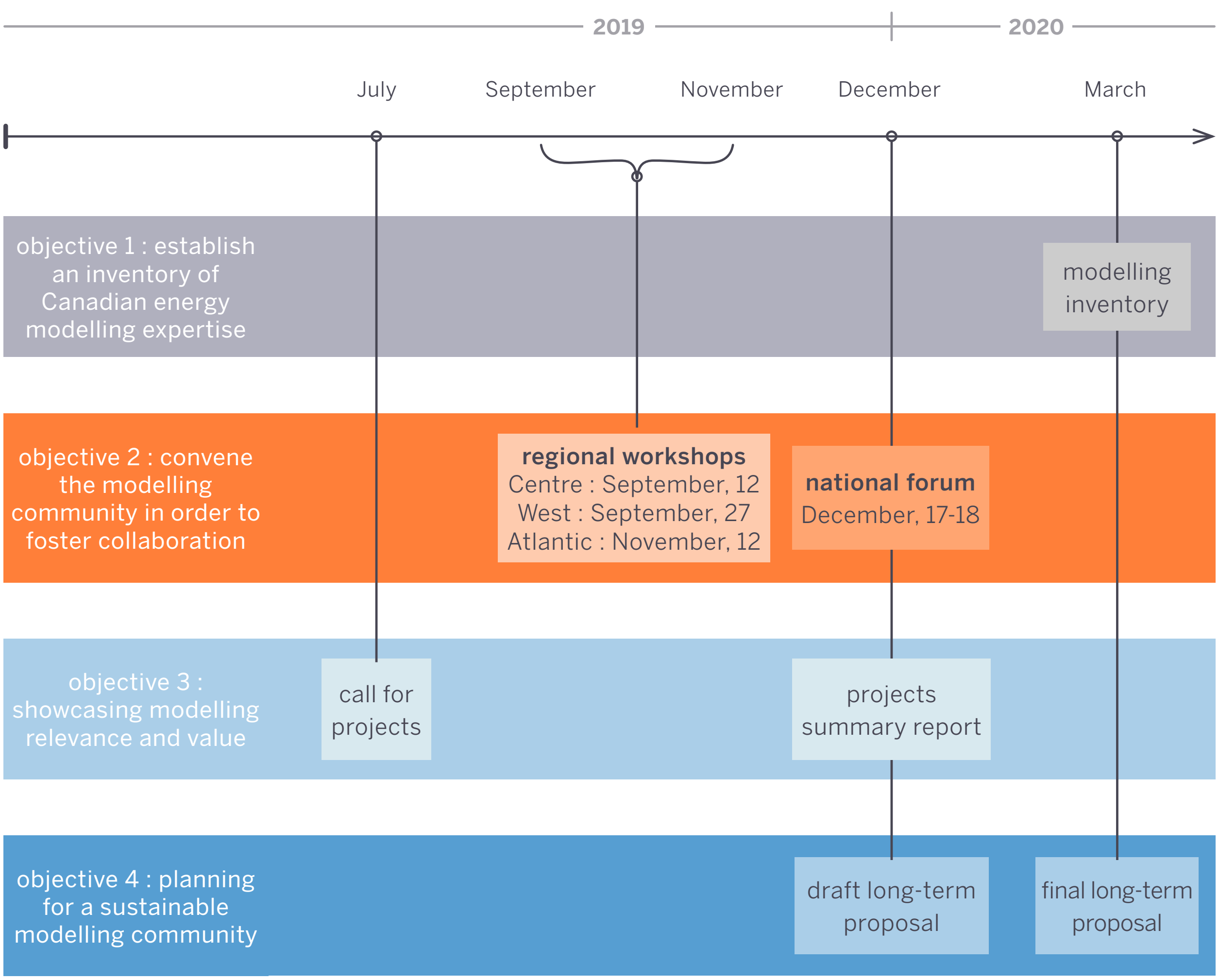

Figure A – EMI's objectives and activity calendar program; a call for proposal was issued to initiate a dialogue with Canadian electricity system modellers and lay the foundation for establishing a modelling network to "support decision making by policy makers and other stakeholders for the transition towards a clean electric future".

The NRCan call for proposal identified the overarching challenge of the initiative: to decarbonize the economy and transform Canada's complex energy systems. Given the lack of an independent institution and research coalition that can advise stakeholders on various aspect of these challenges, NRCan called for a proposal to convene Canadian energy modelling expertise and develop a sustained "Canadian community of electricity system modellers".

In response NRCan's call, the proposal for the EMI has been built around four objectives, each associated with multiple activities (see Figure A).

Since June 2019, EMI has brought the community of modellers together across Canada in three regional workshops with over 150 participants and in a national forum with over 100 participants from academia, governments, NGOs, public services and the private sector.

The resulting proposal for a long-term Energy Modelling Center has benefited from several rounds of consultations and on insights from a broad range of engaged stakeholders. After a year of network facilitation, consultations, surveys and conventions, we are confident that this proposal reflects the positions of a significant part of the Canadian modelling community and a broad range of stakeholders.

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1. INTRODUCTION

Canada has renewed its commitments under the 2015 Paris Agreement to reduce emissions by 30% below 2005 levels by 2030 and to strive to go beyond them. To achieve these goals while maintaining a strong economy and the support of the population, the government must build its policies on the best science available. This means: (1) collecting, producing and releasing relevant, timely and high-quality data; (2) supporting a strong energy modelling capacity to understand the links between sectors, the impact of the transformations taking place and to test policies; and (3) developing appropriate, efficient and acceptable evidence-based policies.

Over the last two years, realizing the gaps in its capacity to deliver on its climate objectives while ensuring a strong Canadian economy as the energy sector worldwide undergoes a deep and rapid transformation, the federal government has created structures to fill these gaps : the Canadian Centre for Energy Information (CCEI) and the Canadian Institute for Climate Choices (CICC). Through these structures, it redresses failings in data production/collection and in the independent development of evidenced-based policies.

However, as this report demonstrates, Canada still needs to address a key element: that is, structured energy modelling. Building on data and feeding into policies, energy modelling has become an essential tool for projection and planning as the world undergoes an unprecedented transformation.

> After creating the Canadian Centre for Energy Information (CCEI) and the Canadian Institute for Climate Choices (CICC), Canada still needs to address a key element for evidence-based policies: energy modelling

Yet for the last decade and more, while other developed countries were strengthening their energy modelling capacities in response to strong perturbations in the energy sector and the challenge of climate change, Canada has moved in the opposition direction, reducing its direct involvement in energy modelling and increasingly subcontracting analysis to foreign consultants.

This approach has undercut Canada's ability to fully understand the social and economic ramifications of key technical transformations and innovations that have impacted the energy sector over the last 15 years, including horizontal drilling, fracking and solar and wind technologies. It has also eroded the efficiency of Canada's earlier climate efforts, contributing to its failure to achieve previous targets.

The following pages will show that Canada already possesses considerable energy modelling expertise, ranging from the technical modelling of buildings to the optimization of the electric grid and the techno-economic evaluation of policies.

This report also demonstrates that although Canada has been laggard in structuring an efficient energy modelling effort that could support its policy making, the above-mentioned expertise is already largely in place. However, these capacities are scattered across the country in governments, universities and consulting firms working in isolation and with limited impacts on policies -- a situation that is costly to Canada but one that can be addressed for the benefit of all, as discussed in the proposal for an Energy Modelling Centre.

2. ENERGY MODELLING

2.1. The emergence of energy modelling

On a global scale, the structuring of energy modelling dates back to the first oil crisis in the 1970s.

Faced with this crisis and a strong increase in energy demand, a number of countries realized that they had to develop an evidence-based understanding of the transformation of this system, its possible evolution over the coming years and its impact on economic and social development (Bahn et al. 2005, Breton et al. 2017, Huntington 1982).

Since then, governments, utilities and many other economic actors have used a wide range of energy models to plan investments, ensure supplies, inform the public and understand the evolution of energy systems.

Most developed countries — including the UK, Sweden and France — and even a number of other large jurisdictions like California have recognized that a strong energy modelling community that can work closely with policy makers is a key element of solid energy and climate change policies (Breton et al. 2017).

Many countries, such as the UK, Sweden and France have recognized the need for a strong energy modelling community.

2.2. What is energy modelling ?

Modelling is the virtual (reductionist) reconstruction of a particular slice of reality for the purpose of analysis. Involving abstraction and simplification, it is particularly useful for experimenting with the conditions of alternative scenarios involving complex systems and projecting possible future realities.

Energy modelling includes a broad spectrum of topics and approaches, covering energy production, transport and distribution, as well as energy use.

Technical modelling focuses on the fundamental and engineering aspects of energy. For example, what type of electrical infrastructure is needed to ensure a specific demand estimated for a region? It also includes various aspects of consumption in buildings and manufacturing and industry, often linked to energy efficiency. In the past years, the definition of energy modelling has been extended to services where energy is a central tool rather than the goal of a sector, with the result that the transport and digital sectors are now often considered part of energy modelling.

Energy modelling includes a broad spectrum of topics and approaches, covering energy production, transport and distribution, as well as energy use.

Given energy's economic importance, techno-economic models have also been developed to try to optimize expenses; for example, in the design of the electric grid, or, more broadly, to understand the impact of access to energy and pricing on the rest of the economy, with bottom-up approaches such as MARKAL and TIMES models, or with top-down descriptions such as the computed general equilibrium method.

More recently, with increased access to supercomputers and, more importantly, access to massive disaggregated datasets, user-based modelling that more discriminatingly incorporates the impact of individual choices has also begun to be deployed. However, its use in policy making is much more limited than the previous approaches.

While each of these approaches has long been developed and applied largely in isolated communities, the pressure of climate objectives that require a serious re-examination of the entire energy sector, from production to usage, is forcing researchers to join forces and search for ways to integrate the various approaches to develop a more comprehensive understanding of rebound and feedback effects, co-developments, etc.

3. ENERGY MODELLING USAGE

Since the oil crisis in the 1970s, developed countries have used energy modelling to plan demand and investments in energy infrastructure and to assess the potential impact of energy prices on their economy through various scenarios. With climate change, many countries have turned to energy modelling to test plans and the potential effect of various policy measures, programs and investments on GHG emissions in order to design efficient pathways to reach their climate objectives. We focus here on two examples close to Canada, either politically and historically or geographically: the UK and California. With solid processes to design and implement measures, these two jurisdictions have managed to reach their objectives repeatedly with no economic backlash, demonstrating the importance of a solid science-based approach to policy development.

3.1. The UK: a rational approach to science-based policies that deliver on climate goals

In the last 15 years in which the UK has been a world leader on climate change, it has systematically met and exceeded its goals as well as developed policies that are becoming the reference for the rest of the world. With strong independent structures and solid governance, the UK leadership on climate was maintained even throughout the Brexit debate.

