Analysis of the Robustness of Canada Economy and Energy Supply/Demand Fluctuations

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ABSTRACT

It is well-known that energy has an important role in social and economic improvements. Understanding the relationships between energy-related issues and the economic growth is crucial for the development of reliable and appropriate energy policies and for handling the possible economic local or regional impacts. Considering Canada as a case study, this article investigates the relationships among gross domestic product (GDP), energy consumption, energy consumption in the industry, and the elasticity of oil prices. Results showed that the GDP and energy consumption (total, industrial) are inelastic with respect to the oil price and GDP, respectively. Moreover, Extra Trees approach is utilized for modeling the primary energy consumption and CO_2 emissions. It was found that the proposed tree-based models provide excellent predictions.

INTRODUCTION

During the last several decades, the capabilities of converting energy from less desirable forms to the more desirable forms have improved. Thanks to technological improvements, more and more energy resources, both conventional and non-conventional, have been developed and utilized. Furthermore, the world's living standards are improving and its population growing. Both global energy demand and consumption are rising. Figure 1 shows the world's total energy consumption from 1990 to 2010 plus the projected energy requirements for the subsequent three decades. Figure 2 provides details regarding the share of each type of fuel in the total consumed energy. It is clear

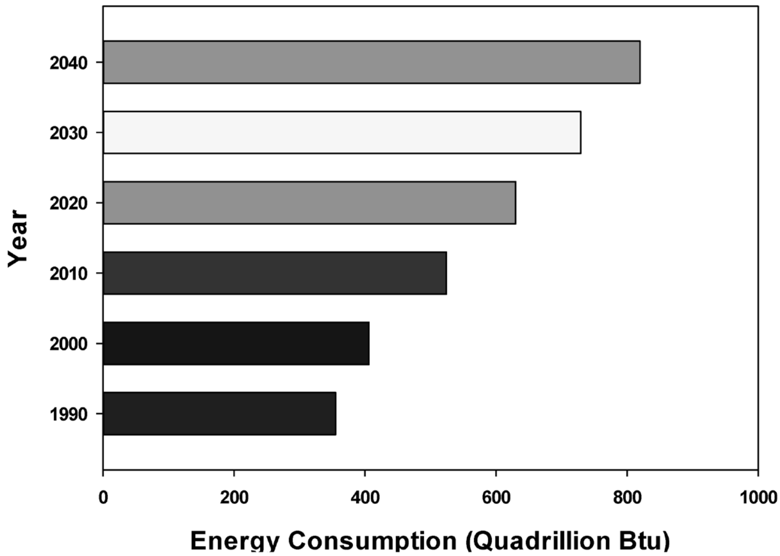


Figure 1. Total energy consumption in the last and upcoming decades (the data are collected from reference 1).

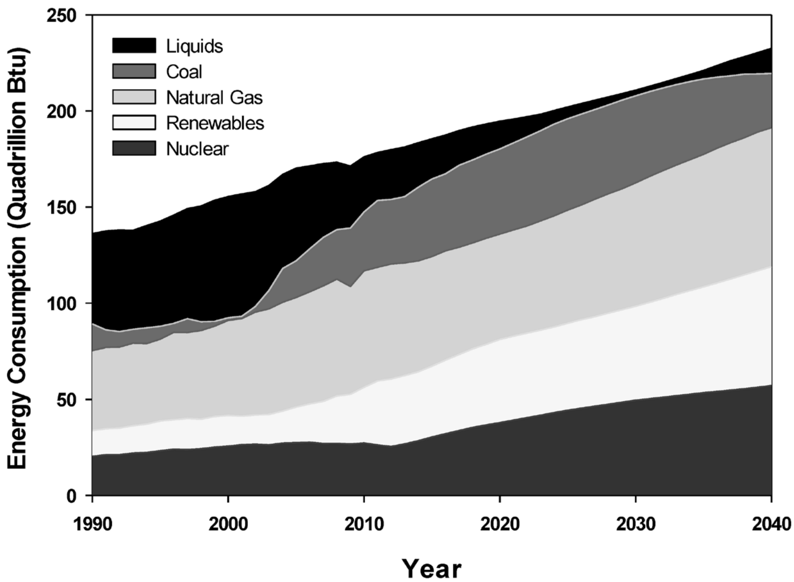


Figure 2. Share of various fuels in total energy consumption (the data are collected from reference 1).

that the increase in the need for energy is variable. Generally, per capita gross national product (GNP) has a positive effect on the amount of consumed energy.

While it is believed that the availability of adequate amounts of energy is vital for economic and social growth and improvement, the combustion of fossil fuels is considered responsible for global warming and climate change. This is mainly due to the atmospheric emissions of pollutants including methane and carbon dioxide (CO_2) generated by production and transportation processes. Water and soil pollution are other environmental impacts of energy utilization. In view of the aforementioned issues, it is crucial to develop and implement appropriate energy policies and technologies to succeed in dealing with the undesirable impacts of energy on the environment. Investigating parameters such as crude oil price and elasticity of supply is important. The objective of this study is to analyze specific energy-related parameters in Canada. First, the energy sector in Canada is reviewed. Next, relevant published works concerning the investigation of energy in Canada are discussed. Then, analysis methods are employed for the application of interest.

