Queen's Economics Department Working Paper No. 1442

A stakeholder analysis of investments for wind power electricity generation in Ontario

Pejman Bahramian
Department of Economics, Queen's University

Glenn Jenkins

Frank Milne
Queen's University

Department of Economics
Queen's University
94 University Avenue
Kingston, Ontario, Canada
K7L 3N6

10-2020

A stakeholder analysis of investments for wind power electricity generation in Ontario *

Pejman Bahramian † Glenn P. Jenkins ‡ Frank Milne§

October 2020

Abstract

This study uses an ex-post evaluation of the grid-connected wind projects in Ontario, Canada, to quantify the stakeholder impacts of such renewable energy projects. Our study includes a financial, economic and stakeholder analysis of these wind farms. The analysis sheds light on the distributional impacts that arise when there is a significant gap between the incentives created by the financial price paid for electricity generation and the economic value of the electricity generated. The analysis shows that the negotiated power purchase agreements (PPAs) have resulted in a negative outcome for the economy in all circumstances. It is found that the present value of the economic costs is at least three times the present value of the economic benefits, including the global benefits from the reduced CO2 emissions. This loss is borne by all the stakeholders of the electricity system, except the private owners of the wind farms. The losers are primarily the electricity consumers followed by the governments. The Ontario Electricity Rebate (OER) programme, which is financed by increased government borrowing, has the effect of transferring a large share of the costs incurred to promote investments in wind power to future generations of taxpayers in Ontario.

Keywords: economic analysis; electricity; Ontario; wind power

JEL Codes: O55, D61, Q42

*This study has benefited greatly from discussions with Peter Kascor, Arnold C. Harberger, Jack Gibbons from the Ontario Clean Air Alliance, and participants of the Annual Meeting of the Society for Benefit-Cost Analysis. Financial support for this research through a Mitacs Accelerate-PDF Fellowship [IT13680] is greatly appreciated. Correspondence to: Bahramian †, Department of Economics, Queen's University, Kingston, Ontario K7L 3N6, Canada; Email: bahramian@econ.queensu.ca, Jenkins ‡, Department of Economics, Queen's University, Kingston, Ontario K7L 3N6, Canada and Eastern Mediterranean University, Famagusta, Mersin 10, Turkey; Email: jenkins@econ.queensu.ca, Milne §, Department of Economics, Queen's University, Kingston, Ontario K7L 3N6, Canada; Email: milnef@econ.queensu.ca.

1 Introduction

With the exception of hydro power, wind electricity generation has been the most significant source of renewable energy implemented in North America. Ontario is Canada's leader in wind generation with installed capacity of 5,076 MW, which is about 40% of Canada's total installed wind energy capacity. There are 2,577 wind turbines currently operating in Ontario at 96 separate facilities (Canadian Wind Energy Association, 2019). Almost all of these wind farms were built and are now operating as independent power producers.

Ontario established renewable portfolio standards in 2003 (Rowlands, 2005). In 2006, a competitive bidding initiative for renewable energy was implemented by introducing feed-in tariffs (FITs) (Rowlands, 2007). In 2009, the province enacted the Green Energy and Green Economy Act (GEGEA) (Songsore and Buzzelli, 2015). The GEGEA was accompanied by a set of FITs that provided guaranteed and fixed long-term prices for renewable energy (e.g. wind, solar, biomass) (Rosenbloom et al., 2016; Winfield and Dolter, 2014). The GEGEA represented the first large-scale FIT programme in North America (Stokes, 2013). In 2014, with the closure of the Thunder Bay plant, coal was eliminated as a source of electricity generation in Ontario (Cundiff, 2015). It was thought that the addition of new renewable energy sources such as wind energy would provide replacement electricity supply without contributing significantly to global warming.

Ontario's electricity grid system follows a diverse supply mix, featuring nuclear baseload generators that provide energy with a high load factor, intermittent generators that produce when they are able (primarily wind and solar), and flexible thermal plants that can change their output quickly (primarily single-cycle natural gas generation and hydro power generation). The province has experienced a surplus of off-peak electricity supply in recent years. During high-demand periods, wind power displaces relatively expensive gas generation. However, during low-demand periods, because the wind is given priority in electricity generation within the system, it may also replace low-cost hydro generation. Surplus electricity may also be sold to neighbouring jurisdictions if there are willing buyers.

In 2018, more than 93% of electricity generated in Ontario came from green resources (nuclear, hydro, wind and solar). Wind power accounts for 12% of installed generating capacity (MW) and almost 8% of total output (TWh) (IESO, 2018). The province's supply mix has further potential to keep changing because of refurbishments of nuclear-generating units, along with the potential retirement of supply from wind generation following the expiry of some contracts (Canadian Wind Energy Association, 2020).