> The UK and California have managed to reach their objectives repeatedly with no economic backlash by basing policies on strong energy modelling.

This success can be attributed to a political class that has unanimously recognized the need to act on climate change and to the UK's early efforts to build the essential institutions to deliver on data, modelling and policies. We will look here at a two of these institutions and at the role of energy modelling in UK policy making.

3.1.1. The UK Energy Research Centre (UKERC)

The UK government has recognized the importance of maintaining a rich Energy Modelling ecosystem to support a successful energy transition that delivers both on its climate and on its economic objectives, recognition that is expressed through two organizations.

The Energy Research Centre (UKERC) is the main organization responsible for coordinating the maintenance, use and development of different energy system models in the UK. Founded in 2004 and funded by UK Research and Innovation, it aims to assist world-class research into sustainable future energy systems, supporting the work of 70 researchers in a dozen universities. Its current budget, ending its third 5-year cycle, is around 3 million pounds per year. UKERC funding has been renewed for a fourth 5-year cycle from 2019 to 2024. This funding is in addition to grants and other support from various grant agencies and charities. As well as research projects, the UKERC also supports four “national capabilities” that benefit not only the scientific community, but also society as a whole by pursuing evidence reviews, hosting and curating energy data, mapping and monitoring public engagement with energy systems, and improving the transparency and understanding of energy models. These capabilities are:

Evidence for Decision Making – to deliver systematic evidence reviews to inform policy makers and stakeholders on key issues and controversies in the energy policy arena.

Energy Data Centre – to provide a comprehensive showcase of UK energy research and host energy data for users in the public, private and third sectors, ensuring future access to valuable data-sets, and enabling an up-to-date understanding of the UK energy research funding landscape, particularly in terms of activities, their location, inter-relationships and outputs.

Societal Engagement with Energy Observatory – to develop new mapping approaches to generate openly accessible whole-system evidence about energy participation on an ongoing basis; to serve as a platform for stakeholder learning and exchange; and to translate the social intelligence produced to help make zero-carbon energy transitions more equitable, responsible and responsive to society.

Energy Modelling Hub – to curate a comprehensive set of energy models to support policy makers in understanding strategies and trade-offs, and to offer mechanisms to support transparent and replicable modelling; including a review of UK energy scenarios, development of a quality assurance protocol, and participatory engagement with key stakeholders.

These mandates, oriented towards society and the stakeholders, contribute to strengthening the role that modelling can play in building social acceptability for the climate change agenda in the UK.

3.1.2. The UK Committee on Climate Change (CCC)

To help establish this agenda, another independent body was created in December 2008 under the Climate Change Act, the Committee on Climate Change (CCC). This committee was mandated to:

- advise on the appropriate level of the UK's carbon budgets and the steps required to meet them;
- conduct an independent analysis and inform evidence-based debate on climate change and its impacts in order to support robust decision making.

Most of the members of the CCC are university professors and specialists, ensuring a link between the committee and the research community where most energy systems modelling activities take place in the UK. Funded by the Department of Energy and Climate Change (DECC) and the Devolved Administrations, the CCC runs energy models it has developed, although it also uses models developed and maintained by other organizations or mandates organizations to perform modelling work.

3.1.3. Model used

Like most OECD countries, the UK does not rely on a single model or modelling agency. While the CCC modelling efforts support an independent view on the policies and progress towards the GHG goals, the UK government runs its own models, including the Energy and Emissions Projections (EEP) model suite (DBEIS 2019). This suite includes three models: the Energy Demand Model (EDM), which projects demands for various energy sources; the Dynamic Dispatch Model (DDM), which focuses on electricity generation and wholesale prices; and the Price & Bills Model, which projects retail energy prices. These models offer a fully documented public description.[1]

In addition to these institution-based models, the government, through the UKERC, also supports other – mainly open – models, such as the techno-economic UK TIMES models, developed by University College London's Energy Institute and the UK Department of Business, Energy and Industrial Strategy, as well as a large number of technical and sectorial models for building, urban planning, industry and transport.

> Like most OECD countries, the UK used a breadth of models supported internally and externally to facilitate engagement with all stakeholders.

Finally, a number of models, including many at the whole-system level are maintained by private consultants. Together these various structures provide a rich model ecosystem that facilitates exchanges, discussions and the exploration of solutions as the UK leads in its energy transformation.

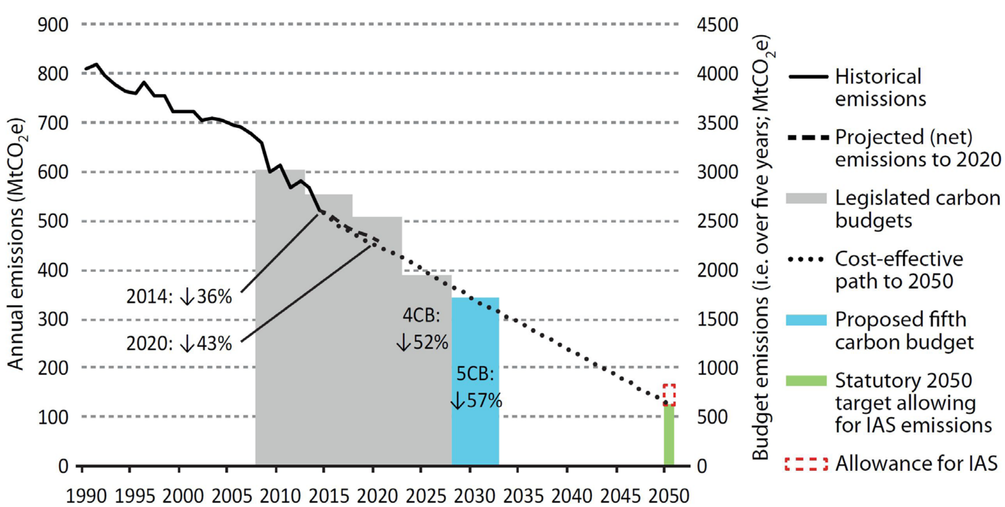
1 Detailed background information on the DDM is available here for example :
https://www.gov.uk/government/publications/dynamic-dispatch-model-ddm

3.1.4. Integration with Policy Development

One of the clearest and most important uses of modelling in the UK's energy and climate policy has been in setting Carbon Budgets. In its first report in 2008, the CCC recommended the first three carbon budgets covering the period from 2008 to 2022. Its proposals were adopted without difficulty by the UK government in 2009.

Although agreement over the CCC's proposal for a fourth carbon budget (covering the period from 2023 to 2027) was not as straightforward, it was nonetheless finally adopted in 2011. The fourth carbon budget emissions level and the identification of pathways to reach it were determined using the DECC Energy Model and MARKAL-UK (CCC 2010). The recommended electricity market reform, also based on modelling results, has been implemented by the UK Government in 2013 (UK Government 2013).

Even if the time period for the fourth carbon budget is still ahead, the fifth carbon budget (for 2028 to 2032) has already been defined since it must be adopted by law 12 years ahead of time. This obligation is to signal the direction in advance, given the time required to develop policies, to grow currently nascent markets, for consumer behaviours to adapt and to invest in supporting infrastructure and innovation (CCC 2016). Establishing the budget such in advance allowed for recommendation to include international aviation and shipping in that fifth carbon budget. The UK Government having agreed with the CCC on the recommended emissions level for that fifth carbon budget ((UK Government 2016) makes for clear demonstration of how central modelling is to decision making.



Source: The Fifth Carbon Budget – The next step toward a low carbon economy. Committee Climate Change, London. (CCC, 2016)

Figure 1 – The recommended fifth carbon budget would continue emissions reduction on the path to the UK's 2050 target

LEADING THE WORLD WITH THE HELP OF ENERGY MODELLING

Energy modelling is at the core of the bold steps that the UK has taken over the last decade, steps that are shaping climate policies worldwide. Models played a major role in the announcement three years ago that the UK would ban the sale of new internal combustion engine vehicles by 2040. Models again brought the UK to move the implementation of this ban from 2040 to 2035, a move that should have a cascading effect on the world scene.

Building on CCC modelling, the UK also passed a law in June 2019 targeting the decarbonisation of heating systems by 2050. This legislation also gives the UK an edge in defining international goals.

Leading with concrete objectives supported by solid plans gives the UK a significant advantage for developing the technology and know-how tied to these profound transformations. It also allows the UK to shape and orient the international debate and goals in a direction that matches its interest. All this is supported by strong energy modelling.

3.2. California: a solid evidence-based approach to ensure long-term planning

Building on decades-old institutions, such as the California Air Resources Board (CARB), which has a long history of modelling-based policy development, California has put in place a solid evidenced-based approach to support its climate-change objectives. The following are some elements that are crucial to this capacity and the use of energy modelling for policy development.

Building on decades-old institutions, California has put in place a solid evidenced-based approach to support its climate-change objectives.

3.2.1. The California Energy Commission (CEC) and California Air Resources Board (CARB)

The relative autonomy of California in the US federal system helps explain the robustness and capacity of energy and climate policy organizations in the state. The CEC is responsible for the biannual Integrated Energy Policy Report (IEPR), while CARB updates a Climate Change Scoping Plan every five years. The two organizations' mandates have become increasingly intertwined with the most recent IEPR stating that "Addressing Climate Change Is the Foundation of California's Energy Policy." In the biannual IEPR, the CEC reports on trends and issues respecting electricity and natural gas, transportation, energy efficiency, renewables, and public interest energy research.

3.2.2. Model used

CARB uses bottom-up and top-down models to evaluate policy options for reducing emissions across all sectors of California's economy: Energy 2020 (bottom-up) and E-DRAM (top-down) (CARB, 2010). In addition, CEC and CPUC have used the PATHWAYS model to develop several scenarios that varied the mix of low-carbon technologies and the timing of deployment (E3, 2017). Significantly, prior to its carbon market linkage with Quebec, CARB had also undertaken modelling exercises (CARB, 2012), following work by the Western Climate Initiative. Reflecting the difference in capacity with Canada, although the Quebec government pursued simple internal analysis, no equivalent modelling exercise was performed.

3.2.3. Integration with Policy Development

The production of a single forecast set in the context of the CEC's biannual IEPR (CEC 2015) is one of the most important applications of energy modelling to policy. It is composed of a baseline forecast and projections for additional achievable energy efficiency savings likely to occur in the foreseeable future, including impacts from future policies. The forecast set forms the basis for a managed forecast to be used for planning purposes in the subsequent year by the CEC, the California Public Utilities Commission (CPUC) and the California Independent System Operator (CAISO). It is also meant to ensure that California customers can rely on an adequate energy supply at a reasonable cost. The CEC has joined forces with CPUC and CAISO to form an interagency process alignment technical team to discuss technical issues and improve infrastructure planning coordination (CEC 2015).