THE ENERGY SECTOR IN CANADA

As the world's second largest country in geographic size, Canada has a population of more than 36 million. According to the 2016 version of the BP statistical review of world energy [2], Canada consumes 2.5% of the world's total primary energy produced and is the sixth largest energy consumer after China (22.9%), the U.S. (17.3%), India (5.3%), the Russian Federation (5.1%) and Japan (3.4%). Figure 3 shows energy consumption in Canada by fuel type. Canada ranks fifth in the world as a producer primary energy (3.6%). The top four primary energy producers are: the U.S. (16.8%), China (16.5%), the Russian Federation and USSR (10.5%) and Saudi Arabia (5.4%) [3]. Since energy produced within Canada is greater than its consumption, Canada is an energy exporting country.

In Canada, both renewable and non-renewable sources of energy are available. Table 1 ranks Canada among the countries with the world's largest proven reserves of crude oil. However, in 2015, Canada's oil production comprised 4.9% of total crude oil produc-

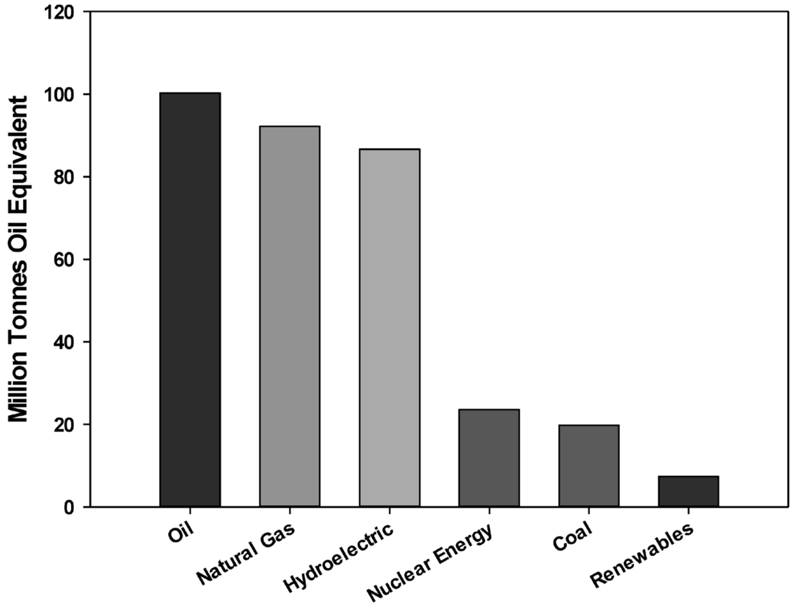


Figure 3. Share of various fuels in Canada's energy consumption (the data are collected from reference 2).

tion [2]. Most of Canada's oil is produced in the provinces of Alberta, Saskatchewan, and Newfoundland and Labrador. Due to the capability of Canada in the refining industry, Canada also imports crude oils mainly from the U.S., Saudi Arabia, Iraq, Norway, Algeria and Angola [4]. Canada is ranked fifteenth among the holders of proved reserves of natural gas with 1.1% of the world's resources, and is the fourth largest producer with 4.6% of the world's total natural gas production [2]. Canada has 0.7% of total world's coal reserves (ranked 15th) and produces 0.8% of the world's coal.

Approximately 8% of total unmined uranium resources are located in Canada. Canada produces about 25% of the global primary uranium [5]. The top five hydroelectric producers and their share of total production in the world are tabulated in Table 2. Canada has a great potential to generate renewable electricity from its hydropower sources. Table 3 offers information regarding the renewable energy production in Canada.

As described above, Canada has multiple and diverse energy resources. Indeed, all forms of energy including renewable and non-renewable are accessible for utilization. The Canadian economy is highly dependent on energy. Hence, reliable and sustainable energy production and utilization are critically important for Canadians. The following section considers Canada's energy policy.

Table 1.
Top 5 countries with the largest proven crude oil reserves (based on the data from reference 2).

Country	*Share of total (%)*
Venezuela	17.7
Saudi Arabia	15.7
Canada	10.1
Iran	9.3
Iraq	8.4

Table 2.
Top 5 countries with hydroelectric production (data based on reference 2).

Country	*Share of total (%)*
China	28.5
Canada	9.7
Brazil	9.1
USA	6.4
Russian Federation	4.3

Table 3.
Information about the renewable energy consumption/production in Canada (data based on reference 2).

Type	*Consumption*		
	Amount (Mtoe)	*Share of total (%)*	*Rank in the world*
Biofuel	1.059	1.4	10
Wind	5.6	2.9	7
Solar	0.6	1.0	14
Geothermal and other	1.2	1.0	19

Energy Policy

During the last decade, Canada witnessed a 20% decrease in energy intensity while its consumption of energy increased by only 2%. This is due to implementation of efficient and novel processes in energy intensive industries like pulp, print, paper and metals. Indeed, the energy consumption of the aforementioned industries was reduced while production increased [6]. This success reflects appropriate decisions and policies that were implemented in Canada.

In Canada's federal system of government, both the provincial and territorial governments are involved in decision-making concerning energy-related issues. Electricity generation and production plus non-renewable resource processes from exploration to management are within the jurisdiction of provincial governments. Inter-provincial regulation along with the international trade and commerce are mainly under the authority of federal government. Furthermore, non-renewable resources available from federal lands are managed by federal government [7].