As the energy produced by wind tends to be concentrated in the off-peak periods, in practice there have been difficulties in reducing the off-peak generation from baseload plants by enough to accommodate the supply from wind generation. Wind farms may have low operating costs, but their capital costs are quite substantial (Lu et al., 2011). The critical analytical issues facing governments when considering this generation technology is to determine the circumstances in which the economic benefits of wind generation outweigh its economic costs. In the consideration of wind power investments there is a need for these facilities to produce electricity in an economically and environmentally compatible manner. At the same time, the overall reliability of the electricity service must be maintained (Borenstein, 2012). However, the effect of aggressive renewable energy policies and financing instruments might lead to negative externalities for the economy as a whole (Peters et al., 2012; Hoppmann, 2013). Hence, understanding who receives the benefits and who pays the costs is a matter of significance (Xia and Song, 2017). This motivated us to undertake an integrated investment appraisal of three operating wind farms in Ontario, Canada. The Wolfe Island wind farm is located in the eastern part of the province, while Melancthon I and II are located in the central/western region. These three wind farms are geographically dispersed and also represent a wide range of generation capacities.

Our study aims to shed light on the magnitudes of the gains and losses created by the renewable energy policies to support the development of wind farms in Ontario. Furthermore, this study aims to identify the stakeholders who have benefited and those who have lost because of the private sector response to these policies, and to quantify these benefits and costs for a typical set of wind farm investments. The economic value of such wind farms arises from savings in the cost of running the electricity system, the amount of revenues from additional energy exported, plus the benefits of the net environmental damage reduction because of the operation of the wind farms. This economic perspective is compared with that of the private investors. Examining this question is important as the FITs reduce risk and provide a relatively stable return to the investor. Still, the cost savings determine the economic return to the country from the investments made in the electricity system in order to substitute renewable energy sources for other generation technologies[1](Frondel et al., 2014).

Empirical studies assessing the economic and financial viability of wind farms are relatively plentiful. Different frameworks have been applied to evaluate the sustainability of wind power. Most studies have concluded that wind integration into the power supply mix would be a feasible option. Ayodele et al. (2016) examined the economic feasibility of various wind farms in Nigeria. Cohen and Caron (2018) investigated the effects of increasing wind electricity on the US economy. Their findings suggested that the US economy gains from the deployment of the cost-competitive wind power. Salci and Jenkins (2018), using an integrated investment appraisal framework, examined an onshore wind project in Cape Verde. Their findings highlighted that in this case the negotiated PPA led to a negative outcome for the economy of Cape Verde, while producing a substantial guaranteed return for the wind farm's foreign owners.

Most of the studies dealing with the economic analysis of wind power have focused on its engineering and technical aspects. We will contribute to the existing literature by completing a financial, economic and stakeholder analysis of wind power through an integrated investment appraisal. In this framework, a clear distinction is drawn between the economic analysis and the financial analysis or, expressed differently, between the evaluation of public

[1]High guaranteed FITs have led to higher prices being charged to consumers for electricity sold at the retail level. As a consequence, consumer demand has fallen in Ontario, particularly in the off-peak period. If demand for off peak falls, the wind energy produced during the off-peak period has a very low value.

benefits and costs and the evaluation of private benefits and costs. As described in some detail by Kennedy (2005), the financial benefits and costs of an investment accruing to a publicly owned utility do not necessarily correspond to the economic costs and benefits that accrue to the country.

The second aspect is to evaluate the project from the perspectives of the different market players, namely the transmission companies, the owners of other power plants, domestic consumers and the governments involved. If the experience from elsewhere (Jenkins and Baurzhan, 2018) is relevant to the situation in Ontario, the distributional outcomes of benefits and costs created by the policies and contracts to promote the wind farms across the stakeholders in the sector may be quite different than those envisaged by the designers of the policies. This framework allows us to determine how the costs and benefits of wind farms are distributed across all the relevant stakeholders. This information is essential for the design of efficient contracts (Flyvbjerg, 2006), including both for the wind farms and for the private generation plants that are being displaced by the wind farms. In brief, the results of such an integrated analysis from a post-evaluation perspective yields an assessment of the contribution of existing investments both on a financial basis to the various public and private stakeholders and on the economic value they yield to consumers over time.

The paper proceeds as follows. Section 2 gives an overview of the wind farms evaluated, section 3 describes the methodology, section 4 presents the empirical results and section 5 concludes the article.