Under the Global Warming Solutions Act of 2006, known as Assembly Bill 32 (AB-32), California is required to develop a comprehensive Scoping Plan to "identify and make recommendations on direct emission reduction measures, alternative compliance mechanisms, market-based compliance mechanisms, and potential monetary and nonmonetary incentives" and achieve "the maximum technologically feasible and cost effective GHG emission reductions." A first

Scoping Plan was adopted in 2008 (CARB 2008) and is updated at least every five years. The most recent update, released in early 2017, maps a strategy to meet California's 2030 emission reduction target (CARB, 2017).

To evaluate the economic impacts of the Scoping Plan, CARB compared estimated economic activity under a business-as-usual (BAU) case to the results obtained when actions recommended in the Plan are implemented. The BAU case was constructed using forecasts from the California Department of Finance, the California Energy Commission and the E-DRAM model. In order to examine the economic impacts of cap-and-trade, California and other WCI partner jurisdictions contracted ICF International and Systematic Solutions, Inc. to perform economic analyses using Energy 2020, a multi-region, multi-sector energy model. However, the scope of sectors and scenarios encompassed by this model is fairly limited.

3.3. The situation in Canada

The following three main federal entities are pursuing modelling activities: the Canadian Energy Regulator (CER), Environment and Climate Change Canada (ECCC) and National Resources Canada (NRCan) (Vaillancourt et al. 2014). The models used are generally employed to forecast trends in energy and GHG emissions. CER has used a combination of commercial models to produce its Energy Futures reports: Energy 2020, an integrated energy model coupled with a macroeconomic model from Stoke Economics. ECCC has used a modelling framework referred to as the Energy, Emissions and Economy Model for Canada (E3MC), based on Energy 2020 and in-house models, to project future emission trends (Environment Canada 2014). NRCan has used MAPLE-C (Model to Analyze Policies Linked to Energy in Canada), an equilibrium model used to forecast energy supply, demand and emissions, although this model is no longer used to provide outlooks, the last dating back to 2006. Internationally, the EIA and IEA also perform energy modelling of Canada's situation when producing global energy outlooks.

While the above Canadian government bodies have acquired a certain degree modelling capacity, it has generally been limited to the production of outlooks based on modelling codes developed and generally run by consulting firms. More advanced modelling competence has been developed at Canadian universities and related consulting firms.

These models have been harnessed in several recent Canadian climate-energy modelling initiatives (ECCC 2016). A 2015 assessment by the Council of Canadian Academies concluded that Canada can significantly reduce emissions by using commercially available technologies and identified many existing technologies that are able to achieve further reductions. The assessment, undertaken by an eight-member expert panel, did not conduct primary research but instead sought to clarify issues that civil society and the private sector are generally unaware of or may be confused about, but which are widely understood and accepted by energy and climate experts and supported by the literature (CCA, 2015). Using an integrated macroeconomic modelling framework (Sawyer and Bataille, 2016), the Deep Decarbonisation Pathways Project identified six decarbonisation pathways for Canada, suggesting that Canada can make significant progress through the decarbonisation of the electricity grid using mainly renewable energy sources, some fossil fuels with CCS, and replacing combustion-based energy sources with electricity in many sectors.

While the Canadian government bodies have acquired a certain degree modelling capacity, it has generally been limited to the production of outlooks based on modelling codes developed and generally run by consulting firms.

The Trottier Energy Futures Project (Trottier Family Foundation, 2016), based on NATEM (a TIMES optimization model run by ESMIA, that includes the entire North American system) and CanESS, looked at 11 different scenarios for Canada to achieve different levels of GHG reductions by 2050 using one optimization model and one simulation model. The main pathways for reducing emissions included expanding the use of non-emitting electricity, increasing the use of biofuels in the transportation sector, and improving energy conservation and efficiency. The more recent Canadian Energy Outlook - Horizon 2050 (Langlois-Bertrand et al. 2018) uses an updated version of NATEM, making it possible to trace the evolution of Canada's energy systems by providing disaggregated results at the provincial levels.

4. THE GROWING IMPORTANCE OF ENERGY MODELLING

For some time, energy modelling was used to develop strategies to ensure that energy supply would meet demand. For example, considerable efforts were dedicated to planning the infrastructures that would deliver in time for the expected growth in electricity demand. This took place in a world where the primary energy sources were relatively stable — conventional oil, coal and gas, hydropower and nuclear — with largely traditional technologies for using this energy, ranging from internal combustion engines to gas furnaces and electric heaters. This was also a time when the choice of energy source was based solely on economic arguments.

Over the last two decades, all aspects of the energy sector have undergone profound transformations, which continue today and are expected to accelerate as the world embarks on an energy transition on an unprecedented scale.

These transformations occur on many levels, bringing the following relationships, feedbacks and challenges that are far from understood today:

- The need to decarbonise the energy sector, and diminish the main cause of climate change, by moving away from fossil fuels, which represent more than 80 percent of all energy production today, forcing the world to redesign its energy sector.
- New economical energy sources, such as shale gas and oil, tar sands, solar photovoltaic and wind-generated electricity, which are introducing new competition and challenging actual business models, putting pressure on major economic sectors.
- The rapidly increasing role of new energy storage technologies, from batteries to hydrogen, which are challenging the alignment between energy supply and demand.
- Rapidly changing consumption habits in transport, IT and decentralized energy production, which are also creating pressure on the system, particularly the electrical system; it remains unknown which investments would best alleviate this pressure.
- The disruption of information technologies, including smart energy use, artificial intelligence and 5G, that perturb many economic models by inserting new players between energy producers and consumers.
- The massive transformation of energy-hungry sectors, from transportation to construction, which will perturb economic sectors distant from production.
- Finally, and crucial for Canada, the fact that all regions of the country will be affected not only differently but also at different points along the transition, requiring a

sophisticated and geographically specific understanding of how to best orient and leverage this transformation.

Even taken individually, it is hard to understand how these transformations will impact investments, services, jobs and other aspects of our lives through a qualitative analysis. When taken together, their integrated impact on our society is simply impossible to assess without solid modelling that can focus either on specific aspects of these transformations or on across-the-board technical, economic or techno-economic analysis. Such information is crucial to ensure the development of the most relevant policies, the selection of the best investments and the accompaniment of those who will be most affected by the changes.

Even taken individually, it is hard to understand how the transformations of the energy sector will impact investments, services, jobs and other aspects of our lives. When taken together it is impossible to assess their impact without solid modelling.

Most importantly, energy modelling does not only facilitate identification of the appropriate reaction to changes on the regional, national and global scale, it also fosters a proactive positioning, indicating where bold steps can be implemented with maximum benefits, as demonstrated in the UK for example. Solid energy modelling will support the development of efficient regulations and legislation and the design of the most promising pathways to reach the objectives in a way that recognizes the rich economic, geographic and cultural diversity of Canada.

MODELLING EFFORTS TO FURTHER SUPPORT DECARBONISATION OF THE ELECTRICAL GRID

Even though the Canadian grid is one of the most decarbonised on the planet, further emission reductions are required to meet Canada's climate targets. Adding renewable capacities is only one element of the solution, for which there are still many unknowns. A recent report from the David Suzuki Foundation (Green 2019) lists a number of unanswered questions about the role renewables can play in advancing electrification:

- How might the set of technologically and economically optimal solutions be constrained by social and environmental values?
- Where and when is electricity generation capacity needed?
- Can energy efficiency and new business models that offer innovative approaches to meeting the need for energy services make a sizeable dent in our appetite for energy?
- How can the existing system be optimized to accelerate the transition?
- What zero-emissions energy source should be built?
- What role might generation with CCS play?
- What are the potential energy savings created by using smart growth principles to plan our communities?
- What pre-commercial technologies offer the most promise?
- How will the energy needed for commuting evolve as autonomous vehicles become more common and work life adjusts to increased automation?
- What future investments in storage and transmission are needed?

It is difficult to provide a definitive answer to any of those questions. Although some modelling efforts are already providing elements of answers, more advanced modelling, from the municipal to the national scale, is expected to better support decision making and the optimization of investments in infrastructure, as disruptive technologies and emerging behaviour changes have to be taken into consideration (see following box).

THE CHALLENGES OF ENERGY MODELS

No single modelling tool can capture the complexity of the energy sector from production to consumption. Energy models therefore cover a wide range of scale, sectors and issues. The following is a brief classification of the various aspects that can and must be covered by energy modelling.

SCALE

Modelling can take place on various scales, from individual elements — buildings, energy production units — to complete systems — cities, the electrical grid. It can also cover various geographical or sectorial scales. This division has been taking place since the inception of the field.

While most government-led modelling activities are national in scale, there is still a need to include local considerations since many energy-related transformations are local in nature. For example, the increasing number of electric vehicles and the integration of distributed energy resources at the customer level are impacting the electrical grid at the distribution level.

Similarly, city-scale transformations can play a key role in energy demand and must be considered in policy development. Since these urban planning decisions are location-dependant, they require modelling at the city or regional level.

DEMAND MODELLING

As demand is rapidly transforming under social and technological pressures, there has been much interest in the last few years in developing models to capture the demand beyond the standard universal assumptions. This endeavour is greatly assisted by access to finer data.

In the electricity sector in particular, the evolution of demand cannot be a simple projection of the past. For most models, demand is exogenous, but new technologies make demand a dynamic parameter of the system. Given that the most immediate consequences are short term and local, thus affecting grid operation, it is also necessary to model demand evolution on a broader scale to take it into consideration in planning activities.

DISRUPTIVE TECHNOLOGIES

It is extremely difficult to model disruption because it tends to be unexpected by default. However, it is essential to capture these disruptions to ensure that investments and policies are most relevant to the reality on the ground.

Many of the disruptions affecting the electrical grid will come from electric vehicles: they will represent variable loads, both in space and time. When connected to the grid they act as storage devices that could be used to balance the grid or participate in a demand response program to reduce demand peak. In any case, they will change the demand profile in yet unforeseen ways.

The integration of distributed energy resources is also affecting network operation at many levels, making it less predictable with variable production capacities, from the production stage all the way to the distribution stage, where power flow will no longer be unidirectional, possibly affecting transformer life expectancy and ultimately asset management.

The challenges are on the short term (network operation), mid-term (use and integration of storage), and long term (capacity expansion planning, business model, etc.)

5. ENERGY MODELLING EXPERTISE IN CANADA

Over the last 10 to 15 years, internal modelling efforts at the federal level have decreased considerably. For example, Canada' Energy Outlook produced by Natural Resources Canada ceased publication after 2006 (NRC 2006). The federal government has also been increasingly relying on foreign consultants for its main model (Energy 2020), thus limiting its capacity to explore various scenarios, control the inputs and validate projections.

