National Round Table on the Environment and the Economy | Table ronde nationale sur l'environnement et l'économie

Greenhouse Gas Emissions Forecasting: Learning from International Best Practices

Canada

Library and Archives Canada Cataloguing in Publication

Greenhouse gas emissions forecasting: learning from international best practices.

Text in English and French on inverted pages.
Title on added t.p.: Prévisions des émissions de gaz à effet de serre : leçons des pratiques exemplaires internationales.
Available also on the Internet.

ISBN 978-0-662-05879-3

Cat. no.: En134-41/2008

1. Greenhouse gases—Canada—Forecasting. 2. Greenhouse gas mitigation—Canada. 3. Greenhouse gases—Forecasting. 4. Greenhouse gases—United States—Forecasting. 5. Greenhouse gases—Great Britain—Forecasting. I. National Round Table on the Environment and the Economy (Canada) II. Title: Prévisions des émissions de gaz à effet de serre : leçons des pratiques exemplaires internationales.

TD885.5.G73G73 2008 363.738'746 C2008-980260-8E

This book is printed on Environmental Choice paper containing 20 percent post-consumer fiber, using vegetable inks.

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Printed in Canada on recycled paper

National Round Table on the Environment and the Economy

About Us

The National Round Table on the Environment and the Economy (NRTEE) is dedicated to exploring new opportunities to integrate environmental conservation and economic development, in order to sustain Canada's prosperity and secure its future.

Drawing on the wealth of insight and experience represented by our diverse membership, our mission is to generate and promote innovative ways to advance Canada's environmental and economic interests in combination, rather than in isolation. In this capacity, it examines the environmental and economic implications of priority issues and offers advice on how best to reconcile the sometimes competing interests of economic prosperity and environmental conservation.

The NRTEE was created by the government in October 1988. Its independent role and mandate were enshrined in the *National Round Table on the Environment and the Economy Act*, which was passed by the House of Commons in May 1993. Appointed by Governor in Council, our members are distinguished leaders in business and labour, universities, environmental organizations, Aboriginal communities and municipalities.

How We Work

The NRTEE is structured as a round table in order to facilitate the unfettered exchange of ideas. By offering our members a safe haven for discussion, the NRTEE helps reconcile positions that have traditionally been at odds.

The NRTEE is also a coalition builder, reaching out to organizations that share our vision for sustainable development. We believe that affiliation with like-minded partners will spark creativity and generate the momentum needed for success.

And finally, the NRTEE acts as an advocate for positive change, raising awareness among Canadians and their governments about the challenges of sustainable development and promoting viable solutions.

We also maintain a secretariat, which commissions and analyses the research required by our members in their work. The secretariat furnishes administrative, promotional and communications support to the NRTEE.

Our Current Projects

The members of the NRTEE meet four times a year to review their research and conduct their deliberations. Our current projects focus on:

- Energy Efficiency in the Commercial Building Sector
- Climate Change Adaptation Policy for Northern Infrastructure
- Carbon Emissions Pricing Policies

For more details on past and current programs, visit our website at **http://www.nrtee-trnee.ca**.

Members of the National Round Table on the Environment and the Economy (NRTEE)

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1. Executive Summary

This report responds to key concerns highlighted by the National Round Table on the Environment and the Economy (NRTEE) in its 2007 Response to its obligations under the *Kyoto Protocol Implementation Act* (2007 KPIA Response). Chief among those concerns were differing and inconsistent forecasting methods used among various federal departments to describe the greenhouse gas (GHG) emissions reductions accruing from a particular policy measure or initiative, leading to issues of *additionality*, *free ridership*, *rebound effect*, and *policy interaction effects*. The NRTEE emphasized the importance of transparency and clarity with respect to key assumptions and methods, and the consideration of important sensitivities and uncertainties when producing GHG emissions forecasts. It also emphasized the importance of consistency in approaches across different departments, programs, and measures, and the need to integrate the findings in a holistic framework. In light of these concerns, the NRTEE felt it could be useful for the federal government if international best practices could be identified and highlighted in the forecasting of emissions reductions resulting from government policies, from both a methodological and a governance perspective.

In its 2008 Climate Change Plan for the Purposes of the *Kyoto Protocol Implementation Act* (2008 Government KPIA Plan), the government responded directly to the above concerns: "the advice of the (NRTEE) is a key factor in the government's methods for estimating reductions."[1] In its 2008 KPIA Response, the NRTEE noted the significant improvements made by the federal government in addressing the issues mentioned above in the 2008 KPIA Plan, in particular the issues of transparency, additionality, and policy interaction effects. Moving forward, the NRTEE believes there is continual benefit in examining and highlighting how other countries approach similar challenges to those faced by the federal government in emissions forecasting.

Recognizing that forecasting GHG emissions reductions *policies*[2] is difficult and inherently uncertain, the challenges of forecasting, including modelling approaches, are probed. In this report, forecasting is defined as a depiction—an energy-economy model—of how a system will evolve in future both with and without policy intervention. The core of the report defines emissions forecasting best practices from methodological and governance perspectives. After a review of Canada's approach to emissions forecasting, the report presents case studies to illustrate how two other industrialized countries—the United States and the United Kingdom—approach forecasting.

Considering the significant role the provinces and territories play in the 2008 KPIA Plan, an important element of this report is considering their role in emissions forecasting. Initial research, however, indicated that few provinces have developed comprehensive emissions forecasts (while the report notes that some provinces are in the process of developing forecasts, they are not required to by law as is the case with the federal government). This has been highlighted in the report as a key area of concern given that substantial emissions reductions are attributed to provincial policies and measures in federal forecasts despite the lack of detailed provincial forecasts. These issues are discussed in sections 4.3 (Canada's Approach) and 5.1 (Lessons for Canada) of the report.

The report concludes with a broad discussion on findings from the case studies, along with detailed lessons for Canada, and specific conclusions on incorporating best practices in GHG emissions forecasting. It is important to note that the report's key findings, listed below, do not imply that Canada does not currently follow some of these practices—these are broad, standard best practices that taken together, should result in improved forecasting methods and approaches in Canada.

Key findings and recommendations from the analysis contained in the report from a *methodological* perspective include the following:

1 Environment Canada (2008), *A Climate Change Plan for the Purposes of the Kyoto Protocol Implementation Act*, p. 30.

2 Business-as-usual (BAU), or "without policy" forecasting, is generally straightforward. However, the production of GHG emissions forecasts based on policies (e.g., Regulatory Framework for Large Emitters, EcoEnergy for Buildings and Houses) is particularly challenging.

- Hybrid energy-economy models are more effective in producing accurate GHG emissions forecasts as they integrate the strengths of both the traditional bottom-up and top-down approaches to modelling emissions forecasts;
- The use of a consistent baseline from year-to-year (including baseline data), assumptions, and conditions across the board is fundamental to ensure emissions forecasts can be accurately compared from year to year;
- The use of consistent and agreed definitions of terms and concepts, such as for free ridership and additionality, across government departments involved in forecasting would ensure greater transparency of emission forecasts and facilitate assessment of the forecasts' accuracy.
- There is need for an international perspective in the model so that it can respond appropriately to world events (since in most cases, Canada is a price taker for both commodities and energy, and a primary trader of goods and energy). Canada is acting in concert with other countries on climate policy and its forecasting approaches need to reflect this reality.

From a *governance* perspective:

- Use of an independent forecasting agency is preferable to provide more accurate and transparent emission forecasts for consideration by government policy makers, external analysts, and Parliamentarians and to facilitate ongoing audit and evaluation.
- Multi-source emissions forecasting from a group of individual government departments can be accurate, but works best both when centrally coordinated and with independent authority by the central coordinating department or agency to question other departmental forecasts.
- Regular independent reviews, audits and evaluations of government forecasts and forecasting methods by a third-party agency or process helps ensure accuracy of forecasts and that forecasting methodologies are up-to-date and robust.
- Forecasting must be sufficiently resourced and financed by governments to ensure data is up to date and most recent improvements in forecasting methodologies are incorporated for the benefit of policy makers taking decisions based on these forecasts.
- Regular, ongoing evaluation of past forecasts for accuracy and effectiveness is necessary to ensure continuous improvement of government forecasting methodologies and approaches.
- Ensure transparency and clarity with respect to key assumptions and methods.