The establishment of more stringent federal energy efficiency standards in multiple sectors is promoted by the federal government in cooperation with the provincial governments [6]. For example, in 2011, the National Energy Code of Canada for Buildings (NECB) was introduced which provided criteria for energy-effective design and construction of buildings. The NECB also covers heating, ventilating and air conditioning (HVAC) systems and equipment, building envelope, lighting, service water heating, and the provision of systems and motors of electrical power. The 2015 edition of NECB included several changes to improve the overall energy-efficiency of buildings [8]. Stringent emission regulations were also enacted for both coal-fired power plants and vehicles (light and heavy duty). As a new legal framework, the federal government supported various efficiency programs for the forest industry. In spite of these regulations, Canada's economy remains highly energy-intensive when compared to other International Energy Agency (IEA) member countries [6].

In some regions of Canada oil pipeline capacities are insufficient and otherwise problematic. For economic, safety, and environmental reasons, it was decided to increase the use of railways to transport oil. However, using railroads to transport oil also risks accidents [6]. In 2015, to mitigate the issues related to the oil transmission using pipeline and rail, new rules including the Railway Safety Act, the Pipeline

Safety Act, and the Energy Safety and Security Act were enacted.

To support the economic and sustainable development of Canada's natural resources and enhance its position as a responsible consumer and supplier of energy, a number of challenges remained. One is that Canada is a relatively energy-intensive IEA member. This is substantially due to the country's climate conditions, geographic size, high living standards, large energy reserves, and extensive energy extraction and processing for exports. The next problem is the high emission rates of greenhouse gas from the petroleum and natural gas industries. Furthermore, Canada must become more adaptive to the volatile pricing of products in the global oil and natural gas markets. Canada also needs to reduce the use of coal and nuclear reactors for electricity generation. Further, it is believed that Canada's budget for public energy research and development (R&D) and demonstration efforts from public enterprises and provincial and federal governments is greater than necessary [6].

LITERATURE REVIEW

In 1993, Gardner used the Divisia index for disaggregating the changes in Ontario's industrial sector aggregate energy intensity into intensity and structural components [9]. Using the approach of composite indicator, Nanduri et al. presented indicators of physical energy intensity for the Canadian manufacturing and industrial sectors in 2002 [10]. The developed method was then compared to the available methods of aggregation that were available in the literature. In 2003, Palmer compared the Divisia index and Laspeyres index methods as the most common factorization approaches [11]. To this end, Palmer employed the data of Canadian industrial energy use from 1995 to 2001 [11].

In 2011, Steenhof and Weber assessed multiple parameters that impact the trends in emissions of greenhouse gas from Canada's electricity sector [12]. The focus of this work is on the impact of energy and climate policy on greenhouse gas emissions for the period from 1990 to 2008. In order to reach the research goals, Steenhof and Weber developed and implemented a decomposition model [12]. For incorporating the indicators of physical activity, Ang and Xu applied index decomposition analysis (IDA) to investigate the industrial energy consumption in 2013 [13]. By employing the Canadian data, they presented the results of their work. In another 2013 study, trends of the energy intensity for 40 economies, including Canada, between 1995 and 2007 have been investigated by De Cian et al. [14]. Wong et al. studied the contributions of energy research and development (R&D) and energy consumption on economic growth [15]. In 2014, the impact of consuming nuclear energy on growth of GDP and carbon dioxide emission in thirteen main nuclear energy consuming economies, including Canada, was investigated by Al-mulali [16]. The panel models of CO_2 emission and GDP growth were used over the period of 1990 to 2010.

For the U.S., Canada, and seventeen countries in Latin America, Rodríguez-Caballero and Ventosa-Santaulària studied the casual link and the relationship between electric power consumption and gross domestic product [17]. In 2016, Torrie et al. employed the logarithmic mean Divisia Index method to understand the reasons for the decline in the total energy intensity of the Canadian economy between 1995 and 2010 [18].

ANALYSIS—ELASTICITY

It is believed that Canada's economic growth became progressively dependent on the energy sector beginning in 2000 [19]. To understand whether or not the GDP of Canada is elastic in respect to crude oil prices is of great importance in studying the energy economics of Canada. Furthermore, this is also true for the elasticity of energy consumption in industry and electricity consumption with respect to the GDP. Elasticities of Canada's GDP with respect to crude oil price changes, *eGDP*, is calculated based on the following equation:

$$eGDP = [d(GDP_{Canada}) \div (GDP_{Canada})t] / [d(P_{Oil}) \div (P_{Oil})\ t] \quad (1)$$

which denote the GDP of Canada and crude oil price, respectively; and t and d indicate a given time period and change in the GDP, respectively.

The elasticities of energy consumption in industry sector of Canada with respect to the GDP are estimated by the following equation:

$$eEC = [d(ECI_{Canada}) \div (ECI_{Canada})t] / [d(GDP_{Canada}) \div (GDP_{Canada})t] \quad (2)$$

where ECI_{Canada} denotes energy consumption in industry. Furthermore, using Equation (3), the elasticities of Canada's energy consumption, EC_{Canada}, with respect to the GDP are estimated.

$$eEC = [d(EC_{Canada}) \div (EC_{Canada})t] / [d(GDP_{Canada}) \div (GDP_{Canada})t] \qquad (3)$$

The information regarding the P_{Oil}, ECI_{Canada}, and EC_{Canada} from 2000 to 2014 are summarized in Table 4. The data of oil prices (USD) and GDP (USD) are gathered from the BP Statistical Review of World Energy (2016) and the World Bank [2,20]. The collected data of energy consumption (ktoe) and energy consumption in the industry (ktoe) are reported by International Energy Agency [21].