2 OVERVIEW OF THE WIND FARMS

The three wind farms studied here were all built by Canadian Hydro, a privately owned energy company, and were subsequently acquired by TransAlta Renewables[2]. Thus, the

[2]Approximately 75% of Ontario's wind power projects are owned by non-Canadian companies (mainly US companies) that enjoy the benefits of the many federal and provincial incentive programmes (Wind Concerns Ontario, 2018). Of the 25% of Canadian-owned wind farms in Ontario, the three wind farms in our study represent 34% of their installed capacity.

financial information is obtained mainly from the annual reports of Canadian Hydro (2008). The first wind farm examined in this study is the 68 MW Melancthon I wind facility that comprises forty-five 1.5 MW wind turbines and is located in Melancthon Township near Shelburne, Ontario. This facility began commercial operations in March 2006. The capital cost of the project is CAD 124 million, and the generation from this facility is sold to the Independent Electricity System Operator (IESO) under a PPA that terminates in 2026. The facility received the Wind Power Production Incentive (WPPI), which consists of a 10-year CAD 10 per MWh payment on generated electricity. The facility agreed to pay the Township of Melancthon an annual community contribution equal to CAD 1000 per turbine. The second wind farm is the 132 MW Melancthon II wind facility that comprises eighty-eight 1.5 MW wind turbines and is located adjacent to Melancthon I, in Melancthon and Amaranth Townships, Ontario. This facility started its operations in November 2008, with a capital cost of CAD 285 million. Similar to Melancthon I, electricity generated by this wind farm is also sold to the IESO following a PPA with a lifespan of 20 years (terminating in 2028). The facility agreed to pay an annual community contribution equal to CAD 4000 per turbine to the Townships of Melancthon and Amaranth. The last wind farm studied is the 198 MW Wolfe Island wind facility, with a capital cost of CAD 475 million, that comprises eighty-six 2.3 MW wind turbines and is located on Wolfe Island, near Kingston, Ontario. The commercial operation of this facility began in June 2009, and its generated electricity is sold to the IESO pursuant to a 20-year PPA contract (terminating in 2029). The project pays an annual amenities fee equal to CAD 7500 per turbine to the Township of Frontenac Islands. The Melancthon II and Wolfe Island wind farms both benefited from the Renewable Power programme ('ecoENERGY')[3], providing an incentive of CAD 10 per MWh for up to 10 years for electricity generated from renewable energy sources (for more details, see Natural Resources Canada (2008)).

[3]In 2006, the Canadian government ended funding for the WPPI and remodelled it as the ecoEnergy Incentive programme (Natural Resources Canada, 2008).

Figure 1: Ontario wind farm locations (source: IESO wind power map)

3 METHODOLOGY

The integrated project analysis developed by Jenkins et al., (2011) measures benefits and costs in terms of domestic prices for both financial and economic appraisals. The stakeholder impacts are then identified and allocated to the different parties. The methodology for an integrated appraisal was applied by Baurzhan and Jenkins (2018) for the appraisal of solar PV generation in sub-Saharan Africa. This study will apply the same methodology for renewable energy facilities where the utility is operating with several independent power generators. Table 1 summarizes the variables used in the economic and financial analyses.

3.1 Canadian economy point of view

The economic benefits of the wind farm that accrue to the country are: (i) the fuel savings due to output displacement, and (ii) the revenue from net exports. These are the resources saved by the project. However, to measure these savings the displacement impacts of wind power generation on Ontario's gas power plants and net exports need to be estimated. Bahramian et al. (2020) estimated that for every additional 100 MWh generated by wind farms in Ontario, almost 53 MWh of gas output and 23 MWh of hydro generation is displaced[4]. In

[4]The waste of hydro generation through the wind power is unfortunate because hydro is the low-cost producer of electricity, a renewable resource, and produces no greenhouse gases. This issue is discussed in a

Table 1: Parameters

	Prices
PW_t^{RES}	Renewable energy supply (RES) contract price of electricity, paid by IESO to wind farm (CAD/MWh)
PX_t^{nx}	Export price of electricity paid by exporters to IESO [a] (CAD/MWh)
PF_t^g	Dawn Hub Gas Price (CAD/million BTU)
$P_t^{intermit}$	Price of intermittency paid by domestic consumers to IESO (CAD/MWh)
SCC_t^g	Social cost of carbon for gas (CAD/tonne)
	Wind farm variables
WO_t	Annual wind farm output (MWh)
WC_t	Annual wind farm curtailment (MWh)
$WCAP_t$	Installed wind farm capacity (MW)
$CAPEX_t^{wf}$	Annual capital expenditure for wind farm construction (CAD)
$OPEX_t^{wf}$	Annual operating expenditure for wind farm operation and maintenance (CAD)
$DECOM_t^{wf}$	Decommissioning costs of wind farm at end of life (CAD)
T_t^{inc}	Income tax paid by wind farm owners (CAD)
T_t^{oth}	Other taxes paid by wind farm owners (CAD)
T_t^{amen}	Amenities fee paid by wind farm owner (CAD)
LD_t	Loan drawdown received by wind farm owner (CAD)
DS_t	Debt service (interest and principal repayment) paid by wind farm owner (CAD)
S_t^{ENERGY}	Renewable energy subsidies (WPPI and econENERGY) paid by the government to wind farms (CAD)
	Other power plant variables
$OD_t^{g,nx}$	Output displacement factor of gas generation and net exports
SG^j	Share of gas output, by type of gas plant (cogeneration, combined cycle, simple cycle, steam turbine, other), estimated using the generator output and capability (GOC) data obtained from IESO for the period 2015–2018.
FCR_t^g	Fuel consumption rate for gas (quantity/MWh) Output-weighted fuel consumption rate for gas plants $FCR_t^g = \sum_{j=1}^{5} SG^j FCR_t^j$, where FCR_t^j is the fuel consumption rate by type of gas plant (cogeneration, combined cycle, simple cycle, steam turbine, other). All related data are extracted from the average tested heat rates report of the US Energy Information Administration (EIA) (Table 8.2).
	Discount rates
$EOCK$	Economic opportunity cost of capital
	Miscellaneous
8760	Hours per year
r_r^{wf}	Proportional rate of Ontario Electricity Rebate (OER) for wind facilities
t_0	PPA commencement year
t_1	2019 as starting year of the OER
t_n	End year of PPA
R_r	Rate of royalty paid to the Alberta government on gas sales
CC^g	Carbon content of gas (tonnes/unit of fuel)