2. Introduction

Successful climate policies are those that achieve forecasted greenhouse gas (GHG) emissions reductions. But, forecasting expected GHG emissions reductions from specific policies and measures is difficult, as noted by the National Round Table on the Environment and the Economy (NRTEE) in its *Response to its Obligations under the Kyoto Protocol Implementation Act* (2007 KPIA Response).[3] It has not only been a challenge for Canada, but for all countries to generate accurate projections of expected GHG emissions reductions from policies over a given time period. However, Canada has consistently produced inaccurate forecasts over the past 10 years, in each instance underestimating the growth of domestic GHG emissions under business-as-usual (BAU) conditions.[4]

The importance of accurate forecasting cannot be overstated. It is the forecast upon which climate policies and programs are developed and measured. Policy makers can be driven to differing policy choices depending upon the forecasted emissions reductions expected to be realized. Inaccurate estimates make it difficult for the federal government to design policies that will result in expected forecast emissions reductions. Some countries, particularly those with similar resource-based economies to Canada's, have had more success in forecasting GHG emissions reductions in some policy areas. While no country produces forecasts that are 100 per cent accurate, some countries utilize approaches that appear to be more reflective of actual emissions events. Therefore, it is well worth examining and understanding how these countries approach their GHG emissions projections, both from methodological and governance perspectives, and then assessing whether and how these might be beneficially applied to Canada.

2.1 Background and Purpose

In its review of the government's climate change plan under its KPIA obligations in summer 2007, the NRTEE found that differing and inconsistent forecasting methods were used among various federal departments to describe the emissions reductions accruing from a particular initiative, leading to issues of *additionality*, *free ridership*, *rebound effect*, and *policy interaction effects*.[5] It is important to note that in its just-released 2008 KPIA Plan, the government has taken significant steps to address these issues.[6] The areas of concern identified by the NRTEE in its evaluation of the government's 2007 KPIA climate change plan are primarily those of methodology and governance. In its 2007 KPIA Response, from which this report originated, the NRTEE emphasized the importance of transparency and clarity with respect to key assumptions and methods, and the consideration of important sensitivities and uncertainties. It also emphasized the importance of consistency in approaches across different departments, programs, and measures, and the need to integrate the findings in a holistic framework. In light of these conclusions, the NRTEE felt it could be useful for the federal government if international best practices could be identified and highlighted in the forecasting of emissions reductions resulting from government policies, from both a methodological and a governance perspective.

At its November 2007 plenary meeting, the Round Table accordingly approved a proposal to develop a best practices guide or backgrounder that would be submitted to the government along with the NRTEE's next response under its KPIA obligations in 2008.

From a *methodological* perspective, the NRTEE identified certain forecasting methods for estimating GHG emissions reductions that did not result in the expected realized emissions, as the difference between

3 For further information, see http://www.nrtee-trnee.ca/eng/publications/c288-response-2007/index-c288-response-2007-eng.htm.

4 Simpson, J., Jaccard, M. and Rivers, N. (2007) *Hot Air: Meeting Canada's Climate Change Challenge*. Toronto: McLelland and Stewart, p.165.

5 Please see Appendix B for a description of these effects.

6 Environment Canada (2008), *A Climate Change Plan for the Purposes of the Kyoto Protocol Implementation Act*, p. 30.

stated reductions and reference case (or BAU) emissions. The sum of stated reductions for a given year should correspond to the expected difference between the reference case and forecasts of realized emissions. As noted above, deviating from the basic computation of measuring reductions against the reference case can lead to issues of additionality, free ridership, rebound effect, and policy interaction effects.

From a *governance* perspective, the NRTEE identified inconsistent forecasting methods across departments for estimating GHG emissions reductions and gaps in the on-going evaluation of forecasting approaches. The NRTEE also found that a consistent definition for "reductions" for policy impacts was not applied in all instances in the plan—some policy impacts were stated in different terms (e.g., in terms of their cumulative impact). Using a consistent model and definitions for forecasting the emissions reductions resulting from specific programs and initiatives is necessary to address this.

For both the methodological and governance areas of concern listed above, it is important to note that in its 2008 KPIA Plan, the government has taken steps to address these issues. Nevertheless, the NRTEE believes the application of certain best practices, as outlined in this report, will ensure more accurate forecasting moving forward and, by extension, inform effective policy choices that will achieve GHG emissions reductions.

2.2 Analytical Approach

In order to ensure optimal climate policy outcomes, accurate and realistic forecasting is vital. The NRTEE believes this report could be useful in assisting the government to develop effective policy by providing examples of how other governments forecast GHG emissions reductions from policies and measures.

Flowing from the key findings of the Round Table's 2007 KPIA Response, the approach to this report has been to not only define and provide examples of international best practices from a methodological perspective, but also to also highlight best practices from a governance perspective.

Specifically, we sought answers to two key questions:

- Methodology: What is the most effective forecasting methodology that countries should use?
- Governance: What are the optimal forms of governance to ensure that best practices in forecasting are followed?

A case study approach was chosen as most appropriate. To the extent possible, countries with economic or national situations most applicable to Canada have been examined. It is important to note that the selection of case studies to provide examples of international best practices in GHG emissions forecasting is not as straightforward as it seems. The original intention was to select countries with similar challenges to those facing Canada in forecasting GHG policies and that followed best practices in methodology and governance as outlined in sections 4.1 and 4.2. What these case studies highlight is that some countries utilize best practices from a methodological perspective and some from a governance perspective, but not all utilize best practices in both areas.[7] Another initial purpose of this report was to highlight best practices in sub-national jurisdictions, particularly some Canadian provinces and U.S. states. No province, however, has released detailed plans with emission policy forecasts[10], raising questions about the methodological basis behind their plans.

In order to ensure rigour in our research, analysis, and findings, this paper was then peer reviewed by several well-respected economic experts.[11] Beyond the peer review, the final report was reviewed and considered by NRTEE members themselves.

7 This issue is further discussed in section 4.4.1.

8 This issue is elaborated upon in section 4.1.

9 Please see *Notice to Reader* for details.

3. The Challenge of Forecasting

The challenges associated with estimating emissions reductions from climate policy measures and actions are well documented.[10] On the methodological side, these include the development of baseline assumptions[11] and the impact of specific policy measures, assumptions about financial costs and consumers' preferences, assumptions about the direction and rate of technological change, costing individual actions versus integrated actions, assumptions about macroeconomic costs, the effect of policy measures on cost incidence and total costs, and the full range of costs and benefits of GHG emission reduction policies. There is no simple method to account for all these actions.

Perhaps less technically complex, but just as challenging, are governance issues related to effective emissions forecasting. The NRTEE's 2007 KPIA Response emphasized the importance of transparency and clarity with respect to key assumptions and methods, and the consideration of important sensitivities and uncertainties. It also emphasized the importance of consistency in approach across various departments, programs, and measures, and the need to integrate findings in a holistic framework. This report will explore how two other countries address both sets of these challenges and determine, to the extent possible, if it is appropriate to apply their methodology and governance approaches to the Canadian context.

3.1 What is Forecasting?

In this report, forecasting is defined as a depiction—an economic model—of how a system will evolve in future both with and without policy intervention. Since the future is of course unknown and thus uncertain, we cannot say that one forecast made today is better than another. What we can do, however, is assess alternative forecasting methods in terms of the following criteria:

1. past accuracy, which may or may not bode well for future forecasts;
2. sound representation of current and emerging system dynamics,[12] which should increase the probability of a better forecast;
3. greater transparency, which increases the ability for outsiders to examine and critique all key assumptions, and perhaps test alternatives; and
4. the ability to conduct and record sensitivity analyses, which should improve the understanding of the critical forecast model assumptions and related key uncertainties.

3.2 Modelling Approaches

Emissions forecasts are calculated using energy-economy models. These models are designed to forecast the effects of policies on energy-related GHG emissions. The structure of most energy-economy modelling approaches ranges from detailed bottom-up models reflecting engineering-economic details of a wide menu of technologies in each sector to top-down models of the whole economy calibrated on historic data from up to hundreds of sectors. Hybrid models—those that combine the strengths of the bottom-up and top-down approaches—are considered by many modelling authorities as optimal approaches to forecasting.[13] Canada's E3MC model[14] is an example of a hybrid model, along with the U.S. Energy Information Administration's (EIA) model (described in section 4.4.2).[15] In the later discussion of specific countries' best practices approaches to emissions forecasting, we will assess what kinds of conclusions can be drawn as to the effectiveness of forecasts from the various modelling approaches used.

10 Examples include Jaccard, M., J. Nyboer and B. Sadownik, *The Cost of Climate Policy* (2002); Bernstein, S., "International institutions and the framing of domestic policies: The Kyoto Protocol and Canada's response to climate change," Policy Sciences, 35 (2002); and Nordhaus, R. and K. Danish, *Designing a mandatory greenhouse gas reduction program for the U.S.* (2003).

11 At the very least, baseline assumptions should include supporting data and data consistency with other agencies.

12 In this case, system dynamics refers to how an energy-economy model captures changes in technologies, costs, and behaviours over time.

13 Dowlatabadi, H., D.R. Boyd, J. MacDonald (2004). *Model, Model on the Screen, What's the Cost of Going Green?* Washington, D.C.: Resources for the Future, p. 10.