The calculation results are provided in Table 5. Its results show that generally when the crude oil price fluctuates, there is a little change in Canada's GDP. The geometric mean of the estimated elasticities is equal to 0.51. Since the obtained value of GDP-oil price elasticity from 2000 to 2014 is less than 1, it can be said that the GDP of Canada was generally insensitive to crude oil prices during this period.

Table 4.
The gathered data for analyzing the energy economics in Canada.

Year	*GDP (USD)*	*Oil Price (USD)*	*Energy consumption (ktoe)*	*Energy consumption in industry (ktoe)*
2000	7.42293E+11	39.22	191,480	55,244
2001	7.3638E+11	32.71	184,983	52,072
2002	7.57951E+11	32.97	190,051	53,724
2003	8.92381E+11	37.14	196,681	55,804
2004	1.0232E+12	48.01	201,440	57,557
2005	1.16936E+12	66.17	198,665	52,710
2006	1.31542E+12	76.59	195,764	51,249
2007	1.46498E+12	82.75	202,454	50,978
2008	1.54913E+12	107.06	196,000	47,113
2009	1.37115E+12	68.13	184,676	42,537
2010	1.61341E+12	86.41	187,422	42,627
2011	1.7887E+12	117.23	195,109	45,590
2012	1.82429E+12	115.28	196,891	45,834
2013	1.83744E+12	110.55	199,094	47,300
2014	1.78378E+12	99.06	200,396	47,985

In case of the GDP-EC_{Canada} elasticities, the geometric mean was determined to be 0.32. This means that the energy consumption in Canada changes only slightly as a result of changes in GDP. Interestingly, for most of the developed countries, this parameter is also less than 1. Influence of the change in GDP on the energy consumption in Canada's industry is negligible. This is due to the fact that the geometric mean of GDP-ECI_{Canada} elasticities is 0.47.

Table 5.
Elasticity response of GDP of Canada to the P_{Oil}, ECI_{Canada} and EC_{Canada}.

Period	*Oil-GDP*	*GDP-* EC_{Canada}	*GDP-* ECI_{Canada}
2000-2001	0.05	4.26	7.21
2001-2002	3.77	0.94	1.08
2002-2003	1.40	0.20	0.22
2003-2004	0.50	0.17	0.21
2004-2005	0.38	0.10	0.59
2005-2006	0.79	0.12	0.22
2006-2007	1.41	0.30	0.05
2007-2008	0.20	0.55	1.32
2008-2009	0.32	0.50	0.85
2009-2010	0.66	0.08	0.01
2010-2011	0.30	0.38	0.64
2011-2012	1.20	0.46	0.27
2012-2013	0.18	1.55	4.44
2013-2014	0.28	0.22	0.50

Employing the following formula, the energy consumption of Canada in future years can be estimated:

$$et = [(EC_{t+1} - EC_t) \div EC_t] / [(GDP_{t+1} - \mathrm{GDP}_t) \div \mathrm{GDP}_t] \quad (4)$$

In case of Canada, the predicted values of the GDP and energy consumption growth rate (per unit time) to 2020 are given in Table 6. As Table 6 indicates, it is projected that the growth rate of energy consumption will reach about 0.33 at 2020.

Table 6. Projections to 2020 for Canada.

Year	*GDP*	*Growth Rate (GDP)*	*Energy consumption*	*Growth rate (energy consumption)*
2015	1.80E+12	1.08	200768.2556	0.18576
2016	1.82E+12	1.00	201168.8284	0.19952
2017	1.86E+12	1.90	201826.2482	0.32680
2018	1.89E+12	1.91	202489.2878	0.32852
2019	1.93E+12	1.93	203161.4712	0.33196
2020	1.97E+12	1.94	203839.3804	0.33368

ANALYSIS—TREE-BASED MODELING

With a goal of modeling the primary energy consumption/CO_2 emissions in Canada as a function of GDP, foreign direct investment (FDI), population, oil price, natural gas price, and electricity generation, the Extra Trees methodology is used for the first time [22,23]. The required data sets for modeling have been gathered from the BP Statistical Review of World Energy (2016) and are reported in Tables 4 and 7 [2].