[a] In this study, using the data obtained from the IESO data centre, the export price of electricity is measured based on the sum of flow-weighted intertie prices over the intertie zones: Manitoba (MBSI), Minnesota (MNSI), Michigan (MISI), New York (NYSI) and Quebec. We have not formally reported the full result in the paper to save space; however, complete details of the findings are available from the authors on request.

addition, incrementally approximately 19 MWh of power is exported. As there is no cost saving in Ontario from the displacement of hydro power generation, the economic value created by wind power generation arises from the reduction of generation by gas plants and the expansion of net exports. These impact factors are 0.53 and 0.19, respectively, of the total amount of electricity generated by the wind farms.

Due to the non-dispatchable nature of wind generation to maintain system reliability, the installed capacity of other dispatchable power plants (e.g. gas, hydro) cannot be reduced. There are no savings in capital or labour at the other plants operating within the system. The economic costs of the wind farms that are borne by the country are: (i) their initial capital investments, (ii) their cost of operation and maintenance[5], and (iii) the decommissioning costs at the end of the projects' useful life[6]. These are the resources used by the

more detail in the empirical findings.

[5]This information is tabulated from the annual reports of TransAlta Renewables Inc (2008–2018).

[6]To estimate the decommissioning cost per turbine, we use the Buffalo Ridge II Wind Farm Decommissioning Report (2008). The report contains a detailed decommissioning plan, including an estimate of costs less scrap/salvage value of turbines.

projects. Since the wind farms are intermittent generators, they will impose additional costs on the system. The main costs of intermittency are: (i) further reserves to meet short-run balancing needs, (ii) additional capacity to ensure peak demand can be achieved, and (iii) additional fuel consumed due to extra ramping at other plants. In this study, we used the available information from the research report by the UK Energy Research Centre (2006) that estimates system costs and impacts of intermittency for wind farms. The economic resource inflows (B_t^{eco}) , outflows (C_t^{eco}) and net present value (NPV_t^{eco}) for the Canadian economy can be expressed as:

$$B_t^{eco} = \sum_{t=t_0}^{T=t_n} WO_t(OD^g * FCR_t^g * PF_t^g * OD^{nx} * PX_t^{nx})$$

$$C_t^{eco} = \sum_{t=t_0}^{T=t_n} CAPEX_t^{wf} + OPEX_t^{wf} + DECOM_t^{wf} + (WCAP_t * 8760 * P_t^{intermit}) \quad (1)$$

$$NPV_t^{eco} = \sum_{t=t_0}^{T=t_n} (1 + EOCK)^{-t}(B_t^{eco} - C_t^{eco})$$

3.2 Wind farm owners

The financial benefits that accrue to the wind farm owners are: (i) payments from the IESO for output generated, (ii) payments from the IESO for curtailed output, (iii) renewable energy subsidies from the government that have come from the WPPI and ecoENERGY incentive programmes, and (iv) loan drawdown received by wind farms. Payments from the IESO are governed by the terms of the PPA contract, and the guaranteed prices of wind power in Ontario are confidential and vary under different procurement methods. We use the price of CAD 101/MWh for Melancthon I wind project[7], and for Melancthon II and Wolfe Island wind farms, the rate of CAD 110/MWh is employed, which is approximately in line with

[7]Based on the information provided in the annual report of Canadian Hydro (2008), the minimum price range for Melancthon I is approximately 8% less than the other two wind farms. Thus, considering the price of CAD 110/MWh for the Melancthon II and Wolfe Island wind projects implies the price of CAD 101/MWh for Melancthon I.

the average price paid to the wind energy developers for different initiative programmes, as reported in the Annual Report of the Office of the Auditor General of Ontario (2011). The electricity purchase price is also subject to a fixed nominal escalation factor of 15% of inflation per year for the duration of the contract, as stated in the annual report of Canadian Hydro (2008). The IESO is obligated to buy all of the power generated plus any additional electricity that could have been generated by the wind farm, if not curtailed by the IESO. Thus, the revenues of the wind farm are secured, and the market risks for the owners are minimized. The financial costs are: (i) the initial capital investment, (ii) the cost of operation and maintenance, (iii) decommissioning costs at the end of the project's useful life, (iv) taxes (income and other), (v) amenities fee, and (vi) the debt service (interest and principal repayment).