14 E3MC stands for Energy-Economy-Environment Model for Canada. A description of it is found in section 4.3.1.

15 Please refer to Appendix A for a discussion of modelling approaches.

4. What are the Best Practices of GHG Emissions Reductions Forecasting?

In reviewing best practices in GHG emissions forecasting, a useful starting point is the main areas of concern addressed by the NRTEE in its 2007 KPIA Response:

- Clear and transparent definitions of the modelling approaches used are absolutely essential. Particularly important are the assumptions about the time frame to which the models are being applied. It is also important to provide sufficient detail on the methods and data employed.
- For any specific modelling framework, it is important to provide prioritized information about the baseline forecast assumptions about behaviour and the cost of technology.
- Also critical is a clear and transparent definition of the particular policies being studied. In general, market-based approaches are commonly modelled within an economic framework. In contrast, non-market based policies are more difficult to assess, with analyses often based on ad hoc assessments. It is in that context that issues of consistency and integration of results are most critical.

Beyond these key concerns are a range of issues pertaining to methodology and governance in emissions forecasting, which we set out below.

4.1. Methodology

From a methodological perspective, BAU forecast has to be explicit about key drivers and assumptions (s.3.1, criteria 3) and about key response dynamics (s.3.1, criteria 2). Even under a BAU forecast, this latter criterion is important. For example, what will be the full response over the next 40 years to a long-run trend to higher real oil prices? Then, the issue of dynamics continues to be extremely important as we try to forecast the effect of policies. At this point, sensitivity analysis is also key (s.3.1, criteria 4).

While there are many approaches to emissions forecasting, the two approaches consistently determined as best practices from a methodological perspective from academic, government, and institutional peer review are the International Energy Agency's (IEA) *World Energy Outlook* and the U.S. Energy Information Administration's (EIA) *International Energy Outlook*.[16]

Through its annual *World Energy Outlook*, the IEA produces a BAU forecast as well as a policy forecast (World Alternative Policy Scenario). It can be determined that the IEA utilizes "best" forecasting practices for the following reasons: first, it provides a systematic analysis of both aggregate measures and intensities: GDP, energy supply, and energy supply per unit GDP. Contrast this with Canada's 2006 reference case[17] where everything is in rates and average shares, which is inherently less easy to verify or adapt. The IEA forecasts are quite flexible, and allow one to easily see where errors have occurred (e.g., growth was underestimated, so emissions will be as well). In Canada's case, there were no hard values for GDP, population, etc., only hard values for energy use and emissions. If the Canadian reference case were to have underlying trends on important aggregates, it might be easier to update emissions forecasts, which would make them more credible. Second, and related to the first, the IEA periodically has a section in its new editions that examines why its previous forecasts may have erred: Was it an error in GDP or in emissions per GDP forecasts that led to an error in emissions forecasts?[18] Third, the IEA also discusses up front the key assumptions and sources of uncertainty. Main uncertainties include macroeconomic conditions (e.g., slower GDP growth than assumed in both scenarios would cause demand to grow less rapidly), uncertain effects of resource availability and supply on energy prices, and changes in government and energy environmental policies.[19] It also expands on one of

16 The EIA's domestic approach to emissions forecasting is described in Section 3.2.2

17 Natural Resources Canada (2006), *Canada's Energy Outlook: The Reference Case 2006*. As noted in this report and the NRTEE's 2008 KPIA Response, a new baseline (March 2008) has been developed that has significantly improved from the 2006 baseline.

18 For example, see International Energy Agency (2004), *World Energy Outlook 2004*, Annex B – Energy Projections: Assessment and Comparison, p. 519.

19 IEA (2006), *World Energy Outlook 2006*, p. 53.

the key sources of uncertainty, the adoption of policy (as the NRTEE assessed through its 2007 KPIA Response). The IEA responds to this uncertainty by proposing an "Alternative Policy Scenario," in which it examines what would be likely to happen given the underlying forecast assumptions if certain policies being discussed were adopted.

The EIA provides worldwide forecasts of energy demand and supply through 2030 in its annual assessment of global energy markets that is published in the *International Energy Outlook* (IEO). Similar to the IEA's long-term outlooks, the IEO employs measures of economic growth (GDP), population, and energy intensity to derive its forecasts. All of these statistics are reported either in the body of the text or in the appendices that accompany the report. The IEO includes regional projections of carbon dioxide emissions by fossil fuel. The report also includes an examination of the forecast relative to prior-year releases and, in the 2006 edition of the report, a comparison of past IEO projections with the actual historical data. This assessment can also be found in the appendices of the various IEO editions, all of which are archived on the EIA website.

In addition to a reference case projection, the IEO typically includes a number of side cases. These cases estimate the impact on energy markets of high and low macroeconomic growth assumptions and high and low energy prices. These results help to quantify the uncertainty in the IEO projections. While the EIA does not routinely include climate change policy side cases in its outlook, in 2006 it did include an analysis of the impact of the Kyoto Protocol on the countries and regions that ratified the treaty (including, of course, Canada).

As described above, the EIA's International Energy Module is similar to the IEA's forecasting approach. For the purposes of this report, it is important to understand that the EIA and IEA forecasts are BAU, and that it is *policy* forecasting that is especially challenging. However, both the EIA and IEA build on their BAU forecasts with complementary analyses and alternative policy scenarios that depict different futures (e.g., the adoption of more aggressive GHG targets or faster deployment of clean technologies) from the reference case or BAU forecast, which projects what will happen if current actions and policies remain in place. This is particularly important for Canada, as discussed in section 5.1. Therefore, for the context of this report, the approaches described above can serve as best-practice benchmarks from a methodological perspective for emissions forecasting.

4.2 Governance

As mentioned above, there are some basic best practices in regard to governance in emissions forecasting. These include clear and transparent definitions of the modelling approaches used, the provision of sufficient detail on the methods and data employed, and clear and transparent definitions of the particular policies being studied. This allows for a common understanding of the government's emissions forecasts and permits a straightforward evaluation of emissions reductions estimates and forecasts by not only government officials, but by third parties as well.

Beyond this, there is the issue of on-going evaluation. The importance of independent peer review cannot be overemphasized as a governance best practice. This ensures that the government's approach to emissions forecasting, including modelling, is rigorous and reflects key analytical, economic, regional, and sectoral considerations. While different types of review are possible, great care should be taken to make sure that the review is truly independent of the sponsoring agency and the modelling effort. Sometimes it is even useful to showcase the results of a report of this sort in a public meeting, as in the case with the EIA's annual forecasts, involving a wide range of stakeholders. Such meetings are able to examine the results and methods, as well as future plans to improve the analysis—all in the context of international best practices.

Broadly speaking, as will be discussed in section 5 below, countries with integrated, centralized, independent emissions forecasting agencies are more likely to produce accurate forecasts than those countries with responsibilities for data gathering and modelling diffused across various departments. Some countries are recognizing this, as shown by the newly created U.K. Committee on Climate Change and the Australian Department of Climate Change.

4.3 Canada's Approach

The Canadian government has set a national goal of reducing GHG emissions, relative to 2006 levels, by 20 per cent by 2020, and by 60 to 70 per cent by 2050. As illustrated by the government's most recent climate change plan *Turning the Corner*,[20] Canada uses forecasts to determine future GHG emissions reductions. In the plan, federal measures alone will reduce emissions in 2020 by approximately 230 megatonnes below forecasted levels, with 165 megatonnes of that reduction being attributable to the federal *Regulatory Framework for Industrial GHG Emissions*.

Various departments collect, analyze, and model data (in some cases modelling emissions forecasts for specific policies and measures) and provide that information to Environment Canada, the department responsible for coordinating climate policy (including forecasting) within the federal government. While this practice does not necessarily lead to inaccurate forecasts, issues arise when the central agency is neither independent nor has the authority to override the data and analysis it receives from other departments. The NRTEE drew attention to this issue in its 2007 KPIA Response when it emphasized the importance of consistency in approaches across different departments and programs, and the need to integrate the findings in a holistic framework. This issue is clearly illustrated in the U.S. case study set out in section 4.4.2 below.

4.3.1 Forecasting Model[21]

The emissions and economic forecasts presented in the government's plan were estimated through Environment Canada's economic model (the Energy-Economy-Environment Model for Canada, or E3MC). The E3MC model is a combination of the Energy 2020 model and the Informetrica Model (TIM). According to Environment Canada, E3MC permits "integrated energy-economy policy simulations in a manner that fully addresses the challenges of additionality, free-riders, rebound effects, and policy interaction effects that commonly arise in this type of complex analysis"[22]—the very effects the NRTEE highlighted in its KPIA Response. This most recent plan was released following the NRTEE's 2007 KPIA Response.

Energy 2020 (E2020) is a "bottom-up" technology model used to forecast the effect of policies on emissions.[23] The model forecasts the adoption of energy-using and energy-producing technologies throughout the Canadian economy. E2020 accounts for the technologies in use and forecasts consumers' choices of future technologies. Consumer choices are based on both financial factors (the operating and capital costs of technologies) as well as non-financial preferences, as drawn from historical data. Technology options (with different efficiencies or powered by different fuels) are associated with different energy use and different emissions. The model forecasts future emissions first under a reference scenario, which models emissions under current conditions, and second under a policy scenario, which models emissions under the proposed policy package. The difference between the two trends illustrates the forecasted effects of the proposed policies.

