Is there a future for new hydrocarbon projects in a decarbonizing energy system? A case study for Quebec (Canada)

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HIGHLIGHTS
• Prospective energy scenarios for the Province of Quebec under GHG reduction targets.
• Impacts of developing new hydrocarbon projects on future GHG abatement costs.
• Use of a TIMES optimization energy model to derive socially optimal solutions.
• Revenues from hydrocarbon exports do not compensate for the higher long-term mitigation costs.

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ABSTRACT
This paper proposes energy scenarios to 2050 for the Province of Quebec under GHG emission reduction constraints with and without new hydrocarbon exploitation. The main objective is to measure the impact of new hydrocarbon projects on achieving stringent GHG reduction objectives (upto ~ 80%). Our analysis relies on the North American TIMES Energy Model (NATEM), which belongs to the MARKAL/TIMES family of models supported by the International Energy Agency. In terms of hydrocarbon exploitation, we consider a recent project proposed by the oil industry for exploiting deposits on Anticosti Island. In our GHG reduction scenarios, the results indicate that the hydrocarbons of Anticosti Island would be exported and thus have virtually no effect on the energy consumption mix in Quebec. This mix would be significantly transformed by the 2050 horizon, through numerous energy efficiency measures yielding reductions in final energy consumption, a massive electrification of end-use sectors, and an increased reliance on bioenergy. However, the 2050 GHG emission levels would increase by nearly 7% in the reference (baseline) case. Greater total GHG reductions would thus be required from the baseline at a significantly higher marginal cost.

1. Introduction

The effects of global warming have been a growing concern internationally for several decades. These concerns culminated in 2015 at the 21st Conference of the Parties of the UNFCCC (COP21) in Paris, where more than 174 countries and the EU acknowledged the need to significantly reduce their GHG emissions [1]. For example, Canada aimed at a 30% reduction below 2005 levels by 2030; China pledged to peak its emissions by 2030 at the latest and to reduce its carbon intensity of GDP by 60–65% from 2005 levels; and the EU pledged to decrease its emissions by 40% by 2030 and by 80–95% by 2050 from 1990 levels [2]. While exact strategies for meeting these targets have not been presented in detail, it is generally agreed that countries will need to expand the use of renewable energy, develop more efficient technologies, and limit emissions by implementing new regulations and/or economic mechanisms such as carbon taxes or carbon trading [3].

In some countries, switching energy production from coal to natural gas, for example, could be enough to meet their reduction objectives. For others, the challenge is more complex. One such region is the Province of Quebec, which has set more ambitious GHG reduction targets than Canada, namely: 20%, 37.5%, and 80–95% (from 1990 levels) by 2020, 2030, and 2050, respectively [4]. However, the province already relies on an electricity mix that is one of the least carbon-intensive in the world: nearly 99% renewable energy, 95% of which is hydroelectricity. Moreover, it implemented a cap-and-trade program in
2013, which expanded in 2014 with the addition of California, and will be joined in 2018 by the Province of Ontario. Even with all these efforts, Quebec is presently emitting around 81 Mt CO2-eq per year, a decrease of only 8.6% relative to 1990 levels [5], with 43% of the emissions coming from the transport sector, 30.8% from the industrial sector, 9.5% from the residential and commercial sectors, 9.2% from the agricultural sector, 7.2% from waste management, and 0.3% from the electricity production sector. Without solutions that can be easily imported, Quebec needs an in-depth analysis to determine the most cost-efficient option(s) to meet the ambitious targets.

In parallel, the province has recently been looking into hydrocarbon extraction. As in several other jurisdictions on the continent (e.g., the Bakken Basin in North Dakota), the exploration and exploitation of new hydrocarbon deposits is attractive for energy security issues and additional profit opportunities. However, the hydrocarbons in Quebec are mostly shale gas and shale oil. To date, only hydraulic fracturing has proved effective, and this requires considerable equipment and poses risks to the environment. However, an extraction project on Anticosti Island, located at the outlet of the Saint Lawrence River into the Gulf of Saint Lawrence, was considered. The Quebec government decided not to proceed with this project, and this stand has been criticized by the main opposition party in the province. The political decision not to exploit Anticosti Island could be reversed in the future. Moreover, the Energy Minister of Quebec has recently asserted that the province will exploit its hydrocarbon reserves [6]. Under that scenario, would it still be possible to meet the ambitious reduction targets? And at what additional cost? Our paper provides insight into these issues as a contribution to the current energy and climate policy debate in Quebec.