The financial inflows (B_t^{wf}) , outflows (C_t^{wf}) and net present value (NPV_t^{wf}) for the wind farm owners can be defined as:

$$B_t^{wf} = \sum_{t=t_0}^{T=t_n} \Big((WO_t + WC_t) * PW_t^{RES}\Big) + S_t^{ENERGY} + LD_t$$

$$C_t^{eco} = \sum_{t=t_0}^{T=t_n} CAPEX_t^{wf} + OPEX_t^{wf} + DECOM_t^{wf} + T_t^{inc} + T_t^{oth} + T_t^{amen} + DS_t \quad (2)$$

$$NPV_t^{wf} = \sum_{t=t_0}^{T=t_n} (1 + EOCK)^{-t} (B_t^{wf} - C_t^{wf})$$

3.3 Domestic consumers' point of view

Adding a wind farm to Ontario's supply mix will have an incremental financial impact on domestic consumers. The payments to the wind farm owners will add to the cost of electricity consumed in the province. At the same time, the cost of electricity that consumers must ultimately pay is reduced because of the value of the fuel saved by other generators as well as the revenue obtained from incremental exports. In addition, with effect from 1 November

2019, the Government of Ontario introduced the new Ontario Electricity Rebate (OER) under the Ontario Rebate for Electricity Consumers Act, 2016. The OER provides eligible customers with a 31.8% rebate on their electricity bill. It is an initiative plan that was introduced to cover a portion of the costs of the global adjustment (GA). As the budget of the Government of Ontario has been in a chronic deficit position, the financing of the OER will increase the government's level of debt. Hence, this scheme is a way to make future generations of taxpayers pay for the effects of the government's electricity policies on the costs of current electricity supply.

The GA is the component of the total commodity cost of electricity in Ontario that covers the cost of building new electricity infrastructure in the province, maintaining existing resources, as well as providing conservation and demand-management programmes[8]. Most electricity generating companies get a guaranteed contract price for the electricity that they produce. The GA is the difference between that guaranteed price and the money the generators earn in the wholesale marketplace. Using the data obtained from the Regulated Price Plan (RPP) manual report of the Ontario Energy Board (OEB) (2019), the amount of the rebate that is applicable to the costs of wind power generation is estimated to be 78% of the price paid to the wind farm owners for generation of electricity[9].

Adding a wind farm to the supply mix will change the average cost of electricity for the IESO. It will also impose an intermittency cost on the system. Since the IESO is a revenue-neutral organization, the net impact will be passed on to domestic consumers.

The incremental financial inflows (B_t^{con}) , outflows (C_t^{con}) and net present value (NPV_t^{con})

[8]More details are available at: http://ieso.ca/power-data/price-overview/global-adjustment.

[9]The 31.8% applies on the retail bill; however, given that about 40% of the delivered retail price of electricity is attributed to the transmission and distribution costs (OSPE, 2014), the rebate on the generation costs of electricity would be 53% ($\frac{31.8\%}{60\%}$) . The RPP manual report in 2019 indicated that GA is not distributed equally between the different sources of electricity generation in Ontario. Thus, the proportion of the rebate on the wind farm must be calculated accordingly. As shown in Table 2 of the RPP report, the unit cost of wind is 14.7 cents per kWh. Given the share of each source in total supply and its corresponding unit costs, the average cost of electricity is calculated as 9.92 cents per kWh. Hence, wind power generation contributes more than proportional to the amount of electricity it produces to the GA. Therefore, a 53% rate of rebate on average costs of electricity generation translates into a rate of subsidy on the costs of wind power of equal to ($\frac{14.7}{9.92} * 0.53 = 0.78$) or 78% of the payments per MWh that the IESO makes to wind farm owners.

for domestic consumers can be expressed as follows:

$$
\begin{aligned}
B_t^{con} &= \sum_{t=t_0}^{T=t_n} WO_t(OD^g * FCR_t^g * PF_t^g * OD^{nx} * PX_t^{nx}) + \underbrace{\sum_{t=t_1}^{T=t_n} r_r^{wf}\Big((WO_t + WC_t) * PW_t^{RES}\Big)}_{\text{OER}} \\
C_t^{con} &= \sum_{t=t_0}^{T=t_n} \Big((WO_t + WC_t) * PW_t^{RES}\Big) + WCAP_t * 8760 * P_t^{intermit} \\
NPV_t^{con} &= \sum_{t=t_0}^{T=t_n} (1 + EOCK)^{-t}(B_t^{con} - C_t^{con})
\end{aligned} \tag{3}
$$

3.4 Governments' point of view

The difference between the economic resource flows and the financial cash flows represents the tax and other externalities generated by the projects. Several levels of government are impacted by the development of these wind farms, namely the federal government (FG), the Ontario government (OG), the municipal governments (MG) and the Alberta government (AG). Our objective is to quantify the fiscal impacts that the investment in these Ontario wind farms have on each of these government organizations.