The Informetrica Model (TIM) is a macroeconomic model used to assess the effect of the *Turning the Corner* policy package on the economy. Using the investments in new technology and resulting savings forecast by E2020, TIM models the effects of these factors on consumption, investment, production, and trade decisions in the rest of the economy. These effects are modelled by balancing inputs and outputs of commodities and capital. TIM includes both industry-specific and regional breakdowns.

The E3MC model is a "hybrid" model as it effectively iterates between the E2020 and TIM models by re-running one model with the outputs of the other. This iteration continues for each year in the simulation until model outputs no longer change (this stability suggests the models have found an equilibrium solution).

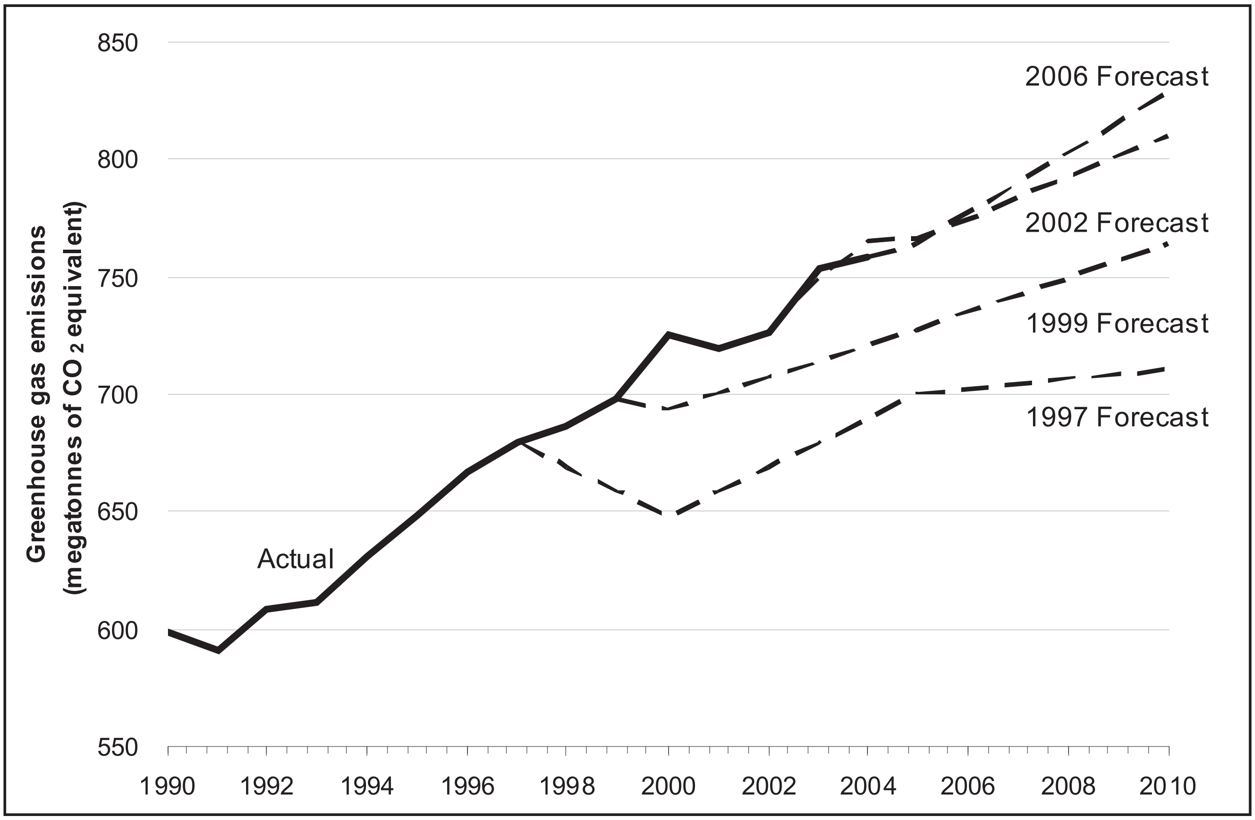
20 For details, refer to Government of Canada (2008), *Turning the Corner – Detailed Emissions and Economic Modelling*.

21 In two recent reports on long-term issues related to energy and climate change, the NRTEE used the Energy 2020 (bottom-up) model and the CIMS (hybrid) model.

22 Government of Canada (2008), p. iii–iv.

23 Please see Appendix C for a discussion on different modelling approaches.

Government Forecasts of Canadian GHG Emissions



Source: Simpson, Jaccard and Rivers (2007), p. 166.

4.3.2 Accuracy of Canada's Forecasts

As the NRTEE has conducted an evaluation of the government's policies and measures in reducing GHG emissions in the accompanying 2008 KPIA Response, this report will not contain an analysis of the government's approach and accuracy of its forecasts. However, as noted earlier in this report, the government has taken significant steps in its 2008 KPIA Plan to address the different and inconsistent forecasting methods that various federal departments used to describe the emissions reductions accruing from a particular initiative, which the NRTEE identified as problematic in its 2007 KPIA Response.

As observed by some economic experts, Canada has found it a challenge to produce consistent and accurate forecasts, "…underestimating growth of GHGs under BAU conditions."[24] These forecasts have presumably been evaluated on the assumption that BAU conditions are what Canada has had. It is important to note there has not been a recent comprehensive, technical analysis and review of the government's forecasting methodology and governance, by either an independent agency or third-party peer review.[25] In regard to the E3MC model, while there was a review of the Energy 2020 model in 2000 through the Analysis and Modelling Group (AMG) process, the model has been updated considerably since that time. There has not been, therefore, a peer review or independent analysis of the E3MC. Canada has, in the past, subjected its environment-economy models to peer review. A good example and potential approach for an independent review of the current E3MC is the 2001 Royal

24 Simpson, J., M. Jaccard, and N. Rivers (2007). *Hot Air: Meeting Canada's Climate Change Challenge*. Toronto: McLelland and Stewart, p.165.

25 The Commissioner of the Environment and Sustainable Development has conducted an audit of specific federal climate change measures but not a full, comprehensive review. For details, see http://www.oag-bvg.gc.ca/internet/English/aud_parl_cesd_200609_e_936.html.

Society of Canada *Report of an Expert Panel to Review the Socio-Economic Models and Related Components Supporting the Development of Canada-Wide Standards for Particulate Matter and Ozone*.[26] The Panel was formed in response to a request from a committee of industry stakeholders and government regulators for an objective and independent review of methods used to estimate and compare the costs and benefits of particulate matter (PM) and ozone reduction.

4.4 Case Studies

4.4.1 Introduction

The selection of case studies to provide examples of international best practices in GHG emissions forecasting is not as straightforward as may seem apparent. The original intention was to select countries with similar challenges to those of Canada in forecasting GHG policies, and that followed best practices in methodology and governance as outlined in sections 4.1 and 4.2. Countries selected as having similar economic traits to those of Canada (e.g., resource-based, export-led) were the U.S., Norway, and Australia; with jurisdictional similarities, the U.S. and Australia; and for well-acknowledged best practices, the U.K. and U.S. However, this study has revealed that very few countries follow all best practices together from both methodological and governance perspectives in their emissions forecasting. Therefore, the U.S. and the U.K. are the sole countries highlighted in this report as having overall best practices in emissions forecasting.

To be fair, the forecasting of emissions reductions from GHG policies is an evolving practice. Some countries have consistently attempted to adopt best practices from the early days of reporting emissions projections; others are only more recently making concerted efforts to improve their methodology and governance vis-à-vis forecasting. There is a discussion of this issue following the case studies.

Another original intention of this report was to highlight best practices in jurisdictions other than national-level governments, particularly some Canadian provinces and U.S. states. Given the unique jurisdictional issues of climate policy in Canada, and the fact that 16 megatonnes of annual emissions reductions in *Turning the Corner* are attributed to provincial and territorial initiatives, it is important to determine if provinces are conducting accurate forecasts of their climate policies and measures. Few provinces, however, have released detailed plans with emission policy forecasts. Nevertheless, they have set GHG emissions reductions targets and announced policies and measures to achieve these targets, but have not accompanied these with detailed emissions forecasts which would attribute specific reductions and measures to forecasts, with accompanying methodology to allow for independent validation.

This is not to say that provinces are not taking action—British Columbia is supposed to release a climate plan with detailed forecasts by summer 2008 and Alberta is also developing its own forecasts. However, it is important that all provinces produce emissions policy forecasts utilizing best practices to ensure an accurate understanding of the scale of the emissions reduction challenge in Canada and ultimately to result in coordinated or complementary policy approaches across Canada.