Nonetheless, Canada has strong and diverse energy modelling expertise and capacity, which, with some structuring, could contribute much more significantly to policy making as the country embarks, along with the rest of the world, on a major transformation of its energy system, economy and society to meet the challenge of climate change.

Canada has strong and diverse energy modelling expertise and capacity, which, **with some structuring**, could contribute much more significantly to policy making.

5.1. Modellers and models

A wide variety of actors, including academia, governments, utilities, regulators, and consultants, perform energy modelling in Canada. The current structure of the field reflects a relatively organic development: many practitioners work in fairly small communities that developed independently for disparate ends and do not greatly interact with each other.

In March 2019, Natural Resources Canada called for proposals to lay the groundwork for an energy modelling network that could support decision making by policy makers and other stakeholders in energy transition. The mandate of the resulting Energy Modelling Initiative (EMI) included mapping the landscape of energy modelling and related expertise across Canada.

Accordingly, the EMI's deliverables and tasks have been designed to respond to the need to build and mobilize the community to converge the expertise towards applicable approaches in political and economic decision making. These deliverables include identifying and synthesizing the most relevant projects and building an exhaustive inventory of the expertise in Canada.

5.1.1. A rich and solid modelling capacity

The first expression of the breadth and depth of Canadian energy modelling expertise was reflected in the attendance at the various convening events organized across the country and the responses to the inventory survey that was conducted.

The variety of stakeholders participating in these events emphasizes the value of building an inventory of modelling development expertise and potential users. Maintaining this inventory should help coordinate the network and encourage collaboration. One of the few points of clear consensus among participants in the three regional workshops and most sections of the national forum was the need for a structure (1) to act as a "matchmaker between modellers and users" and therefore, in "de-silo-ing" the modelling community and other energy stakeholders and (2) to provide much needed support for model maintenance, distribution and training.

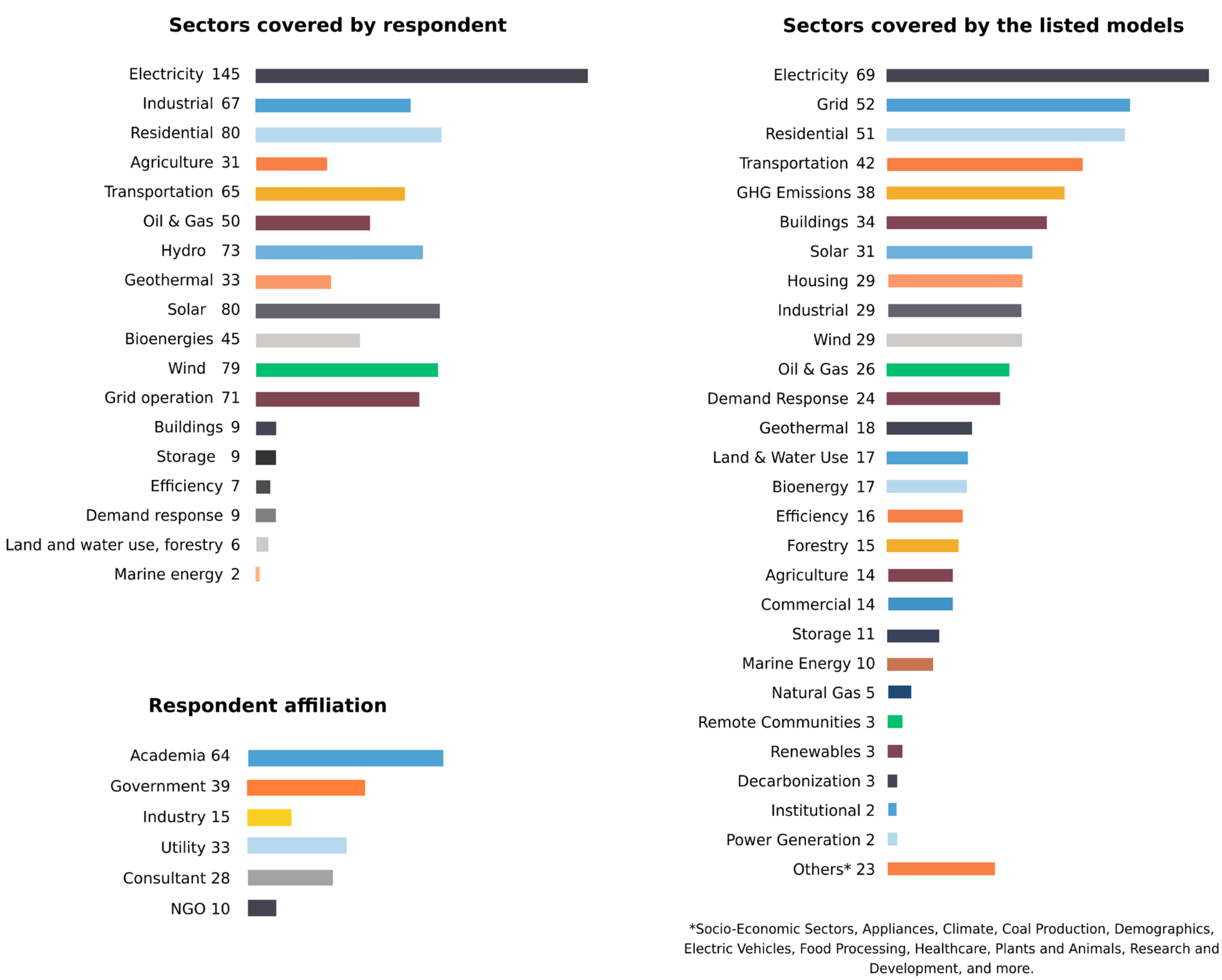


Figure 2 – Inventory Overview

5.1.2. Funded modelling projects

EMI's modelling project component confirms the wealth of Canadian energy modelling expertise. Despite a budget to fund only 10 projects, 43 proposals were submitted in response to the call for proposals in mid-June 2019, with only a three-week window. These figures exceeded initial expectations given the short timeframe for putting proposals together, as well as for project executions and the amount of money granted.

The range of proposals received reflects the rich and fertile landscape of Canadian energy modelling. Although funding was available for only 10 projects, 13 reports, one voluntary project and two non-eligible for funding (as executed by government organizations) were received. See Appendix A for more information.

Selection was difficult given the quality of the proposals. The projects were selected based on their potential to contribute to political and economic decision making, to address critical decarbonisation issues, or to help design innovative solutions, synergies and benefits beyond the sole energy transition, as well as to show the breadth of modelling capacity in Canada.

Below we regroup some of the projects under three themes to illustrate the Canadian modelling community's potential for complementarity to address different aspects of a greater problem, each being of interest to different stakeholders and delivering essential and strategic information to policy analysts and policy makers.

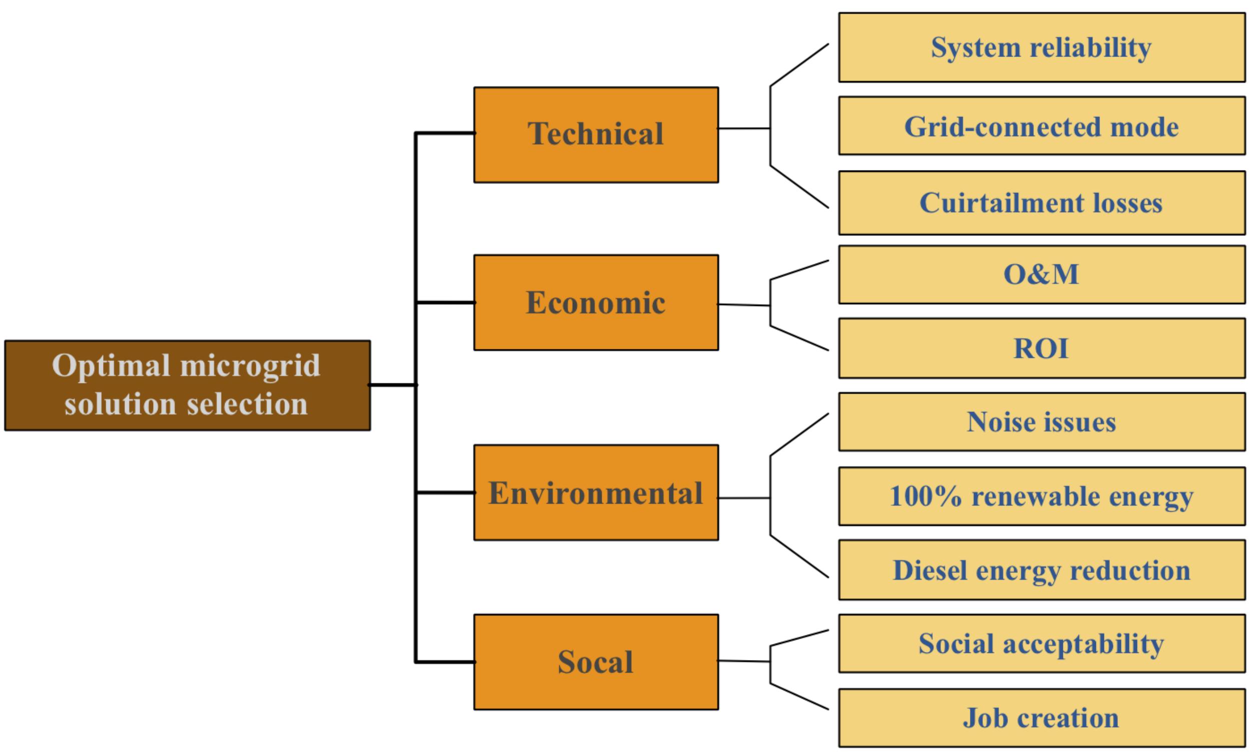
Microgrid, smartgrid and the decarbonisation of remote communities

One of Canada's unique problems is serving its remote, off-the-grid communities, particularly indigenous communities. These communities primarily rely on electricity from diesel generators which, given their cost and the pollution they generate, limit these communities' potential growth (Knowles 2016). The federal government has been committed to reducing this reliance as part of the Pan-Canadian Framework through several programs and has committed to invest $220 million over six years (Infrastructure Canada 2018, p.7). Energy modelling can support these efforts by facilitating implementations that maximize the benefits and optimize the transition process; three projects submitted to EMI have proposed attractive solutions.

One of the main obstacles for integrating renewable energies in remote communities is the extreme weather in the Canadian Territories, which poses a challenge to the deployment of renewable energy generation capabilities. One selected project, entitled "Modelling of Remote Diesel-Based Power Systems in the Canadian Territories," submitted by Yukon College, can test the resilience of the network and, more importantly, determine the minimum diesel backup infrastructure needed to ensure energy security for the Northern population.