We start by considering the federal government. Our assumption is that the compensation received by the owners of gas power plants and hydro plants for their capital investments in generation capacity does not change. Hence, their corporate income liabilities are assumed not to be changed. Therefore, the incremental receipts that accrue to the federal government through income taxes are those paid by the wind farm owners. However, income taxes are shared between the federal government and the provincial government. The Ontario government receives 44.23%[10] of total corporate income taxes, while the rest (55.77%) transfers to the federal government. The incremental expenditures borne by the federal government are

[10] The Ontario corporation income tax is 11.5%, as stated by the Ontario Ministry of Finance, while the income tax rate including federal and provincial is 26%, as reported in the annual report of TransAlta Renewables (2015). Thus, the Ontario share of corporation income tax is 44.23%.

simply the payments made (to the wind farm owners) via the incentive programmes. Thus, the net present value of the federal government (NPV_t^{FG}) can be stated as:

$$\begin{aligned} B_t^{FG} &= \sum_{t=t_0}^{T=t_n} 55.77\% * T_t^{inc} \\ C_t^{FG} &= \sum_{t=t_0}^{T=t_n} S_t^{ENERGY} \\ NPV_t^{FG} &= \sum_{t=t_0}^{T=t_n} (1+EOCK)^{-t}(B_t^{FG} - C_t^{FG}) \end{aligned} \tag{4}$$

Moving to the Ontario government, the incremental benefits are the portion of incomes taxes paid by the wind farm owners, while the incremental expenditures are the value that the Ontario government pays in electricity rebate to consumers of electricity. Therefore, the net present value of the Ontario government (NPV_t^{OG}) can be expressed as:

$$\begin{aligned} B_t^{OG} &= \sum_{t=t_0}^{T=t_n} 44.23\% * T_t^{inc} \\ C_t^{OG} &= \underbrace{\sum_{t=t_1}^{T=t_n} r_r^{wf}\Big((WO_t + WC_t) * PW_t^{RES}\Big)}_{\text{OER}} \\ NPV_t^{OG} &= \sum_{t=t_0}^{T=t_n} (1+EOCK)^{-t}(B_t^{OG} - C_t^{OG}) \end{aligned} \tag{5}$$

For the municipality governments, the incremental benefits (B_t^{MG}) are the values of the other taxes and amenities fees, while the incremental expenditures are assumed to be zero. Hence, the net present value of the Ontario municipalities (NPV_t^{MG}) can be defined as:

$$B_t^{MG} = \sum_{t=t_0}^{T=t_n} T_t^{oth} + T_t^{amen}$$
$$C_t^{MG} = \sum_{t=t_0}^{T=t_n} 0 \tag{6}$$
$$NPV_t^{MG} = \sum_{t=t_0}^{T=t_n} (1 + EOCK)^{-t}(B_t^{MG} - C_t^{MG})$$

Wind farms in Ontario lead to less natural gas being purchasing from Alberta by gas-fuelled power plants. This causes there to be a tax loss incurred by Alberta due to the reduced royalty payments for natural gas. Using the rate of the royalty paid to the Alberta government on gas sales (R_r) of 8% (Alberta Ministry of Energy, 2019), the incremental expenditures (C_t^{AG}) are the value of the tax loss, while the incremental benefits (B_t^{AG}) are zero. Hence, the impact on the net present value of royalty revenues obtained by the Alberta government (NPV_t^{AG}) can be defined as:

$$B_t^{AG} = \sum_{t=t_0}^{T=t_n} 0$$
$$C_t^{AG} = \sum_{t=t_0}^{T=t_n} Rr * \Big(WO_t(OD^g * FCR_t^g * PF_t^g)\Big) \tag{7}$$
$$NPV_t^{AG} = \sum_{t=t_0}^{T=t_n} (1 + EOCK)^{-t}(B_t^{AG} - C_t^{AG})$$

3.5 Environmental point of view

A key promise of wind farm generation is the reduction in greenhouse gas (GHG) emissions, through the output displacement of thermal-powered generation plants. Here, the benefits arise from the substitution of electricity generated by the wind farms for that produced by the gas-fired plants in both Canada and its major export market, the United States. The US electric utilities gain financially from importing additional electricity from Ontario. More imports from Ontario result in less electricity produced in the United States using natural gas (fuel-saving)[11] and, accordingly, less GHG emissions[12]. In this study, estimates are made of these benefits of the CO2 emissions in both regions to draw a conclusion based on the net financial and global impacts[13].