Even in the case of California, often touted as a North American leader in climate policy and filling a federal policy vacuum on climate change, forecasts are based on the voluntary Climate Action Registry. No systematic, independent forecasting is conducted. Considering the large scale of regional initiatives taking place (including proposed emissions trading initiatives), and the expected need for emissions trading systems to link, the collection of data and forecasting of emissions at both the federal and provincial levels is vital to ensure coherent, coordinated climate policy making for Canada as a whole.

4.4.2 United States

Approach

In the U.S., the Energy Information Administration (EIA) performs the majority of energy-based emissions forecasting. The EIA, created by Congress in 1977, is a statistical agency of the U.S. Department of Energy. Its mission is to provide "policy-neutral data, forecasts, and analyses to promote sound policy making, efficient markets, and

26 For details, see http://www.rsc.ca//files/publications/expert_panels/ozone_&_pm/Ozreport.pdf.

Table 1: Comparison of Governance and Methodology in Emissions Forecasting

	Governance	**Methodology**
United States	Independent statistical agency responsible for forecasting (EIA)	Single hybrid model (NEMS); independent peer review of forecasting model
United Kingdom	Central department responsible for forecasting with input from other departments (DEFRA); central agency coordinating climate action across departments (OCC)	Single hybrid model (M-M model); two independent audits of government forecasts; one non-governmental review of forecasts.
Norway*	Independent statistical agency responsible for forecasting (Statistics Norway); climate policy coordinated by Ministry of the Environment	General equilibrium model (MSG); commitment by government for future independent peer review of model and forecasts
Australia*	Newly-created Department of Climate Change responsible for all climate policy, including forecasting	Use of multiple models across sectors.

*Studied for the purposes of this report but not included as a best-practice case study.

public understanding regarding energy and its interaction with the economy and the environment."[27] The Department of Energy Organization Act (Public Law 95-91) allows EIA's processes and products to be independent from review by Executive Branch officials.[28] Its domestic energy projections are based on the National Energy Modeling System (NEMS), a detailed model that utilizes various modelling methodologies to represent individual domestic energy markets (electricity, refining, industrial, etc.) Confidence in the model may be reflected by the number of think tanks, academic institutions, private entities, and laboratories that use it. The EIA's Annual Energy Outlook (AEO) contains a reference case and often more than 30 alternative scenarios. In addition, the EIA publishes an assumptions document, model documentation, and an assessment of its forecasts.

In its publications, the EIA makes reference to the importance of sustained and significant levels of resource commitment to the production of national GHG emissions projections. Producing detailed forecasts and alternative policy scenarios on an annual basis requires substantial funds. Significant resources also ensure capacity in producing the forecasts and ensure that the model is based on the most recent data.

The forecasts produced by the EIA are based on current laws and regulations but the EIA does produce forecasts on future policies when directed by Congress. This issue is particularly important for Canada, as one of the issues noted in section 4.3.2 is that the *Turning the Corner* modelling analysis assumed that "provincial mitigation policies improve over time and become more consistent between provinces." Since provincial GHG reduction policies are emerging as an important issue in Canada, this distinction takes on added significance. One implication here is that future Canadian analyses might consider starting with projections of GHG emissions based on existing laws and policies and then explicitly add scenarios to reflect assumptions about improvements in provincial policies. This would give policy makers more precise information as to the challenges and opportunities surrounding

27 http://www.eia.doe.gov/neic/aboutEIA/quickfacts.html

28 Further information on the EIA can be found at http://www.eia.doe.gov.

specific policies. Such an approach would, at a minimum, increase transparency and facilitate evaluation of future forecasts.

Governance

As noted, the EIA is an independent statistical agency. The only person appointed to a position in the EIA is the Administrator. The Administrator is always an energy professional or statistician. The EIA responds to requests from Congress from all political parties. From its inception, the EIA organizing legislation was constructed in such a way as to make it as independent and free from political manoeuvring as possible. Its products are not reviewed or approved by the Administration. They go out under the signature of the Administrator.

Because it is an independent statistical agency, the EIA is often considered "unbiased." Beyond its annual projections, the EIA performs policy analyses at the request of Congress or the Administration that specifies the "policy." EIA analyses usually illustrate the impact of the policy compared to its reference case, the nature of the critical assumptions, and the uncertainty of key variables.

A corollary to the methodological issue mentioned earlier concerns the treatment by the responsible forecasting agency of analyses performed by other government departments or agencies. In the U.S., as in other countries, individual departments or agencies routinely prepare analyses of specific GHG reduction programs—typically of programs they themselves administer. For example, the U.S. EPA routinely projects emissions reductions resulting from its voluntary programs. While these agency analyses are reviewed by the EIA, they are *not necessarily adopted by the EIA*. This is an important point. Unless the agency in charge of forecasting GHG emissions has the authority/independence to make its own professional judgments about the effectiveness of individual programs, there is a potential for the forecasts to be driven by more narrow program-driven considerations rather than a more independent and integrated analysis. A perceived strength of the EIA is that it can, and does, have the authority and independence to disagree with other agencies on the forecasts they are provided with.

Audit/Review Function of Forecast Accuracy and Methodology

Audits and reviews of emissions forecasts are an important evaluation and accountability tool. Internal to the U.S. Department of Energy is an Inspector General with authority to review the EIA's products and processes. There is also the General Accountability Office that has authority to review government programs. According to communications with EIA officials for the purposes of this report, neither has expended much effort to date in reviewing EIA data or projections. Internal to the EIA, however, is an office of statistical methods that reviews documentation and hires independent experts to review model results and accuracy. Prior to publication, all of the offices of the EIA review the AEO through an established clearance process. There are also working groups composed of experts from throughout the department and industry that meet biannually and review model methodology and projections. The EIA also publishes a retrospective that evaluates its previous reference case projections.[29] Along with these processes, the EIA holds an annual conference that highlights the AEO projections and models. Its projections and models have been reviewed frequently in academic journals; it has a memorandum of understanding with the American Statistical Association; it conducts biannual meetings that often address model methodology and statistical methods; and it participates in energy modelling fora that compare and contrast modelling methodologies and results.

Beyond academic peer reviews in journals and stakeholder meetings, the only significant external evaluation of U.S. emissions forecasts have been the UNFCCC through its *Report on the in-depth review of the third national communication of the United States of America*. The report is highly complimentary of NEMS, stating "the rich representation of technology in NEMS allows analysis of the impact of mitigation policies thanks to the model's explicit representation of vintaged (time-dependent) capital (energy equipment and structures such as power plants), and tracking of its turnover rates."[30]

29 See http://www.eia.doe.gov/oiaf/analysispaper/retrospective/pdf/table18.pdf.

30 UNFCCC (2004), *Report on the in-depth review of the third national communication of the United States of America*, p.11.

4.4.3 United Kingdom

Approach

While there are a number of inputs into forecasting emissions reductions in the U.K., the Department for Environment, Food and Rural Affairs (DEFRA) coordinates and releases the emissions forecasts on an annual basis. The U.K. MARKAL-Macro Energy Model (M-M model) has been the main model to explore the technological and macroeconomic implications of reducing U.K. domestic carbon emissions by its declared target of 60% by 2050. The M-M model is an integrated energy-macro model, covering the entire energy system in considerable technological detail, including electricity generation, heat, and transport. The model explores how, under different assumptions about future fossil fuel prices and the pace of technological innovation, the energy system will evolve under a carbon constraint, and what the macroeconomic implications to the U.K. economy might be, including the costs to GDP. The main driver for increased emissions is economic growth, as described by the macro module of the model apparatus. Because the M-M model describes the economy in equilibrium, it is unable to capture transition costs that might occur as the economy adjusts to changes in energy policy or prices. As a U.K- only model, it also does not capture the implications for U.K. trade and competitiveness as a result of policies aimed at reducing carbon emissions. Therefore, in addition to the M-M analysis, the U.K. government has also used the Oxford Energy-Industry Model (OEIM) and global macroeconomic model (GMM) to explore the potential short- to medium-term adjustment costs associated with moving to a low carbon economy. As a purely domestic model, the M-M model also cannot explore the implications of international carbon trading.

The way in which activity data are broken down to estimate emissions closely resembles the basis on which the government monitors economic activity. As a result, much of the economic activity data gathered by government is already classified in a format that can facilitate estimates of emissions. One of the major sources of activity data, covering around 85 per cent of emissions, is the Digest of U.K. Energy Statistics (DUKES) produced annually by the Department of Business, Enterprise and Regulatory Reform. It is the most authoritative source of annual data on energy use in the U.K. The rest of the data activity comes from a variety of sources, including the Transport and Environment Departments. Many of the data providers are government departments but some of the data used to estimate emissions come from trade associations and directly from industry.

Governance

While DEFRA coordinates and releases emissions forecasts in the U.K., the newly-created Office of Climate Change (OCC) will work across the U.K. government to support analytical work on climate change and the development of climate change policy and strategy. Many government departments are involved in climate-related activities or in helping the U.K. and other countries adapt to its possible future impacts. All departments utilize the OCC.