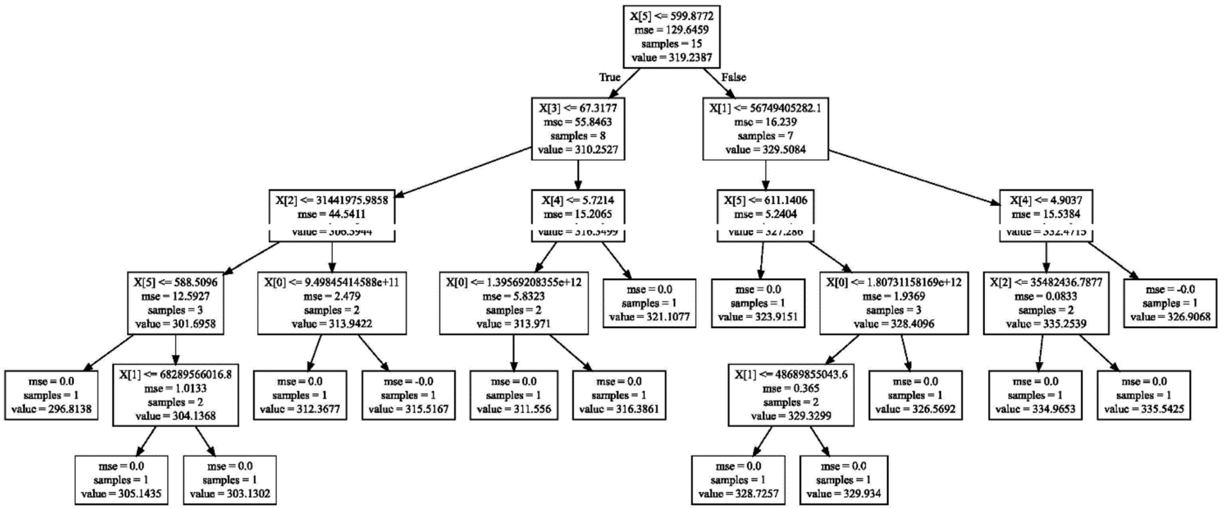
The created trees for predicting the primary energy consumption (Mtoe) in Canada are shown in Figures 4 (Tree #1) and 5 (Tree #2). Similarly, Figures 6 (Tree #3) and 7 (Tree #4) demonstrate the developed trees to estimate CO_2 emissions (Mt) in Canada. In Figures 4-7, the X[0], X[1], X[2], X[3], X[4], indicate the independent parameters including GDP (USD), FDI (USD), population, oil price (USD), natural gas price (USD), and electricity generation (TWh) respectively.

The proposed tree-based models are easily used and understood. The average of the outcomes of Tree #1 and Tree #2 are the predicted values of primary energy consumption. Similarly, the average values of the outputs of Tree #3 and Tree #4 represent the predicted values of CO_2 emissions.

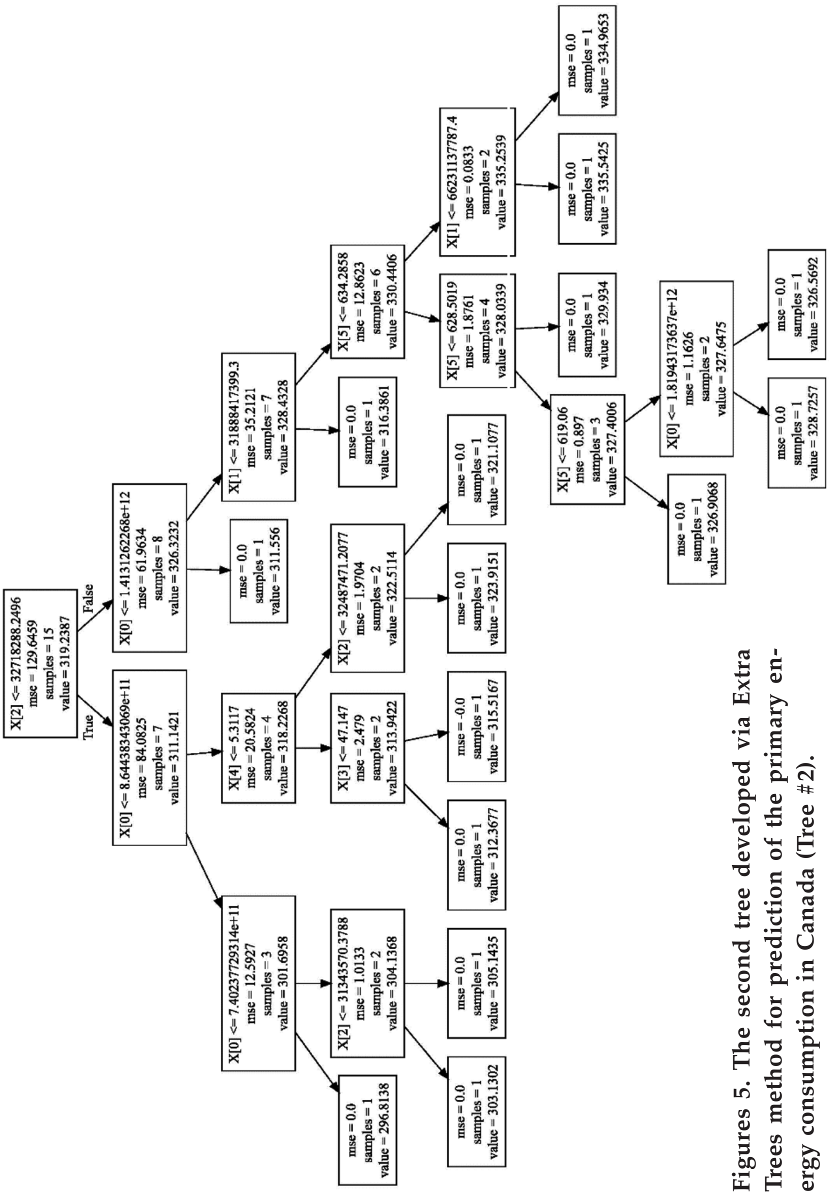
A sample procedure for estimating the CO_2 emissions is as follows: considering the input data of year 2010 and using Tree #3, since the natural gas price is lower than 4.6854, the left sub-tree is selected. At second stage, the left sub-tree is selected. Because the population (year 2010) is lower than 35,745,198.7. The third stage compares the value of natural gas price. Again, the left sub-tree is selected. At the fourth stage, since the FDI (year 2010) is lower than $48,379,824,042.9, the left sub-tree is our selection. Stage five considers electricity generation values. In 2010, 588.16 TWh electricity is generated. So, we go to the left sub-tree.