The size of the cost saving depends on the type of generation being displaced, its carbon emission rates and the social cost of carbon. Unfortunately, there is no commonly accepted estimate of the social cost of carbon. However, following the estimated social cost of carbon for regulatory impact analysis by the US Environmental Protection Agency (EPA), we set the price of CO2 at CAD 51.25/tonne as the carbon price (EPA Fact Sheet, 2013). Note that the value of fuel saved (gas) is represented in millions of British thermal units (MBTU). Hence, there is a need to convert this value into tonnes of carbon reduction. We use the conversion factor of 0.053 (MBTU/tonnes of carbon dioxide) for this transformation[14]. Here, there are no negative externalities (C_t^{envir}) attributed to the wind farms; hence, the incremental impact on positive externalities (B_t^{envir}) is equal to the present value (NPV_t^{envir}) for the environment, and it can be presented as:

$$PV_t^{envir} = B_t^{envir} \sum_{t=t_0}^{T=t_n} (1 + EOCK)^{-t} (WO_t * OD^g * FCR_t^g * CC^g * SCC_t^g) \quad (8)$$

[11]The United States is a main partner for electricity exported from Ontario. Natural gas was the largest source of US electricity generation in 2018 (EIA, 2019). Thus, using the same assumptions for the efficiency of producing electricity through natural gas power plants in the United States and Canada, the benefits are measured.

[12]Here, like the approach employed for Ontario, the value of gas saved in the United States due to the import from Ontario is first quantified and then, using the same carbon price, the environmental benefits are obtained.

[13]Given that the main products of the combustion of natural gas are carbon dioxide (EIA, 1999), the impact of the reduction of nitrogen oxides (NOx), sulfur dioxide (SO2) and particulates are ignored in our study.

[14]The conversion factor is obtained by dividing the carbon content of the gas by the ratio of the pounds (lbs)/tonne (1000 kg). Here, the CO2 content is set to 117 lbs/MBTU based on the US EIA report (2016) on carbon dioxide emissions coefficients by fuel, and the number of pounds (lbs)/tonne (1000 kg) is 2,204.62. Thus, the ratio is found to be $\frac{117}{2,204.62} = 0.053$.

4 EMPIRICAL FINDINGS

Using the integrated investment appraisal framework discussed in section 3, the net impacts of each wind facility are measured and distributed to find the feasibility of the project from each point of view. While evaluating the viability of the wind farm project, a single real rate of discount (net of inflation) of 8% (Treasury Board of Canada Secretariat, 2007) is used for the cost of capital to all parties throughout the project's life. For the economic analysis, the economic conversion factor for gas is calculated to be 0.92[15].

Table 2: Estimated PVs in CAD million as of 2008 adjusted at 2019 price level.

#		Melancthon I	Melancthon II	Wolfe Island	Total
	Economic analysis				
1	PV of economic costs	225.93	414.48	626.29	1266.70
2	PV of economic benefits	58.17	74.73	113.92	246.82
3	Net Canadian economy gain/loss	−167.76	−339.75	−512.37	−1019.88
	Stakeholder analysis				
	Financial analysis				
4	NPV of wind farm owner	8.31	−8.56	−18.79	−19.04
	Domestic consumer				
5	NPV of domestic consumers	−155.64	−292.22	−436.01	−883.87
6	PV of Ontario rebate to consumers [+]	29.62	76.81	123.05	229.48
7	Net consumer gain/loss	−126.01	−215.41	−312.96	−654.39
	Government				
8	PV of federal government fiscal impacts	−3.88	−5.69	−10.30	−19.87
9	PV of Ontario government revenues (taxes)	8.70	13.17	18.93	40.80
10	PV of Ontario government costs (rebate) [−]	−29.62	−76.81	−123.05	−229.48
11	Net Ontario government gain/loss	−20.92	−63.64	−104.12	−188.68
12	NPV of Ontario municipality government	4.82	10.18	17.04	32.04
13	NPV of Alberta provincial government	−3.76	−4.79	−7.41	−15.96
14	Total all governments gain/loss	−23.74	−63.93	−104.79	−192.46
	Environmental externality				
15	NPV of Canada environmental externality	23.27	37.69	55.91	116.87
16	NPV of US environmental externality	8.35	13.51	20.04	41.90
17	NPV of global environmental externality	31.62	51.20	75.95	158.77

Note: PVs are evaluated at a capacity factor defined as $\frac{Capability}{InstalledCapacity}$ which then is projected using the 1.6% annual decline (Staffell and Green, 2014) throughout the project life.