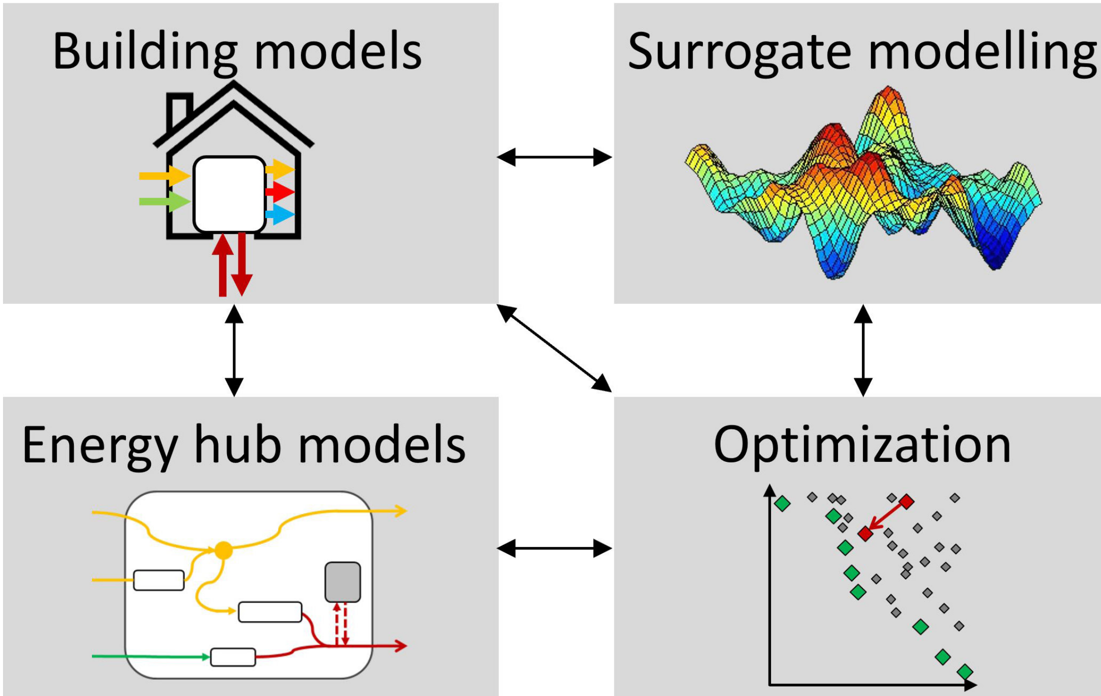
Another project, submitted by the University of New Brunswick, entitled "Smart Microgrid Solutions to Reducing Fossil Fuels Dependence in Canada's Rural and Remote Communities," moves a step further with a modelling platform for optimizing decisions for integrating renewables in smart microgrids. This would entail minimum costs and a maximum return on investment to ensure that the taxpayer money invested by the government has the maximum effect and achieves the greatest efficiency in serving the remote communities.

Finally, a voluntary project submitted by graduate students at the University of Victoria, entitled "BESOS – an Expandable Building and Energy Simulation Platform," offers a model for estimating electricity use at the design stage for new residential buildings, coupled with the volume of renewable energy generation and storage, which allows for the maximum energy independence of units and reduces uncertainty in the grid. Together, these three modelling projects can offer outstanding solutions to ensure energy security, minimum reliance on diesel generators and maximum utilization of renewable energies to reduce emissions, while bringing state-of-the-art technologies to Canadian remote communities. Considering that most participants in EMI events emphasized and agreed that indigenous communities should be among the key stakeholders in this initiative, such projects offer extraordinary value.



Source: Smart Microgrid Solutions to Reducing Fossil Fuels Dependence in Canada's Rural and Remote Communities. EMI Project Report (Cao 2020). https://emi-ime.ca/wp-content/uploads/2020/02/UNB_Cao_Smart_-Microgrid_Solutions.pdf

Figure 3 – Hierarchy of Criteria for Microgrid Feasibility Assessment2050 target



Source: BESOS – an Expandable Building and Energy Simulation Platform. EMI Project Report (Faure et al 2020). https://emi-ime.ca/wp-content/uploads/2020/03/UVic_Faure_BESOS.pdf

Figure 4 – An overview of the main functionalities of BESOS, an integrated modelling platform

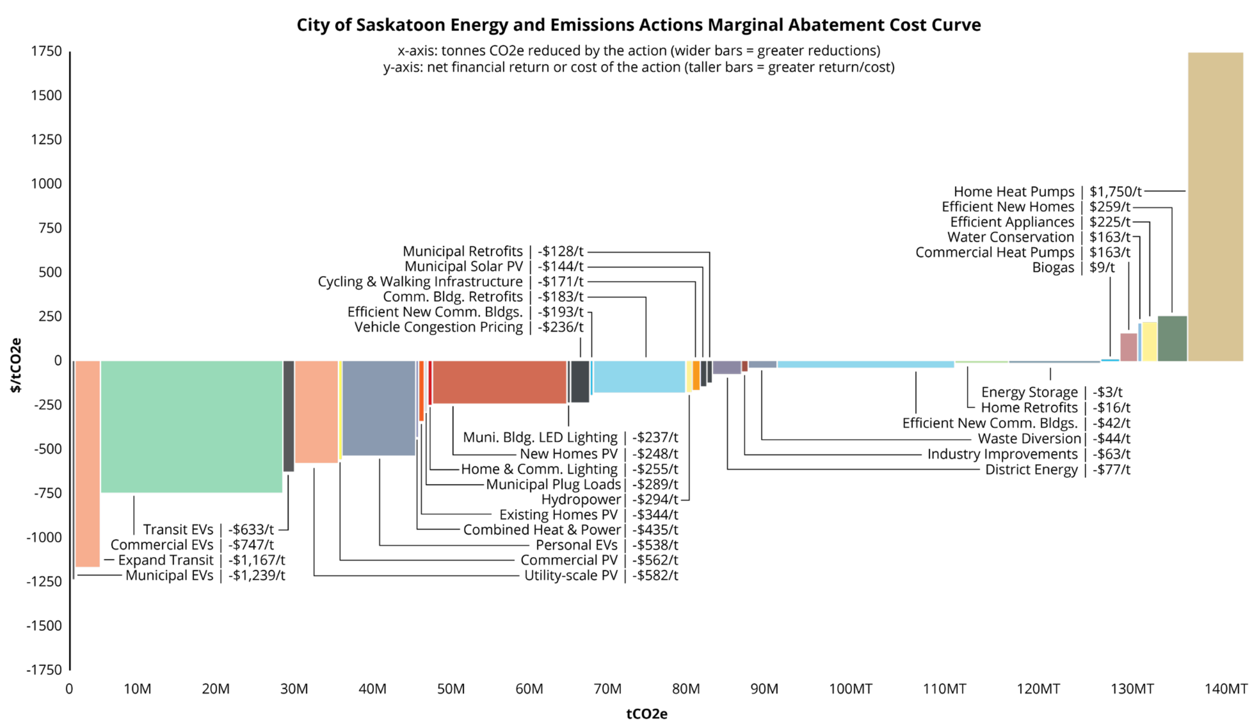
City-level modelling to improve urban planning

The municipalities constitute another stakeholder category that is well-positioned to benefit from better coordinated modelling efforts, as participants repeatedly mentioned and emphasized. As the amount of energy consumed in urban centres rises, cities become important target areas of intervention for energy transition. Initiatives such as the electrification of transportation, expansion of public transit and energy efficiency in buildings have been widely popular in the municipalities' political toolbox.

On the one hand, municipal governments do not have the full jurisdictional control needed over all these sectors to be able to enforce policies. On the other, existing energy-economy models tend to lack a spatial dimension, making it difficult to address many of the actions targeted by such policies. Although models exist at the city level, they are relatively less advanced than subnational and national models (Keirstead et al. 2012). Two of the projects submitted to EMI have set benchmarks for the kind of modelling that could best inform municipal policy planning.

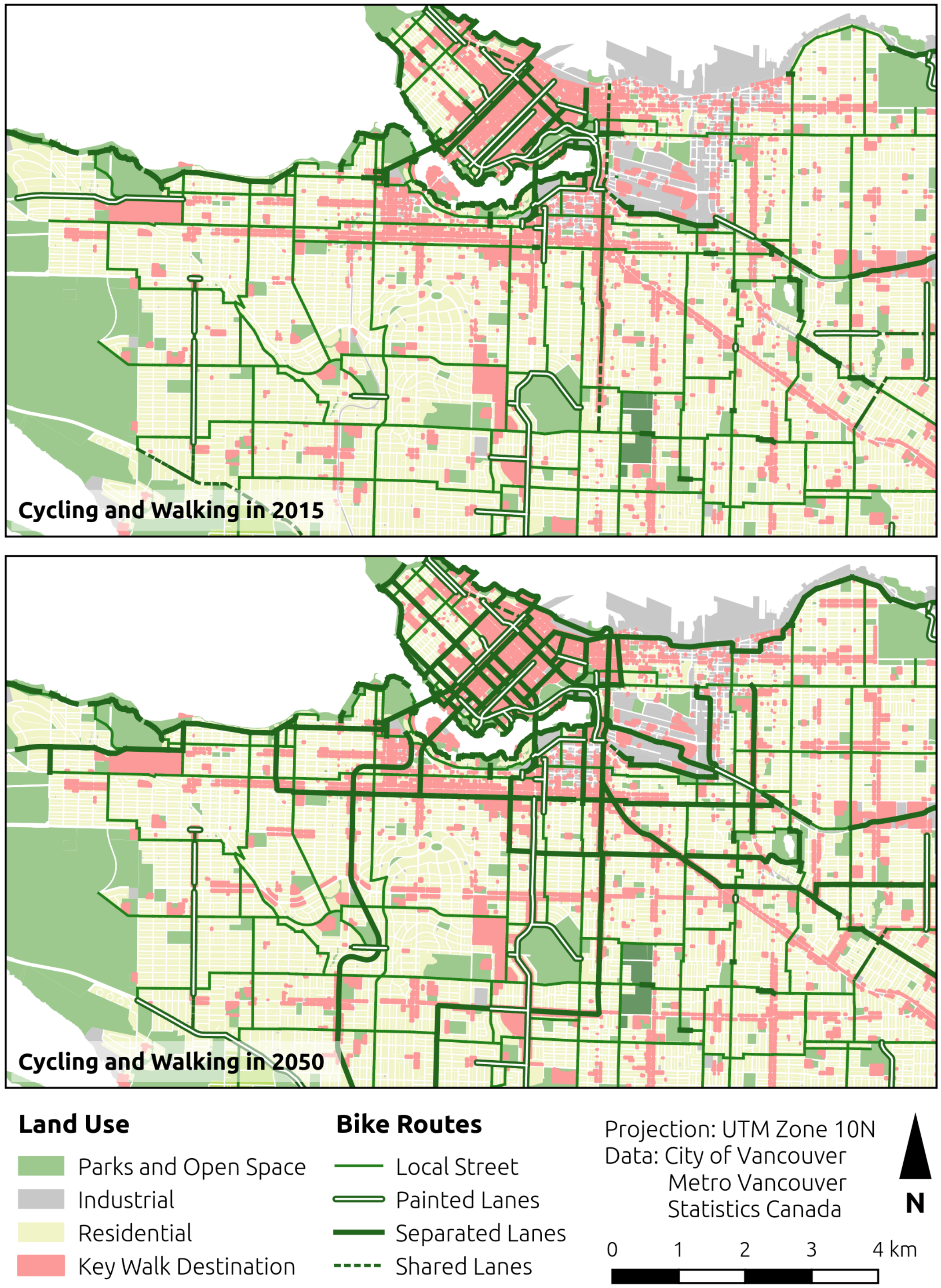
First, the "Modelling urban climate mitigation in Canadian municipalities" project, submitted by Sustainability Solutions Group, provides a sophisticated and visually oriented model that helps cities evaluate the impact of urban policy strategies (e.g. microgrids, zoning, transportation) on the financial decision making of households and businesses based on their cost and saving potentials. This model has already been deployed in municipalities of all sizes across Canada (from populations of 8,000 to 2.8M) and thus represents current best practice for supporting municipal climate action plans. Most notably, the Toronto City Council used an analysis based on this model to unanimously adopt the TransformTO report, which lays out a solution for reducing emissions by 80% by 2050. The following figure illustrates the GHG emission reduction potential of each action evaluated across the x axis and indicates whether that action results in costs or savings (negative) on a per tonne basis.