Table 7.
Information gathered for modeling the primary energy consumption/CO_2 emissions in Canada.

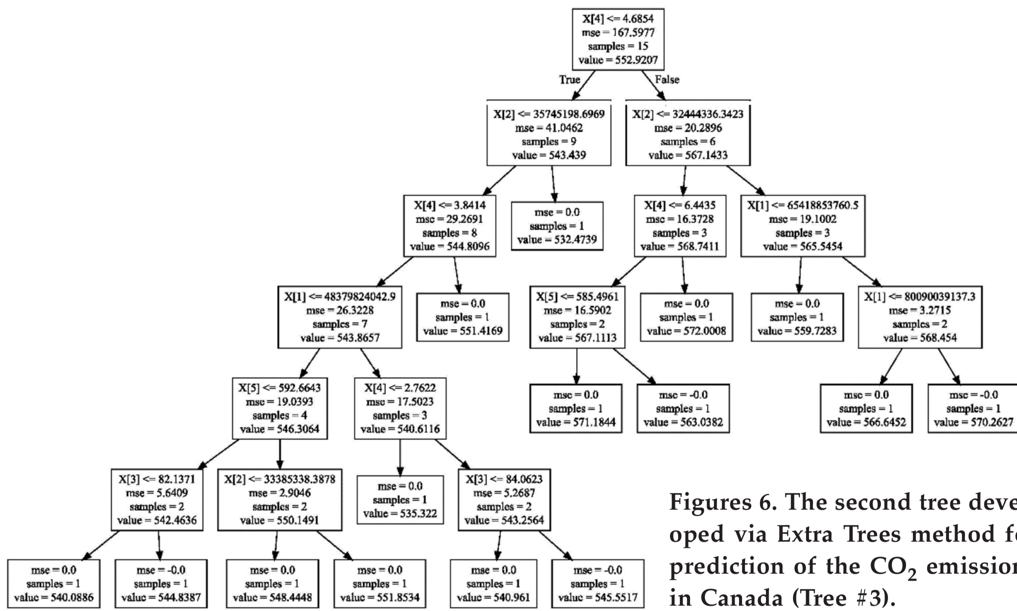
Year	*FDI*	*Population*	*Natural gas price*	*Electricity generation*	*Primary energy consumption*	*CO_2 emissions*
2000	68309240320	30769700	3.747500000	599.2420000	303.1302217	540.961
2001	28392596347	31081900	3.611666667	581.8320000	296.8137786	540.088
2002	24496718382	31362000	2.571666667	594.8330000	305.1434689	548.445
2003	7011850120	31676000	4.829166667	580.2440000	312.3677341	571.184
2004	1441912587	31995000	5.031666667	587.1068743	315.5167082	563.038
2005	25545319852	32312000	7.250000000	604.3699650	323.9151052	572.001
2006	64302242675	32570505	5.833333333	592.6352370	321.1077200	559.728
2007	1.20423E+11	32887928	6.167500000	616.7601890	326.9068322	570.263
2008	70116945931	33245773	7.990000000	618.0471460	327.3867684	566.645
2009	20931399830	33628571	3.382500000	595.5373040	311.5560237	525.756
2010	29712896616	34005274	3.685905023	588.1612100	316.3860734	544.839
2011	38318064819	34342780	3.474574576	619.5813256	328.7256952	551.853
2012	49377811367	34751476	2.268458564	619.7653286	326.5692243	535.322
2013	69427637252	35155499	2.926014838	641.3238171	334.9652585	545.552
2014	65440742032	35543658	3.868372192	638.0185129	335.5424516	551.417



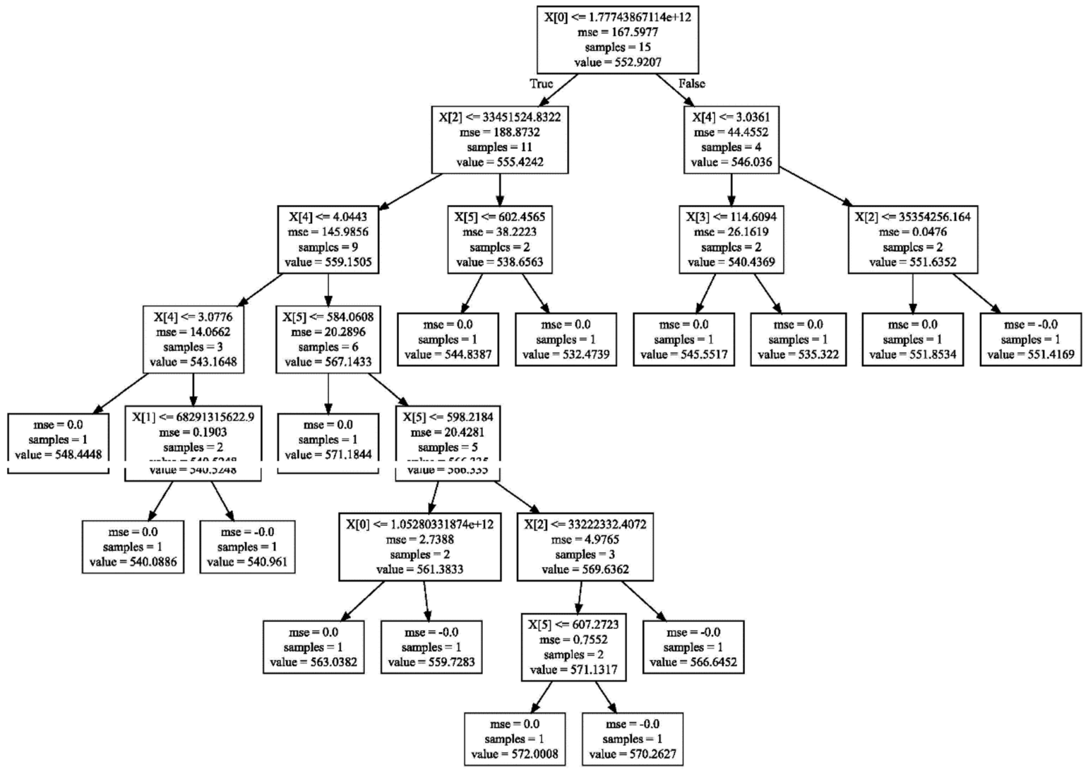
Figures 4.
The first tree developed via Extra Trees method for prediction of the primary energy consumption in Canada (Tree #1).