The Climate Change Bill, which is currently being subjected to a full public consultation alongside pre-legislative scrutiny in Parliament, sets out a fundamentally new and more structured approach to the setting of emissions reduction targets and the monitoring of performance against them. It will translate into U.K. legislation, the goal of which the government announced in its 2003 White Paper—namely, a 60 per cent reduction in carbon dioxide by 2050 measured against a 1990 baseline. It will create a system of five-year carbon budgets to place the U.K. on a trajectory to meet its long-term goal, and require the Secretary of State for the Environment to set and meet carbon budgets for up to 15 years in advance. A newly created Committee on Climate Change will be responsible for advising the government on the level of carbon budgets to be set, and for monitoring emissions through annual reports to Parliament that will include a more comprehensive assessment of performance after the end of each five-year budgetary period.

Audit/Review Function of Forecast Accuracy and Methodology

The forecasting of GHG emissions reductions has been the subject of at least two audits[31] by the U.K. National Audit Office. Of the countries researched

31 National Audit Office (2006), *Emissions Projections in the 2006 Climate Change Programme Review*; National Audit Office (2008), *U.K. greenhouse gas emissions: measurement and reporting.*

for this report, the U.K. is the only one to have had its entire emissions forecasting measurement and reporting audited by an independent third party. The audit had a number of key findings:

- The U.K. will meet or exceed its Kyoto target on all but the most pessimistic assumptions, and will fall short of its 2010 domestic target in all but the most optimistic assumptions.
- Forecasts made in 2000 have been revised to reflect a reduction in the expected savings from individual policy measures, changes in fossil fuel price assumptions, and gradual refinements to the former Department of Technology and Innovation's (DTI) energy demand model and adjustments to the 1990 baseline. A degree of change in projections is to be expected; the U.K. government recognized that the 2000 estimates were subject to considerable uncertainty.
- The forecasts are based on sophisticated modelling approaches. The models are subject to expert review and other quality assurance processes.
- U.K. Government has taken steps to make the 2006 forecasts more robust than those in 2000. The review of projected policy impacts that took place in 2006 involved a more skeptical scrutiny of the emission reductions to be expected from policy measures. There was also more detailed analysis of uncertainty.
- Forecasts against the 2020 and 2050 domestic targets to reduce CO_2 are less well developed and necessarily more speculative. As the 2010 target approaches, it is important to switch attention to the realism and delivery of these future targets.
- International reporting requirements specify the basis on which emissions should be estimated. The U.K.'s estimates follow best practices and have been reviewed favourably by international experts in GHG measurement appointed by the UN.
- The Climate Change Bill provides a new framework for setting U.K. targets. Its provisions will introduce concepts such as the "net U.K. carbon account" and requirements to account for the contribution made by carbon credits and debits from emissions trading schemes. Such provisions could complicate the reporting framework further, or else provide an opportunity to develop a more comprehensive and transparent basis for presenting climate change statistics.[32]

The forecasting of emissions in the U.K. was also the subject of an audit undertaken by University College London's Environment Institute. In its report entitled *U.K. Greenhouse Gas Emissions: Are We on Target?* the Environment Institute found that while the U.K. GHG emission target of a 12.5% cut to the baseline levels required by the Kyoto Protocol will be met, the emissions reductions forecast for the 2020 target will be difficult to meet because of continued significant economic growth that will cause emissions to rise after 2010. The audit suggests current policies would achieve a GHG emission reduction between -12 and -17 per cent by 2020 as opposed to the government's policy aim of -30 per cent. The audit states that the overriding reasons for the possible failure of current government policies to achieve their stated targets is that nearly all the policies are voluntary.

In its *Report of the centralized in-depth review of the fourth national communication*, the UNFCCC commends the U.K. for its emissions projections.[33] The U.K. was also commended not only for its consistency with earlier reports, but the transparent and concise nature of its report. The U.K. is further commended for not only including a "with measures" scenario, but a baseline scenario and two "with additional measures" scenarios (including the effect of planned measures). From a governance perspective, the U.K. received praise for the establishment of the Climate Change Projects Office (CCPO), the appointment of a designated national authority for the Clean Development Mechanism (CDM), and the appointment of a designated focal point for joint implementation (JI) projects. The UNFCC further commended the U.K. for its role in the development of the registry software and finally, "lauds the U.K. for its solid and coherent program of action."[34]

32 National Audit Office (2008), *U.K. greenhouse gas emissions: measurement and reporting*, p.5.

33 The NRTEE expressed similar concerns to the Canadian government in its 2007 KPIA Response.

34 UNFCCC (2007), *Report of the centralized in-depth review of the fourth national communication of the United Kingdom of Great Britain and Northern Ireland*, p.18.

5. Discussion

While the case studies yield many interesting findings in relation to best practices in GHG emissions forecasting, it is important to determine to what extent the case studies follow the best practices criteria discussed in sections 4.1 and 4.2. It is also important to understand how forecasting methodology and governance relate to one another. Is one dependent on the other? Does strong methodology alone lead to strong forecasts? Is it possible for countries to have accurate forecasts without strong governance in climate policy? Is strong governance a key factor in determining accurate forecasts?

As both the U.S. and U.K. approaches are subject to extensive peer review and rigorous analysis and constant updating, it is likely from a methodological perspective that they produce accurate emissions forecasts.

From a governance perspective, it is preferable to have one central agency or group undertaking or coordinating emissions forecasting. It does not, however, necessarily detract to have several sources of forecasts, arising from competition among forecasters and also from the characterization of model uncertainty facilitated by multiple models. This is *only* preferable, however, if the oft-cited case of multiple forecasters who do not communicate with each other, do not compare results, and do not learn from each others' errors, is avoided. But multiple forecast groups who talk, compare, and learn may produce better forecasts than just one group. Only in this circumstance, but still with the coordination of a central agency, could a multi-source approach to emissions forecasting be useful.

It is also important to bear in mind that different agencies within government obviously have different problems to solve and different policy and program objectives, so that different models may help get the appropriate answers they individually need.[35] This does not mean, however, that this should be replicated for the complex, integrated challenges of large-scale GHG emissions forecasting, which is the Canadian government's current approach. However, instead of individual departments submitting their estimates to Environment Canada, a preferable solution within this approach would be to require the different departments that produce the various forecasts to meet regularly to compare results and attempt to arrive at consensus on common questions of interest, or at least learn from others' attempts. Even if no consensus is possible, the variety of results might provide an indication of uncertainty attributable to a lack of knowledge of the primary model.

In the area of governance, both the U.S. and U.K. received praise from the UNFCCC for the consistency in their approaches to forecasting. Aside from the U.S. and U.K., it is important to note the recent commitments by the other governments studied for the purposes of this report but not included as best-practice countries; the Norwegian and Australian governments have made commitments to independent peer review, centralized forecasts, and developed ambitious climate policy (including aggressive reduction targets) in general. This is especially of interest to Canada as these governments face similar economic and jurisdictional challenges.

With the exception of the U.K., the other case studies (U.S., along with Norway and Australia) reveal the lack of independent reviews by government auditors on the accuracy of emissions forecasts. In the case of the U.K., audits by an independent federal authority and an academic research institute can be said to improve understanding and credibility of its forecasts.

An important issue is the criticism levelled at all governments by the UNFCCC (and in the case of the U.K., its own independent auditors) on the significant forecasted emissions reductions attributed to *voluntary* measures. There is extensive literature on the limited success of attributing a level of specific emissions reductions as a result of voluntary measures. For example, studies highlight the paucity of credible evidence on the performance of voluntary programs compared to a realistic baseline.[36] In its 2007 KPIA Response, the NRTEE noted that with

35 For example, a specific program or measure (i.e., fuel efficiency vehicle programs) may require a different forecasting model than one designed for large-scale, integrated modelling.

36 Morgenstern, D. and W.A. Pizer (eds) (2007), *Reality Check: The Nature and Performance of Voluntary Environmental Programs in the United States, Europe and Japan*. Washington, D.C.: RFF Press.

"few exceptions, little evidence exists through which one can evaluate the incremental effect of information-provision programs for emissions control or energy conservation."[37] This reliance on voluntary programs can therefore raise questions about the likelihood that the emissions forecasts from these measures will be accurate. For example, past emissions forecasts in Canada have relied on voluntary measures and programs to deliver significant reductions and in all cases have overestimated the forecast emissions reductions. Attributing significant emissions reductions to voluntary measures will by their very nature continue to result in inaccurate emissions forecasts. In this way, the governance and methodological issues raised in our analysis point to the need for policy makers to consider alternative climate policy measures to achieve desired GHG emissions reductions.