Second, the "Interactions of policies acting at the local, subnational, and national scales for Canada's energy transition" project, submitted by Simon Fraser University, offers another urban spatial model of energy use and GHG emissions. The outstanding feature of this model is that it allows the assessment of the effectiveness and costs of urban policies (e.g. public transit, land use) in light of provincial and national policies for GHG emissions. Furthermore, it can capture the unobserved cost and benefits that influence energy decisions of households and firms. The modelling tool used, which combines an energy-economy model with an urban land use and infrastructure model, has tested how the interaction of policies can affect urban energy use and GHG emissions in the city of Vancouver.



Source: CityInSight - Modelling urban climate mitigation in Canadian municipalities. EMI Project Presentation (Herbert et al 2020). https://emi-ime.ca/wp-content/uploads/2019/12/P08_-Herbert_Spatially_Resolved_Modelling_of_Energy_and_Emissions.pdf

Figure 5 – GHG emission reductions strategies vs. their cost/saving potentials for a municipality



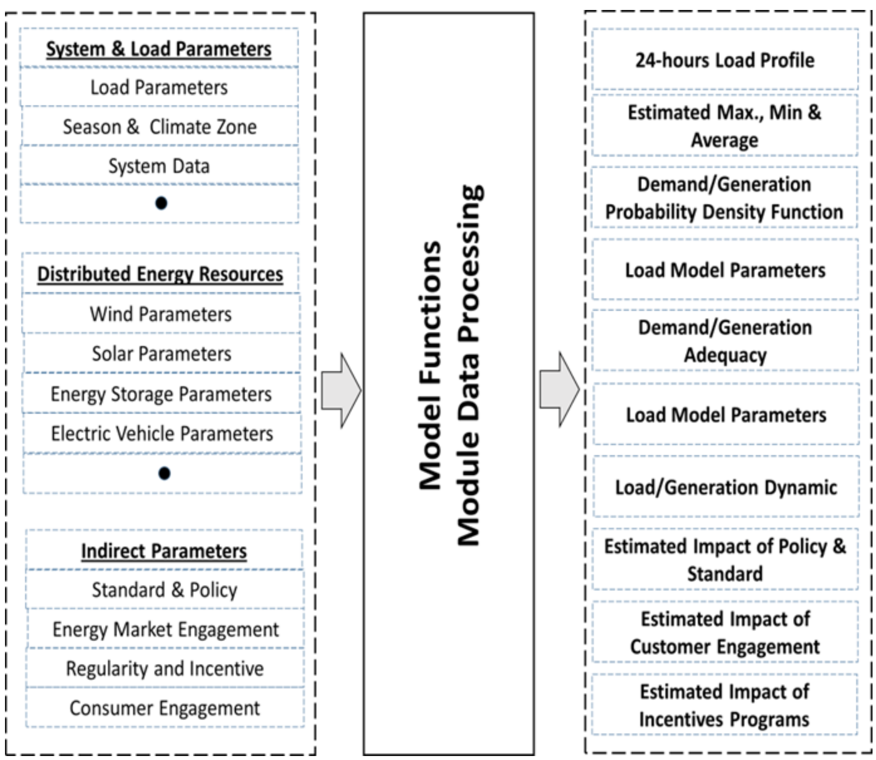
Source: Interactions of policies acting at the local, sub-national, and national scales for Canada's energy transition. EMI Project Report (Murphy et al 2020). https://emi-ime.ca/wp-content/uploads/2020/02/SFU_Murphy_Jaccard_Griffin_Pardy_Budd_Interactions_Of_Policies_At_Different_Scales-1.pdf

Figure 6 – Vancouver's land use pattern and cycling network under the city's Renewable City Strategy

Revisiting grid operations at the community level

Electricity utilities (including producers, distributors and other system operators) form another key stakeholder group, as emphasized at the EMI national forum. Traditionally, utilities have been the organizations that have most heavily invested in in-house modelling expertise, although they have also collaborated with external modellers. This sector is one of the most challenged given the disruptive technologies affecting it at all levels and in ways scarcely considered up to now. Two of the funded projects address some of these issues.

The first, entitled "A Cluster-Based load Model for a Resilient and Sustainable Community," submitted by University of Waterloo, can be used to increase the resilience and suitability of a community grid during severe climate conditions through robust resource and capacity planning, with the potential collateral benefit of increasing customer loyalty. The model's unique approach allows utilities to delay infrastructure expansion by improving demand management measures. Through its sophisticated functions and comprehensive modules, it can also optimize energy mix strategies, as well as the location placement of community solar and storage systems and their penetration limitations.



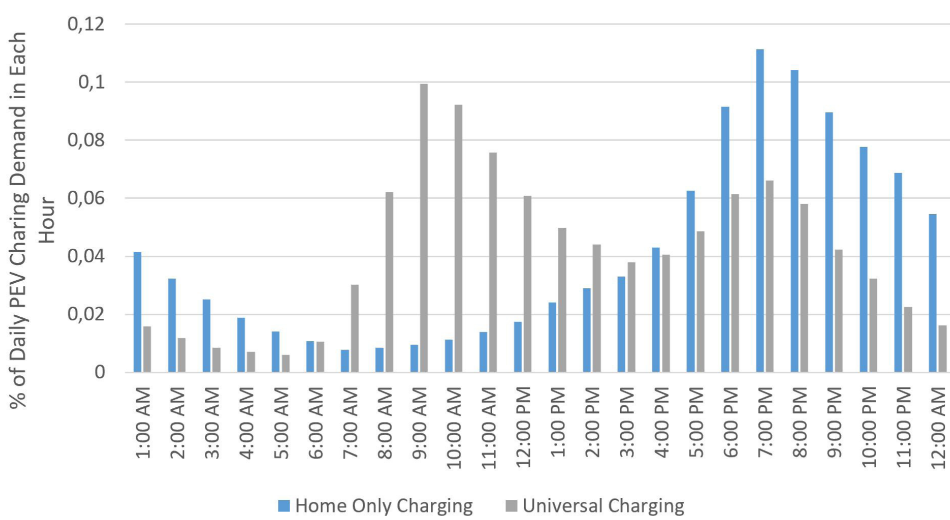
Source : A Cluster-Based load Model for a Resilient and Sustainable Community. EMI Project Report (Salama et al. 2020). https://emi-ime.ca/wp-content/uploads/2020/02/UWaterloo_Salama_Gouda_A-cluster-based-load-model-for-a-resilient-and-sustainable-community-1.pdf

Figure 7 – Modular representation of input/output relations in a cluster-based load model

The other project, entitled "Modeling Increased Electric Vehicle Charging Demand in Quebec," submitted by IQCarbone, is a compelling example of how useful models can be deployed to new datasets to broaden the range of their value. It uses data from the Ministère des transport du Québec within a model initially designed for the northeastern USA. It offers highly resolved, time-of-day specific electric vehicle charging demand scenarios in Quebec, which can be used to plan renewable energy utilization for vehicle charging or to identify optimal periods for this charging. It can be used not only to inform capacity investment decisions, but also to establish new infrastructure depreciation factors by exploring the impact vehicle charging has on transformer aging at the microscale.

These projects offer just a glimpse into the kinds of models that are already available in Canada and can be utilized to inform policy design and economic decision making by a broad range of actors. There were many more projects with great potential for which funding was not available and many others that have been captured by the inventory and have yet to be introduced. They make a case for energy modelling expertise in Canada as a fertile ground that needs to be cultivated and harvested to reduce the reliance on foreign expertise and obtain better results tailored to the Canadian reality.

The richness of Canada's energy modelling potential also sheds light on an important fact: the gaps in the current use of modelling as a decision-making tool are not so much the result of a lack of expertise, but rather of the lack of a coordinating body to leverage them. In addition to optimized climate change related action, a coordinated approach to modelling could lead to synergies creating added socio-economic value.



Source: Modeling Increased Electric Vehicle Charging Demand in Quebec. EMI Project Report (Purdon et al 2020) https://emi-ime.ca/wp-content/uploads/2020/02/Iqcarbone_Purdon_Bahn_Modeling_Increased_Electric_Vehicle_Charging_Demand_In_Qc.pdf

Figure 8 – Distribution hourly EV charging demand per day, for different charging station scenarios in Quebec

5.2. The ecosystem

Currently, the ecosystem of energy modelling in Canada can be described as an organic field of activities and stakeholders that has grown out of isolated operations and collaborations rather than as a coordinated structure strategically designed to achieve national and provincial targets. As such, stakeholders can be grouped into the following four general categories.

5.2.1. Modellers

Modellers are actors that develop and maintain energy models. A significant number of modellers work within academia as professors, students and research associates. Modellers can also be found in the private sector, acting as consultants working either independently or in association with other modellers in consulting enterprises that serve a broad range of customers, ranging from government organizations (municipal, provincial, federal) to businesses, industrial organizations and utilities. Many utilities and some government organizations also maintain in-house modelling staff, which operates models that are immediately relevant for their work.