This paper proposes scenarios to 2050 for energy consumption and production for Quebec under GHG emission reduction constraints with and without new hydrocarbon extraction. The main objective is to measure the impact of new hydrocarbon projects on achieving stringent GHG emission reduction targets. The analysis is based on the North American TIMES Energy Model (NATEM), which is a highly detailed multi-regional optimization model for Canada [7,8]. NATEM belongs to the MARKAL/TIMES family of models supported by the Energy Technology Systems Analysis Program (ETSAP) of the International Energy Agency [9,10]. We analyze six scenarios to simultaneously assess the impact of meeting the provincial GHG reduction targets for the energy system, with and without hydrocarbon development on Anticosti Island. Moreover, we carry out a sensitivity analysis to further explore the role of behavior changes in the context of climate-change mitigation policies. Quebec has set an ambitious 37.5% GHG reduction target for 2030, but to date no specific action plan supported by rigorous analyses has been proposed to achieve this goal. This paper thus brings new and relevant information about the sectors to be targeted and the priority actions to be implemented to achieve this target with or without hydrocarbon exploitation. Furthermore, an original contribution of our paper is that we provide possible energy transition pathways that can achieve Quebec’s long-term vision of an 80% GHG reduction by 2050. Finally, we contribute to the assessment of the complex relationship between energy security and climate-change mitigation using a detailed energy system model for the long-term (2050), whereas the literature mostly relies on simplified indicators, as reported in [11].

The paper is organized as follows. Section 2 briefly introduces the NATEM model. Section 3 presents the different scenarios and their underlying assumptions. Section 4 gives an overview of the main results in terms of GHG emissions, energy profiles, and mitigation costs. Section 5 briefly discusses these results. Section 6 concludes with a summary of the key points and limitations of the study.

2. Methodology

2.1. TIMES energy model generator

NATEM was developed based on the TIMES optimization model generator [9]. A TIMES model describes the entire integrated energy system of a region through specific technologies with their techno-economic attributes and emission coefficients. The model is demand-driven: end-use demands for energy services are specified exogenously over a specific time horizon.

TIMES is a dynamic linear programming model that maximizes net total surplus (the sum of consumer and producer surpluses), which is operationally achieved by minimizing the net total discounted cost of the whole energy system. The main model outputs are technology-specific investment and activity levels for each specified time period; the shadow price of each energy, material, and emission commodity; and the reduced cost of each technology. The main model assumptions (and thus the main limitations) concern future technological developments and the structure of energy markets. On the one hand, technological progress is exogenously assumed, and economic agents have a perfect foresight of this. On the other hand, energy markets are assumed to be under perfect competition. Moreover, TIMES considers only energy markets, and thus not all markets in the economy. From that perspective, TIMES computes only a partial equilibrium on energy markets. However, TIMES models include own-price elasticity of demand, allowing for behavioral changes and their impact on the energy system to be captured through endogenous changes in demand in constrained scenarios (i.e., GHG reduction scenarios) compared to the baseline. Finally, the traditional limitations of a linear-programming approach (e.g., the “bang-bang” behavior of the solution) are traditionally dealt with using carefully designed constraints (e.g., market penetration constraints).

TIMES models are currently used in nearly 70 countries for climate policy analysis. Indeed, these models enable one to capture in particular substitutions of energy forms (e.g., switching to low-carbon fuels) and energy technologies (e.g., use of battery-electric vehicles instead of vehicles equipped with an internal combustion engine running on conventional fuels) to comply with climate policy targets (GHG emission limits). Important insights can be gained from the use of optimization models, namely the ranking of the technology options that are most likely to play a significant role in the future energy system of a given region as well as the marginal costs of energy commodities and GHG reductions. The role of optimization models in the exploration of clean energy transition pathways has been effectively demonstrated in specific regions through a variety of scenario definitions, including GHG emission targets compared with a specific past target year [12–15] or a specific baseline [16,17], temperature goals such as the 2°C target [18,19], and renewable penetration targets [20,21].

Similarly, optimization models are powerful decision support tools for addressing energy policies or new hydrocarbon project developments (especially natural gas) that can potentially maintain or improve the energy security in a given region. The role of hydrocarbons in low-carbon energy systems has been studied in several publications. In the US for instance, the energy security and climate-change issues associated with the boom of the shale gas industry have been studied using a MARKAL model [22]. Multiple scenarios were defined to identify how energy security could be maintained while meeting other environmental challenges through carbon pricing and regulation of the power sector. The complex trade-offs between climate change and energy security policies have been analyzed for the EU using a multi-regional optimization model and a theoretical approach to address the multidimensional nature of energy security through the whole energy supply chain [11]. Other studies (in Pakistan [23] and Ireland [24]) look at the impact of reducing fuel imports on the diversification of supply, costs, and GHG emissions. The role of natural gas as a potential bridge to a deep decarbonized energy system in the UK has been explicitly addressed using two optimization energy system models [25]. Optimal solutions for natural gas distribution in China, minimizing both the economic cost and the external cost of pollutants, are presented in [26], including the impact on CO2 emissions.

Obviously, these complex challenges have also been studied using
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