How strong is the link between good forecasting methodology and good forecasting governance in producing accurate emissions forecasts? From a governance perspective, all countries studied for the purposes of this report reveal that strong, central departments or agencies with independence should be responsible for emissions forecasting. In the case of the U.S., an independent statistical agency is responsible for producing its country's GHG emissions forecasts.[38] Where there is not an independent statistical agency responsible for forecasting (e.g. the U.K.), there is strong political commitment and centralized governance structures in place. Therefore, a significant finding (as noted in section 4.4.2) is that unless the agency in charge of forecasting GHG emissions has the authority or independence to make its own professional conclusions about the effectiveness of individual programs, there is a potential for the forecasts to be driven by more narrow program-driven considerations rather than a more independent and integrated analysis aimed at overall GHG emissions forecasting.

5.1 Lessons for Canada

While the above discussion, and key findings summarized in the conclusion below, provide important insight for Canada on potential areas to explore in its approach to emissions forecasting, it is important to determine key lessons from the case studies that can be applied to the Canadian context.

Independence of Agency/Department Responsible for Forecasting

In the U.S., as in other countries, individual departments or agencies routinely prepare analyses of specific GHG reduction programs – typically of programs they themselves administer. For example, the U.S. EPA routinely projects emission reductions resulting from its voluntary programs. While these agency analyses are reviewed by the EIA, they are not necessarily adopted by the EIA. This is an important point. Unless the agency in charge of forecasting GHG emissions has the authority/independence to make its own professional judgments about the effectiveness of individual programs, there is a potential for the forecasts to be driven by programmatic rather than analytic considerations. A perceived strength of the EIA is that it can and does have the authority and independence to disagree with other agencies on issues of this sort.

At the federal level in Canada, the closest existing body in terms of governance to the EIA would be Statistics Canada. While it does not currently undertake emissions forecasting, it collects emissions data for Environment Canada's GHG emissions inventory. Through legislation, Statistics Canada could be given the responsibility and sole authority to produce Canada's emissions forecasts. The independence of Statistics Canada would ensure that emissions forecasting would be free from interference and that it would have the authority to question and if necessary reject emissions reductions estimates from government departments. Alternatively, the federal government could also follow the example of

37 NRTEE (2007), *Response of the National Round Table on the Environment and the Economy to its Obligations under the Kyoto Protocol Implementation Act*, p. 32.

38 Statistics Canada – Canada's independent, federal statistics agency – collects emissions data for the purpose of *reporting*, not forecasting.

Australia and create a new federal department or agency responsible for all climate change policy, including forecasting.

Clearly Articulated Legislated Roles, Responsibilities, and Milestones for Climate Policy

The U.K. Climate Change Bill, which is currently being subjected to a full public consultation alongside pre-legislative scrutiny in Parliament, sets out a fundamentally new and more structured approach to the setting of emissions reduction targets and the monitoring of performance against them. It will translate the goal the government announced in the 2003 White Paper into legislation—namely, a 60 per cent reduction in carbon dioxide by 2050 against a 1990 baseline. It will create a system of five-year carbon budgets to place the U.K. on a trajectory to meet its long-term goal and require the Secretary of State to set and meet carbon budgets for up to 15 years in advance. A newly created, external Committee on Climate Change will be responsible for advising the government on the level of carbon budgets to be set, and for monitoring emissions through annual reports to Parliament that will include a more comprehensive assessment of performance after the end of each five-year budgetary period.

Canada should consider a truly integrated long-term climate policy with similar characteristics. Given the comprehensive nature of the climate challenge, which crosses a range of government departments (not just environment), a central policy development and coordination body that links policy and program choices with integrated emissions forecasting would likely result in more confidence in the efficacy of proposed emissions reduction measures. Legislating its role and mandate to incorporate independent forecasting and evaluations would further strengthen its effectiveness and confidence in the policy approaches being pursued. Providing an external review or audit of emission forecasts would complete this new approach.

The Role of Provinces and Territories

An original intention of this report was to highlight best practices in jurisdictions other than national-level governments, particularly some Canadian provinces and U.S. states. Given the unique jurisdictional issues of climate policy in Canada, and the fact that 16 megatonnes of annual emissions reductions in *Turning the Corner* are attributed to provincial and territorial initiatives, it is important to determine if provinces are conducting accurate forecasts of their climate policies and measures.

With its past two reports on long-term issues related to climate change and energy,[39] the NRTEE has consistently called for a coordinated, national approach to climate change issues in Canada. If the federal government is to produce accurate national emissions forecasts and ensure adopted policy measures achieve forecast reductions, there needs to be better coordination and understanding of projected emissions reductions from provinces' climate policies and measures. There also needs to be a better understanding among governments in Canada as to various approaches to forecasting and how consistent methods can be applied to ensure accurate forecasts of GHG emissions reductions. Provinces should be encouraged to develop and release detailed emissions forecasts to inform their own policy choices necessary to meet the reduction targets they have set for themselves.

Scenario-Based Emissions Policy Forecasting

The U.S. EIA's reference case projections are based on current laws and regulations with additional forecasts incorporating future policies. This issue is particularly important for Canada, as one of the concerns noted in section 4.3.2 is that the *Turning the Corner* modelling analysis assumed that "provincial mitigation policies improve over time and become more consistent between provinces." As noted in the NRTEE's 2008 KPIA Response, potential future emissions reductions from provincial actions are counted as realized emissions reductions.

39 NRTEE (2006), *Advice on a Long-term Strategy on Energy and Climate Change*; NRTEE (2008), *Getting to 2050: Canada's Transmission to a Low-Emission Future.*

Scenario-based emissions policy forecasting can help address this concern. Future Canadian analyses might consider starting with projections of GHG emissions based on existing laws and policies and then explicitly add scenarios to reflect assumptions about improvements in provincial policies. This same, scenario-based approach can be extended to policy-level analysis, presenting a forecast of economy-wide emissions with and without the policy in place, each in a scenario where all other policies are in place. This provides an estimate of the marginal or incremental effect of the policy including adjustments for *free-ridership* and *policy interaction effects*, and depending on the structure of the model, *rebound effects*. These estimates could be included along with the current policy-level analysis or as replacement for them. Such an approach would, at a minimum, increase transparency and facilitate evaluation of future forecasts.

6. Conclusions

The NRTEE's research and analysis of international best practices in GHG emissions forecasting leads it to conclude the following:

From a *methodological* perspective:

- Hybrid energy-economy models are more effective in producing accurate GHG emissions forecasts as they integrate the strengths of both the traditional bottom-up and top-down approaches to modelling emissions forecasts;
- The use of a consistent baseline from year-to-year (including baseline data), assumptions, and conditions across the board is fundamental to ensure emissions forecasts can be accurately compared from year to year;
- The use of consistent and agreed definitions of terms and concepts, such as for free ridership and additionality, across government departments involved in forecasting would ensure greater transparency of emission forecasts and facilitate assessment of the forecasts' accuracy.
- There is need for an international perspective in the model so that it can respond appropriately to world events (since in most cases, Canada is a price taker for both commodities and energy, and a primary trader of goods and energy). Canada is acting in concert with other countries on climate policy and its forecasting approaches need to reflect this reality.

From a *governance* perspective:

- Use of an independent forecasting agency is preferable to provide more accurate and transparent emission forecasts for consideration by government policy makers, external analysts, and Parliamentarians and to facilitate ongoing audit and evaluation.
- Multi-source emissions forecasting from a group of individual government departments can be accurate, but works best both when centrally coordinated and with independent authority by the central coordinating department or agency to question other departmental forecasts.
- Regular independent reviews, audits and evaluations of government forecasts and forecasting methods by a third-party agency or process helps ensure accuracy of forecasts and that forecasting methodologies are up-to-date and robust.
- Forecasting must be sufficiently resourced and financed by governments to ensure data is up to date and most recent improvements in forecasting methodologies are incorporated for the benefit of policy makers taking decisions based on these forecasts.
- Regular, ongoing evaluation of past forecasts for accuracy and effectiveness is necessary to ensure continuous improvement of government forecasting methodologies and approaches.
- Ensure transparency and clarity with respect to key assumptions and methods.

Good climate change policy stems from accurate emissions forecasting. It is the first building block. The public must have confidence that their government's GHG policies and measures will result in the emissions reductions promised by political leaders. The government has taken a significant step in the right direction with its 2008 KPIA Plan.

Most countries face similar challenges in producing accurate forecasts for emissions reductions from policies and measures. As highlighted in the introduction to this report, the NRTEE, recognizing that forecasting is difficult and challenging not only in Canada but in all countries, wanted to provide the federal government with examples of how other governments approach and produce emissions forecasts. The case studies show there are few countries that truly utilize all best practices, from both methodological and governance perspectives, in their approaches to emissions forecasting. However, there are best practices in other countries that could be applied to the Canadian context.

The NRTEE hopes that these international best practices can provide insight to the federal government on how best to address some of Canada's forecasting challenges as identified in the 2007 KPIA Response—those of transparency and clarity with respect to key assumptions and methods; the consideration of important sensitivities and uncertainties; the importance of consistency in approach across various departments, programs, and measures; and the need to integrate findings in a holistic framework.