Academic modellers, which comprise the majority of energy modellers, mainly work on developing cutting-edge models due to the incentive structures of academic funding. These models incentivise model development

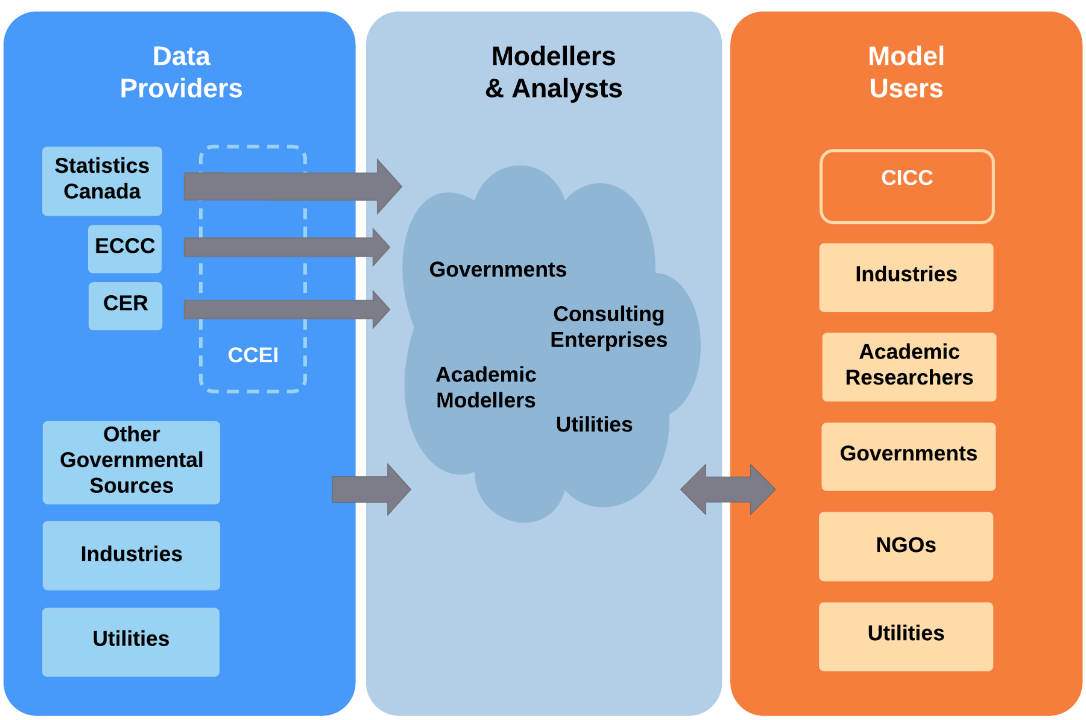


Figure 9 – The current energy modelling ecosystem

and innovation rather than maintenance and utilization, which poses a major problem. Models either gain immediate traction by offering lucrative spin-off opportunities to monetize their maintenance or, as is often the case, they will be used for research publications and subsequently abandoned. In any event, the lack of coordination and dispersion of modelling efforts leads to closed models, duplication of work and a lack of continuity, and accordingly to the loss of many interesting models as students and researchers move on to other projects.

5.2.2.Data Providers

Even though Statistics Canada is an important source of energy data for the modelling community, no central source is available. Sources of energy data are scattered across a variety of organizations, many of which include key stakeholders such as governments, utilities or industrial organizations.

For instance, CER, which maintains an in-house modelling unit, also presides over a vast body of energy data that it shares with the general public. The ECCC also maintains a large data set that it partially shares through its biennial reports. Some provincial and municipal governments also share the data at their disposal, as long as it does not conflict with privacy issues or other legal obstacles.

Utilities are most protective of their data for a number of reasons, one of which is that their data, particularly their consumer data, is more sensitive to privacy concerns. Although they occasionally share their data with researchers, they bind them to tight non-disclosure agreements that limit the use of the data to a specific project and prevent it from being used for alternative explorations or being shared with the broader modelling community.

CER, ECCC and Statistics Canada recently joined forces to create an entity that has been long awaited and advocated for by the modelling community: the Canadian Centre for Energy Information (CCEI). This Centre is poised to become a crucial reference for energy data, providing access to the general public. Even though CCEI does not harvest new data, it mobilizes the competency of Statistics Canada to gather existing data from across the country by negotiating with different stakeholders and offering them technological and legal frameworks that encourage and enable them to share their valuable data.

However, CCEI is still in its early stages of development, determining its role, the mechanisms at its disposal and strategies of implementation. To be able to fulfill its mandate, define targets and design strategies, CCEI will have to engage closely with its user base. Since the modelling community has been identified as one of the key users, a coordinated effort by this community has been launched in collaboration with CCEI to identify common needs and priorities, allowing CCEI to focus on its initial mandate of delivering a revamped data access, rather than discovering these needs and priorities.

5.2.3. Model Users

Model users are actors that either use the results of modelling directly or consume the analysis of the results for a variety of purposes, often tied to anticipation and planning activities. Model users include government organizations on various levels, utilities, industrial organizations – such as the Canadian Association of Petroleum Producers (CAPP) and the Canadian Wind Energy Association (CanWEA) – and non-governmental organizations – such as the Institut de l'énergie Trottier (IET), the David Suzuki Foundation, the Canadian Energy Systems Analysis Research initiative (CESAR) and the newly created Canadian Institute for Climate Choices (CICC), as well as numerous academics.

Some (CAPP, governments, utilities) use results and analysis to draw conclusions for their work and mandate, while others (CICC) act as intermediaries by using results to produce analysis for their clients and constituencies. Some research institutes (CESAR, IET) also use models to inform their broader research activities or to elevate the conversation around energy system choices. A number of model users (e.g. CER, ECCC and CanmetENERGY), various provinces (e.g. BC, AB and MB) municipalities (e.g. the City of Ottawa and Edmonton) and provincial utilities maintain their own in-house modelling capacities. Some of these users also use external models and alternative analyses to complement their own. When model users do not use their in-house capabilities, they often rely on contracts with modelling consultants or, on rare occasions, with academic modellers on an ad-hoc basis. As a result, useful models are often not sustained or kept up to date since there is no reliable likelihood that they can be deployed regularly and no incentive for investing in their maintenance. As such, the success and usefulness of models are ephemeral and a matter of coincidence rather than a product of strategic decision making and investment from a national perspective.

Without coordination, it is difficult for model users to find the right models and gain access to the expertise to run the codes, modify and customize hypotheses and, in general, engage in a dialogue with other stakeholders with similar interests.

5.2.4. Funders

Sources of funding for modelling activities vary according to organizational context. Nonetheless, the current system of funding sources does not promote modelling capabilities that can be sustainable, of collective value or applicable beyond their immediate context.

Academic modellers who innovate and develop models can benefit from funding provided by tri-council and other funding providers like NRC to develop their models. However, these organizations are only interested in innovative research and do not offer resources for maintaining and updating models.

Private sector modellers have to rely on contract opportunities with governments or NGOs, which often offer limited term contracts, need the results quickly and cannot necessarily commit to long-term engagements. As such, the sources of funding for the private sector are unpredictable and rarely reliable, making it difficult to invest in model development.

A few stakeholders that rely heavily on models maintain in-house expertise. These are the modellers with the most reliable access to sources of funding since they are part of a permanent staff. However, governments, utilities and other organizations that maintain in-house modellers have to commit to certain approaches and particular perspectives, thus limiting their abilities to explore other, newer and potentially more useful approaches and models. Yet even those model-using organizations that opt for long-term commitments with certain modellers often face the same dilemma. They may sometimes benefit from opportunities to compare the results of their in-house (or their regular contactor) models with external ones that happen to be available and aligned with the problems at hand. Nonetheless, without a permanent external capacity and despite their permanence, in-house modelling capacities remain limited to their inherent biases.

6. ESSENTIAL ELEMENTS OF ENERGY MODELLING

The government has announced that it still plans to reach and even exceed its GHG emissions objectives for 2030 and that it aims for carbon neutrality for 2050. Since energy is directly responsible for 80 percent of Canada's GHG emissions, reaching these objectives will require a profound transformation of Canada's energy system from production to usage, which will affect the daily life of all Canadians and the operations of a large share of its economy. To maximize the benefits of this massive transformation, policies, programs and investments must be strategically oriented.

A strong integrated energy modelling capacity is an essential tool to support the development of this strategic approach.

As explained in the previous section, Canada can count on a rich and diverse energy modelling community. However, it lacks the integration and convening opportunities to enable it to respond satisfactorily to the needs in system understanding and policy design required to meet current challenges. This lack of structure considerably reduces the impact of energy modelling for a number of reasons:

1. Difficulty accessing data

The quality of energy modelling rests largely on the quality of the input data. Yet access to open data is challenging; much of it is confidential, of dubious origin, or significantly delayed or incomplete, thus reducing Canada's quality modelling capacity as compared to its global trading partners and competitors.

2. Lack of openness

The opacity of the hypothesis and data used in many models prevents an accurate understanding of the models' value and application zone. This also leads to mistrust in any prospective exercise for stakeholders and interested parties not involved in the models, making it more difficult to raise relevant questions and create a common scientific basis for the debate to evolve.

3. Stakeholders' diverse modelling expectations

Not only is energy modelling complex and broad, but it is also often misunderstood. For instance, outlooks can be mistaken for predictions; technical or economic constraints are often imposed and limit the range of applicability; and the question asked might not reflect the expected outcome.

4. Lack of long-term support for energy models

Although funding is available to develop new models or for intermittent modelling work on specific projects, Canada does not offer any funding for long-term model support such as updating databases, developing capability and training users. This has led to a highly inefficient situation where most models disappear as their creator moves on, either after graduation or into a new job. By forcing researchers to constantly redevelop the same codes in isolation, the current structure is wasteful, costly and suboptimal.

A strong integrated energy modelling capacity is an essential tool to support the development of a strategic approach to energy transition.

From these limitations, which have been discussed at length in various activities and consultations held within EMI, a number of elements have been identified as key components for a successful energy modelling infrastructure:

1. Continuity of models

To understand the long-term transformation of the energy sector, and to follow its evolution over short periods, it is essential to be able to count on a number of stable models that are supported over long periods of time, with stable criteria.

2. Increased transparency

Models are more than ever used as a basis for debating policies and choices. To instill confidence in the results, facilitate exchanges and ensure science-based decisions, as discussed previously, many jurisdictions are choosing to work with open models that can be tested, analyzed and rerun independently. This transparency is not limited to the models alone; constraints, limitations and assumptions must also be discussed.

3. Reference scenarios

Developing reference scenarios makes it possible to compare various methods and to more effectively measure the significance of the various results. This is a crucial part of establishing solid knowledge-based debates and actions on energy.