Figures 5. The second tree developed via Extra Trees method for prediction of the primary energy consumption in Canada (Tree #2).



Figures 6. The second tree developed via Extra Trees method for prediction of the CO_2 emissions in Canada (Tree #3).



Figures 7. The second tree developed via Extra Trees method for prediction of the CO_2 emissions in Canada (Tree #4).

Finally, since the oil price is more than \$82.1, the right sub-tree is our section. Consequently, Tree #3 gives 544.8 Mt as CO_2 emissions. Similarly, Tree #4 gives the value of 544.8. Hence, the predicted CO_2 emissions (year 2010) is 544.8 Mt which is in agreement with the real value.

The error analysis results, employing statistical parameters including R^2, AARD%, and ARD%, are reported in Table 8 for the presented tree-based models. According to Table 8, both the developed models on the basis of Extra Trees provide satisfactory results for the application of interest.

Table 8.
Error analysis results for the proposed tree-based models.

Model	*Parameter*		
	R^2	*AARD%*	*ARD%*
Primary Energy Consumption	1	0.0	0.0
CO_2 Emissions	1	0.0	0.0

Figure 8 demonstrates the influence of each independent parameter on the creation of trees to predict values of primary energy consumption. As can be seen from Figure 8, electricity generation has the highest effect of the tree development. On the other hand, the minimum impact is related to the price of natural gas. The graphical representation of the effect of input parameters on the development of Tree #3 and Tree #4 is illustrated in Figure 9. As opposed to the previous model, the natural gas price has the maximum effect on the development of trees to estimate CO_2 emissions. It can be observed that the price of oil has the least impact in this case.

CONCLUSION

In this article, the GDP-oil price, GDP-EC_{Canada}, and GDP-ECI_{Canada} elasticities were calculated for Canada using data from 2000 to 2014. In all cases, it was found that the value of elasticity is less than 1. It was also revealed that the growth rate of energy consumption will reach to about 0.33 by 2020. Furthermore, employing Extra Trees algorithm two

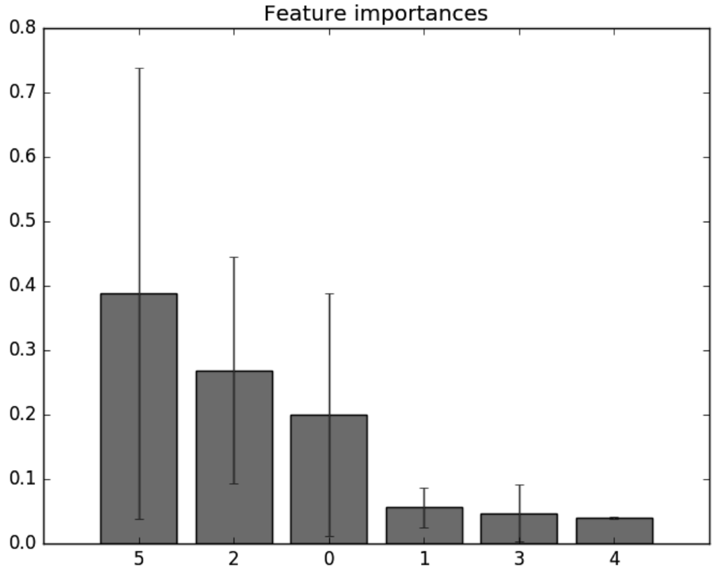


Figure 8. Importance of each inputs on development of Tree #1 and Tree #2 (vertical: importance; horizontal: inputs).