While the NRTEE appreciates the extent to which the federal government addressed these challenges in its 2008 KPIA Plan, it encourages the government to continue improving its methodology and governance in its approach to emissions forecasting.

Appendix A:
List of Abbreviations and Acronyms

AEO	Annual Energy Outlook (annual report on domestic energy-based emissions—U.S.)
AMG	Analysis and Modelling Group
BAU	Business-as-usual
CCPO	Climate Change Projects Office
CDM	Clean Development Mechanism
DEFRA	Department of the Environment, Food and Rural Affairs (U.K.)
DTI	Department of Technology and Innovation (U.K.)
DUKES	Digest of U.K. Energy Statistics
EIA	Energy Information Administration (U.S.)
E3MC	Energy-Economy-Environment Model for Canada
GDP	Gross domestic product
GHG	Greenhouse Gas
GMM	Global macroeconomic model (U.K.)
IEA	International Energy Agency
IEO	International Energy Outlook (annual report on international energy-based emissions—U.S.)
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
KPIA	*Kyoto Protocol Implementation Act*
M-M Model	MARKAL-Macro Energy Model (U.K.)
MSG	Norwegian equilibrium model
Mt	megatonne
NEMS	National Energy Modeling System (U.S.)
NRTEE	National Round Table on the Environment and the Economy
OCC	Office of Climate Change (U.K.)
OEIM	Oxford Energy-Industry Model (U.K.)
PM	particulate matter
UNFCCC	United Nations Framework Convention on Climate Change
WEO	World Energy Outlook (annual report of the IEA)

Appendix B: Description of *Additionality, Free-ridership, Rebound Effect,* and *Policy Interaction Effects*

There are four key reasons the emissions reductions were overestimated in the Government of Canada's 2007 KPIA Plan. First, the estimates of the reductions generated by the various initiatives suffered from biases related to *additionality* (including *additionality* concerns resulting from a lack of accounting for *free-ridership*). Second, the *emissions-reduction factors* used in the calculations were, in some cases, not consistent with recent scientific evidence. Third, *rebound effects* were not always taken into account in the estimates. Finally, policies were treated independently, so *policy-interaction effects* are ignored.

Problems of *additionality* arise when the stated emissions reductions do not reflect the difference in emissions between equivalent scenarios with and without the initiative in question. If emissions reductions from an initiative have already been included in the reference case, these emissions reductions will be double-counted.

A key source of *additionality* issues that arises frequently and so was treated separately in the NRTEE's 2007 KPIA analysis is the failure to account for *free-ridership*. *Free-ridership* is not properly accounted for when stated reductions include the results of behaviour that is rewarded but not influenced by the policies. This can occur when subsidies are paid to all purchasers of an item, regardless of whether they purchased the item because of the subsidy. Those who would have purchased the product regardless are termed *free-riders*, and their behaviour (since it would have happened regardless of the policies) has already been accounted for in the reference case. Not correcting for this implies that induced emissions reductions will be overestimated by the proportion of *free-riders*, which has been estimated to be between 40% and 80% (NRTEE, 2005).

The *rebound effect* describes the increased use of a more efficient product resulting from the implied decrease in the price of use: for example, a more efficient car is cheaper to drive and so people may drive more. While estimates vary, emissions reductions will generally be overestimated by between 5% and 20% if estimates do not account for increased consumption due to the *rebound effect*.

The relative successes of emissions-control policies will be interdependent, and an evaluation framework that takes this into account is important for proper interpretation of stated results. The 2007 Government KPIA Plan provides results from separate evaluations of individual policies, while these are slated to be imposed simultaneously. This approach omits any *policy interaction effects* and will only be accurate when the sum of all individual policy effects is equal to the total effect of all policies, which is not likely to be the case. A general finding of the NRTEE's 2007 KPIA Response, which is consistent with the statement above, is that in order to deliver a statement of total expected emissions reductions, all policies should be imposed simultaneously in a modelled economy.

Appendix C:
Discussion of Top-down, Bottom-up, and Hybrid Approaches to Energy-Economy Modelling

Energy-economy models generally range from detailed bottom-up models reflecting engineering economic details of a wide menu of technologies in each sector, to top-down models of the whole economy calibrated on historic data from a few to hundreds of sectors. Hybrid models—those that combine the strengths of the bottom-up and top-down approaches—are considered by many modelling authorities as optimal approaches to forecasting.[40]

The essential element in a bottom-up model is that it is a model of individual units in a system, in which aggregate properties are then deduced from the behaviour of the individual units. For example, in a bottom-up model of soft drink consumption in a group of teenagers, we would look at the soft drink consumption of each teenager, and then add them up to get the group's consumption. By contrast, a top-down model begins with a model of the aggregate; an attempt may be made to deduce properties of sub-units from the aggregate. In a top-down model of the group of teenagers, total soft drink consumption by the group is modelled, and then we try to allocate it among individuals.

Weaknesses in traditional top-down models include the fact that they do not explicitly represent the technologies in the energy system, so policies designed to influence technology evolution directly can only be crudely simulated at best. Bottom-up models are based on theoretical assumptions about human behaviour, with the result that their predictions do not represent the economic system. Because of their different structures and definitions of costs, the two types of models tend to predict very different economic structures. Top-down models usually predict high costs of GHG emission reduction policies while bottom-up models usually predict low costs. In order to address these weaknesses, modellers have attempted to create hybrid models that integrate the strengths of both the bottom-up and top-down approaches.[41] Such hybrid energy-economy models have attempted to bridge the methodological schism between top-down and bottom-up approaches by meshing the description of the economy in terms of specific technologies (as in bottom-up models) into an integrated energy-economy model.

In Canada, both the E3MC and CIMS models are hybrid models used by a variety of actors. Hybrid models used in the U.S. and U.K. are NEMS and the U.K. MARKAL-Macro Energy Model.

40 Rivers, N. and M. Jaccard (2005). "Combining Top-Down and Bottom-up Approaches to Energy-Economy Modeling Using Discrete Choice Methods," *The Energy Journal*, Vol.26, No.1; Grubb, M (1993) "Policy Modeling for Climate Change: The Missing Models" *Energy Policy*, 21(3); Intergovernmental Panel on Climate Change (IPCC) (1996), *IPCC Second Assessment Report: Climate Change 1995*.

41 Grubb (1993), Hoffman and Jorgenson (1977), Jacobsen (1998), Bohringer (1998), and Koopmans and te Velde (2001) have all designed hybrid models.

Appendix D:
Glossary of Useful Modelling Terms

TERM	DEFINITION
Behavioural parameters	Parameters in CIMS used to more realistically represent consumer preferences for technologies. They include **discount rate**, representing time-value preferences; heterogeneity, representing the extent to which different consumers have different preferences for technologies and thus perceive costs and benefits differently; and **intangible costs**, representing non-financial costs associated with specific technologies, such as the greater risk associated with new technologies or technologies with longer payback periods.
Behavioural Realism	A criteria for assessing model usefulness; the extent to which consumer choices—and their response to price signals—is incorporated into a model and supported through empirical means.
Bottom-up models	Techno-economic models that have extensive technological detail, but provide overly optimistic emissions forecasts, since they assume new technologies are perfect substitutes for older ones, and that consumers always will choose the least-cost technology option. Bottom-up models also typically do not include feedbacks with the economy as a whole.
CIMS	A technology vintage model that forecasts emissions via the turnover of energy-using and energy-supplying technology stocks. CIMS models consumers' choices of new technologies.
Computable General Equilibrium (CGE) Models	A specific type of top-down model that models multiple markets in equilibrium with each other in an economy.
E3MC	The Energy-Economy-Environment Model for Canada, which is Environment Canada's emission forecasting model. Essentially the model consists of the Energy 2020 and TIM models linked together.
Energy 2020	A technology vintage model that forecasts emissions via the turnover of energy-using and energy-supplying technology stocks. Energy 2020 models consumers' choices of new technologies.
Hybrid Models	Models that combine the strengths of **top-down** and **bottom-up models**. CIMS and Energy 2020 are examples of hybrid energy-economy models.
Macroeconomic completeness	A criterion for assessing model usefulness; the extent to which interactions between the energy sector and the economy as a whole are represented in a model. This criterion particularly affects how useful the model is in assessing the costs of policy options to the economy.
Technological Explicitness	One criterion for assessing model usefulness; the extent of detail in which a model includes specific energy-using and supplying technologies.
TIM	The Informetrica Model—a macroeconomic model that examines the economy as a whole. TIM would be useful for examining issues such as trade and economic impact of policies. TIM can be linked to microeconomic models focusing specifically on the Canadian energy system.
Top-down models	Models that represent the energy-use, technological change, and the economy as whole at an aggregate level. These models typically do include macroeconomic effects and realistically represent consumer behaviour. They usually lack any detailed representation of technologies.

Notice to Reader

This report was reviewed by the following well-respected economic experts:

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