4. Ease resource sharing

The current lack of organization leads to considerable inefficiency. There is a significant need to structure the sharing of data, codes and models, hypotheses and scenarios. Eliminating the duplication of efforts will significantly increase the capacity of analysis and deliver on energy transformation.

5. Timely delivery

The EMI consultations have underlined the frustration of policy makers and analysts about the difficulty of obtaining timely delivery from modellers on questions of interest, unlike the situations observed in other countries. It is imperative that Canada make sure that the modelling community is structured to offer rapid and appropriate support to those who need this information.

6. Training and education

Because energy modelling is complex, not only modellers, but also policy makers and the general public must be provided with training and education so that this essential tool can play its full role in the energy transition.

7. Convening and working with all partners
The energy modelling community is broad and rich. The federal government has also created new structures that can interact with modellers. One example is the Canadian Centre for Energy Information, which will attenuate some of the current limitations on access to quality data. The energy modelling community will also be able to provide needed analysis for the Canadian Institute for Climate Choice, which is mandated to develop policy recommendations on GHG mitigation, climate adaptation and clean growth. Creating a place to facilitate collaboration and exchanges will not only have a significant multiplying effect on modelling efforts in Canada but will also promote the development of even more relevant efforts.

8. Multidimensional modelling
To maximize positive impacts from policies, models able to pair multiple social, technical and economic aspects of the energy system are essential. This requires a structure able to coordinate collaboration, provide infrastructure and, given the amount of work it represents, ensure continuity.

While some of these essential elements of energy modelling can emerge from local or intermittent initiatives, they cannot survive in the long run or be integrated at a national level without a specific structure with the appropriate mandate, as has been demonstrated in countries that have managed to integrate solid energy modelling in their policy development.

6.1. Benefits of energy modelling for policy design

The transformation of energy under environmental constraints and technological developments is so profound that traditional thinking no longer suffices to ensure good policy design. The sheer speed of these transformations calls for the development of a capacity to integrate a much richer environment in order to assess the impact of a potential policy or to estimate the environment in which these policies will exist.

As indicated above, governments around the world use modelling to evaluate possible evolutions of economic sectors, their response to policies and indicators of policy impacts.

Energy and GHG modelling are at the core of the UK climate change policy given that the UK has embraced a very forward-looking type of climate change governance, adopting a carbon budget twelve years in advance. Such an approach must rely heavily on modelling to test possible trajectories and the long-term impact of various policies and technologies, including rebound effects, which are notoriously difficult to evaluate through simple scenario developments. The decision to adopt a very open approach to energy modelling has also enabled these tools and their results to play an important role in public debates.

Beyond these universal advantages, in the Canadian context, an open and structured energy modelling community can play a crucial role in successful policy development through election cycles by:

1. Developing a science-based consensus on a number of issues and facilitating moving the debates from the existence of a challenge in the energy sector driven by environmental, economic and technological pressure to the selection of the best policies to meet this challenge. This is valid across the political spectrum as well as for the various stakeholders from civil society

2. Allowing the development of a broad range of policies, adapted to regional realities yet able to attain the global objectives

3. Providing stability in the application of policies and, at the same time, support sufficient flexibility to adapt to the reality and changes in perspectives

4. Strengthening public support by providing more independent information as well as facilitating the empowerment of groups through access to shared modeling tools

7. CONCLUSION: THE URGENCY OF A LONG-TERM COMMITMENT TO SUPPORT ENERGY MODELLING IN CANADA.

In the UK, uncertainties in the funding environment throughout the 1990s and early 2000s created difficulties for developing and maintaining modelling expertise within UK universities. Most models require extensive and long-term investment to construct and maintain, with much of this expertise embodied in teams of researchers. While short-term consultancy funding can be obtained for using models to address particular market or policy questions, this is insufficient to maintain modelling capacity. Over the last decade a sustained growth in funding spearheaded through the Research Councils (initially the Towards a Sustainable Energy Economy (TSEC), followed by the RCUK Energy Programme) is partially addressing this.

UKERC Energy Research Landscape
Energy Systems Modelling (Strachan, 2011)

Climate and environmental objectives, new energy sources, storage technologies and the transformation of the energy-driven sectors will have a major impact on the Canadian economy and the day-to-day life of every citizen. Planning these transformations to ensure that objectives are reached, while maximizing the benefits for all Canadians, is a major challenge for all governments, utilities and the private sector. To put in place the right policy, select the best investment and structure services in this fast-changing world requires a strong modelling capacity to project ourselves, test approaches and evaluate the impact of various decisions. At present, this capacity is not available in Canada

As demonstrated through the convening efforts of the Energy Modelling Initiative, Canada's energy modelling community is rich and diverse. It covers a wide array of approaches, as well as technical and geographical foci. It is present in governments, utilities, regulators, the private sector and academia across the country.

However, as we have discovered, most members of this community work largely in isolation, exchanging ideas with their close peers, but remaining unaware of the overall capacity across Canada. Without programs that ensure the long-term development and maintenance of specific models, this community is fragile and cannot leverage the important investments made by research councils on specific model development. Following the pattern observed in the UK 10 years ago, Canada provides funding for developing new models linked to specific problems mainly through its research councils. However, the lack of model maintenance capabilities means that these models are either abandoned at the end of the funding period or are shifted to consultants who lack the means to continue significant developments.

This lack of maintenance funding is also observed within government agencies and departments. Models are typically under the responsibility of very small teams, often composed of only one or two people who barely manage to keep the dataset up to date and run the requested scenarios, lacking any capacity to develop, fully document or open the model to the rest of the community.

The cost to Canada of NOT structuring energy modelling capacity to make the best use of its contribution is enormous. It greatly limits the possibility of establishing a scientific basis to start national debate and the ability to develop a consensus. It also limits the development of the most relevant policies, their optimization and their follow-up, as well enlightened investments. Above and beyond the considerable economic cost, the lack of such tools constitutes a barrier to democratic decisions since it leaves the population in the dark as to challenges, options and solutions.

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APPENDIX A – **EMI MODELLING PROJECTS OVERVIEW**

This appendix presents an overview of the modelling projects that have been submitted to EMI. More information on those – project reports, material presented at the national forum – can be found at https://emi-ime.ca/projects/.

Figure A.1 : Geographic distribution of the modelling projects received by EMI

Table A.1 – List of modelling projects received by EMI

Ref.	Title	Team	Organizations	Geographical scale	Temporal Scale
1	Examining the contribution of hydroelectric renewal and greenfield development to grid ecarbonization: An enhanced capacity expansion model	Reza Arjmand, Richard Hendriks, Madeleine McPherson	Sustainable Energy Systems Integration & Transitions Group, University of Victoria. Department of Civil and Mineral Engineering, University of Toronto	National	Hourly to yearly
2**	BESOS – an Expandable Building and Energy Simulation Platform	Gaëlle Faure, Theo Christiaanse, Paul Westermann, Ralph Evins	Energy Systems and Sustainable Cities group, University of Victoria	Local, regional, municipal, provincial	Multi-minutely to monthly
3	Interactions of policies acting at the local, sub-national, and national scales for Canada's energy transition	Rose Murphy, Mark Jaccard, Bradford Griffin, Thomas Budd, Aaron Pardy	School of Resource and Environmental Management, Simon Fraser University. Canadian Energy and Emissions Data Centre, Simon Fraser University	Municipal, provincial, terprovincial, national	Five-yearly
4	Modelling of Remote Diesel-Based Power Systems in the Canadian Territories	Jason Zrum, Spencer Sumanik, Michael Ross	Northern Energy Innovation, Yukon Research Centre, Yukon College	Regional, municipal, provincial, territories	Minutely to yearly
5*	Hourly Electricity Projections from Canada's Energy Future 2019	Mantaj Hundal, Michael Nadew, Matthew Hansen	Energy Outlooks Division, Canada Energy Regulator	Provincial, nterprovincial	Hourly to yearly

6	Management of Canada's energy transition and associated risks through optimized CGE approach	Guohe Huang, Hua Zhu, Jocelyn Crivea, Renfei Liao, Lirong Liu, Jiapei Chen, Xiaoyue Zhang	University of Regina, Saskatchewan, Saskatchewan Ministry of Environment	Provincial, terprovincial, national	Multi-yearly
7	A Cluster-Based load Model for a Resilient and Sustainable Community	Magdy Salama, Ahmed Gaouda, Mohamed Nassar	University of Waterloo. QualSys Engco Inc	Regional, municipal	Hourly to yearly
8*	Pumped Hydro Storage (PHS) and Battery Energy Storage Systems (BESS): An Assessment of Energy 2020 Initial Response and Identification of Possible Improvements	Jean-Sébastien Landry, Glasha Obrekht, Robin White, Raj Ghosh, Monique Brugger, Justin Quan, John St-Laurent O'Connor, Kyprianos Antzoulidis, Afshin Matin	Environment and Climate Change Canada	Provincial, terprovincial, national	Monthly, multi-monthly, yearly
9	Modelling urban climate mitigation in Canadian municipalities	Yuill Herbert, Ralph Torrie, Michael Hoffman, Robert Hoffman, Bastiaan Straatman, Jeremy Murphy, Chris Strashok, Marcus Williams, Deryn Crockett, Mel de Jager	WhatIf? Technologies. Sustainability Solutions Group	Local, regional, municipal	N/A
10	Modeling Increased Electric Vehicle Charging Demand in Quebec	Mark Purdon, Olivier Bahn, Samuel Forget Lord, Lisa Aultman-Hall, Jonathan Dowds	Institut Quebecois du Carbone. École des sciences de la gestion de l'UQAM. Hautes études commerciales de Montréal (HEC). University of Vermont	Provincial, regional, local	Hourly, daily, weekly

11	Toward a smarter electricity consumption	Thomas Dandres, Ana Carolina Riekstin, Antoine Langevin, Lawrence Abdulnour, Julien Walzberg, Manuele Margni, Réjean Samson, Mohamed Cheriet	Polytechnique Montréal. International Reference Centre for the Life Cycle of Products, Processes and Services (CIRAIG). Synchromedia Laboratory, École de technologie supérieure (ÉTS)	Provincial, inter-provincial, national	Real-time (5minutely), hourly, adjustable
12	Smart Microgrid Solutions to Reducing Fossil Fuels Dependence in Canada's Rural and Remote Communities	Bo Cao	Emera & NB Power Research Centre for Smart Grid Technologies, University of New Brunswick	Local, regional, national	Hourly
13	Open and Accessible Renewable Electricity System Modelling for Prince Edward Island	Matthew McCarville, Peter Rukavina, Matthew Hall	University of Prince Edward Island	Regional, provincial	Hourly or sub-hourly

* These projects were selected, but due to their organizational affiliation, were not eligible for funding.

** This project report was submitted voluntarily and included in the synthesis.

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