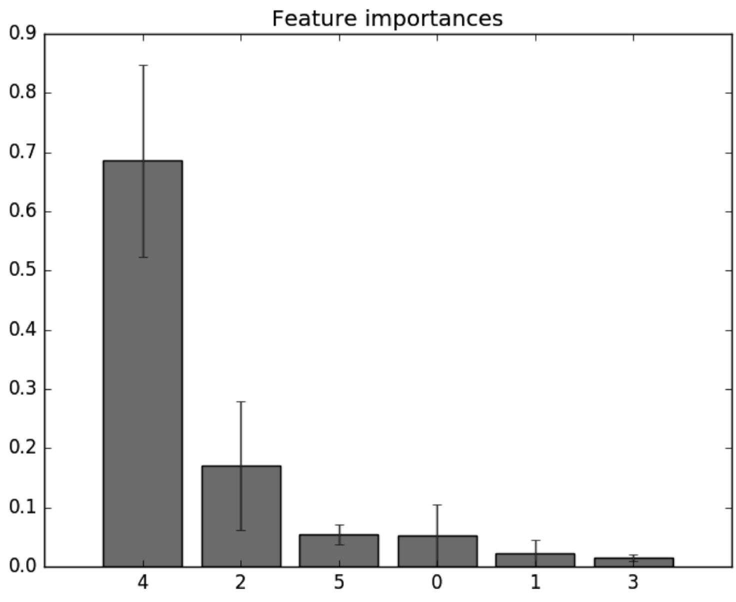


Figure 9. Importance of each inputs on development of Tree #3 and Tree #4 (vertical: importance; horizontal: inputs).

distinct predictive models were developed to estimate the primary energy consumption and CO_2 emissions in Canada. The independent parameters for both of the presented models are GDP, FDI, population, oil price, natural gas price, and electricity generation. Based on the error analysis results, the proposed tree-based models can be successfully used for estimating the target values. Electricity generation and the natural gas price are the most important parameters influencing the creation of models for estimating the primary energy consumption and CO_2 emissions in Canada, respectively. The minimum impacts on the aforesaid models are respectively linked to natural gas price and oil price.

References

[1] U.S. Energy Information Administration (2013). International energy outlook 2013. Washington, D.C.

[2] BP (2016). Statistical review of world energy.

[3] Shift Project Data Portal. Countries with highest primary energy production. http://www.tsp-data-portal.org/TOP-20-Producer#tspQvChart, accessed 21 November 2017.

[4] Government of Canada. Natural resources Canada. http://www.nrcan.gc.ca/energy/oil-sands/18086, accessed 21 November 2017.

[5] Government of Canada. Natural resources Canada. http://www.nrcan.gc.ca/earth-sciences/geography/atlas-canada/selected-thematic-maps/16872, accessed 21 November 2017.

[6] International Energy Agency (2016). Energy policies of IEA countries, Canada, 2015 Review.

[7] Natural Resources Canada (2006, January). "Legal and policy frameworks—Canada." North America: The Energy Picture, accessed 16 August 2008.

[8] Natural Research Council Canada (2015). National energy code of Canada for buildings. http://www.nrc-cnrc.gc.ca/eng/publications/codes_centre/2015_national_energy_code_buildings.html, accessed 21 November 2017.

[9] Gardner, D. (1993). Industrial energy use in Ontario from 1962 to 1984. *Energy Economics*, pages 25–32.

[10] Nanduri, M., Nyboer, J. and Jaccard, M. (2002). Aggregating physical intensity indicators—results of applying the composite indicator approach to the Canadian industrial sector. *Energy Policy*, pages 151–163.

[11] Palmer, J. (2003). Decomposition of changes in energy use: the comparison of two approaches from a Canadian perspective. *Proceedings of the 2003 ACEEE Summer Study on Energy Efficiency in Industry*, 6, pages 150–158.

[12] Steenhoff, P., Weber, Chris, J. (2011). An assessment of factors impacting Canada's electricity sector's GHG emissions. *Energy Policy*, 39, 4,089–4,095.

[13] Ang, B. and Xu, X. (2013). "Tracking industrial energy efficiency trends using index decomposition analysis." *Energy Economics*, 40, pages 1,014–1,021.

[14] Enrica, D., Schymura, M., Verdolini, E. and Voigt, S. (2013). Energy intensity developments in 40 major economies: structural change or technology improvement? Paper No. 13-052. Centre for European Economic Research.

[15] Siang, W., Chang, Y. and Chia, W. (2013). "Energy consumption, energy R&D

and real GDP in OECD countries with and without oil reserves." *Energy Economics*, 40, pages 51–60.
[16] Al-mulali, U. (2014) "Investigating the impact of nuclear energy consumption on GDP growth and CO_2 emission: a panel data analysis." *Progress in Nuclear Energy*, 73, pages 172-178.
[17] Rodríguez-Caballero, C. and Ventosa-Santaulària, D. (2016). "Energy-growth long-term relationship under structural breaks. Evidence from Canada, 17 Latin American economies and the U.S." *Energy Economics*, 61, pages 121–134.
[18] Torrie, R., Stone, C. and Layzell, D. (2016). Understanding energy systems change in Canada: 1. Decomposition of total energy intensity. *Energy Economics*, 56, pages 101–106.
[19] Fremeth, A., Holburn, G., Ventatesh, P. and Wilkie, A. (2014). "Developing global market access for Canada's oil and gas industry." Ivey Energy Policy and Management Centre.
[20] World Bank. http://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=CA, accessed 21 November 2017.
[21] International Energy Agency. Statistics. http://www.iea.org/countries/membercountries/canada/statistics, accessed 21 November 2017.
[22] Geurts, P., Ernst, D. and Wehenkel, L. (2006). "Extremely randomized trees." *Machine Learning*, 63, pages 3-43.
[23] Cholwich N., Nirattaya K., Luckhana L. and Pisanu, T. (2017). "A novel prediction approach for antimalarial activities of Trimethoprim, Pyrimethamine, and Cycloguanil analogues using extremely randomized trees." *Journal of Molecular Graphics and Modelling*, 71, pages 13-27.

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