As shown in Table 2, the key potential benefit for the Canadian economy is the value of

[15]Moving from the financial analysis to the economic analysis implies the usage of the conversion factor (economic value/financial value) for gas to calculate the savings from a country's economic point of view. Financial prices are market prices, which include all tariffs, taxes and subsidies. This results in a higher financial price than the economic price (see detail in Jenkins (1999)).

gas saved, which is not sufficient to compensate the costs imposed on the economy by each wind project. In total, the economic benefits (Table 2, row 2) obtained from these wind facilities are about 19.5% ($\frac{246.82}{1{,}266.70}$) of the PV of the total costs of the wind facilities (Table 2, row 1). Given the imposed costs and the benefits of each wind project, the economic benefit-cost ratio (row2/row1) of Melancthon I is 26%, while for each of the other wind farms the ratio is about 18%. As mentioned before, Melancthon I began its commercial operations in early 2006, while Melancthon II started its operations at the end of 2008.

According to the historical data published by Canadian Enerdata Ltd (https://enerdata.com), from 2006 to 2008 the natural gas price experienced a large increase in parallel with the crude oil price. The average price of the Dawn Hub for the period 2006–2008 was USD 8.03/MBTU, which is approximate twice the average price of natural gas for the period 2009–2018 (USD 3.77/MBTU). This is the cause of the higher than expected benefits of Melancthon I. The economic value of the fuel savings was substantial for two of its initial operating years.

The economic analysis here demonstrates that the economic NPVs (Table 2, row 3) of all wind projects are found to be negative. In total, these three wind farms yield a net loss of about CAD 1 billion for the Canadian economy. This indicates that these representative wind projects are a drain on Canada's economic resources. It is also observable that as the size of the facility increases, the magnitude of the adverse impact of the project on the economy increases.

For the economic NPV of the projects to break even with the current pattern of displacements, the average price of gas would have to be approximately 60% higher than that experienced throughout the life of the projects. Based on the history of gas prices, this is extremely unlikely. Alternatively let us assume that the electricity generated by wind were to displace gas fired power generators by 100% rather than the empirically estimated 53%. In this case, the total benefits obtained from gas savings through these three wind farms would have a present value of CAD 346.32 million. This amount is only about 27% of the present value of the costs of these wind farms.

With the price of CAD 101/MWh for Melancthon I and CAD 110 CAD/MWh for the other two wind projects[16], the financial NPV (Table 2, row 4) of Melancthon I is found to be positive while the financial NPVs of the other two wind farms, Melancthon II and Wolfe Island, are negative[17]. The main reason for the negative financial NPVs for the Melancthon II and Wolfe Island wind facilities relates to their planned capital investment. In both cases, the completion of the project was delayed, which imposed a higher than expected capital investment (CAD 10 million for Melancthon II and CAD 25 million for Wolfe Island, as highlighted in the annual report of Canadian Hydro (2008)). The latter two wind farms also pay higher annual amenities fees to the local municipal governments than does the Melancthon I wind power plant. However, increasing the contract price for these two wind facilities would make their financial NPVs positive. Our break-even examination shows that the price of CAD 112/MWh for Melancthon II and CAD 116/MWh for the Wolfe Island wind farm results in a positive financial NPV. Given the target rate of return on equity set at a real 8%, the financial internal rate of return (FIRR) of Melancthon I is found to be a real rate of 9.43%, while the FIRRs of Melancthon II and Wolfe Island are 7.23% and 6.86%, respectively.

The negative net economic NPV of all wind facilities is compensated with a loss which must be borne by the various stakeholders of the electricity system, primarily the electricity consumers and taxpayers of Ontario (a consumer loss of 64% ($\frac{654.39}{1,019.88}$) and about 19% ($\frac{192.46}{1,019.88}$) of the economic loss borne by all governments combined).

These wind farms will impose a total PV loss of CAD 883.87 million on domestic consumers (Table 2, row 5). This loss is partly offset by CAD 229.48 million from the Ontario government's rebate programme (row 6). This is the amount of economic losses of these three

[16]Note that the pricing of renewable power projects such as wind power is related to the financing parameters and some other market and non-market (e.g. political risks) factors which strongly affects the distribution of project benefits and costs (Gifford et al., 2011).

[17]The wind projects signed after 2009 were mostly compensated under the FIT rates (which started at CAD 135/MWh (Canadian Wind Energy Association, 2020) and have recently declined to CAD125/MWh (IESO, 2016)). These secure PPA rates are above those received by our sample of wind farms. Their higher guaranteed prices will result in more losses to be borne by Ontario electricity consumers and the future generations of taxpayers of Ontario.

wind farms that have been transferred to future generations of Ontario taxpayers. Thus, the amount of CAD 654.39 million is the net loss borne by current consumers (row 7).

This substantial loss to Ontario's consumers relates to several issues. Consumers must bear the cost of intermittency and curtailment[18]. In addition, part of this financial loss to Ontario's electricity consumers stems from the fact that the compensation Ontario receives for its exports is the intertie price. This price is much lower than the wind farms' contract prices. For instance, the average intertie price between 2016 and 2017 is indicated as CAD 30 per MWh (OSPE, 2017). As the IESO is revenue neutral, the difference is added to the GA charge and passed on to Ontario's consumers.

To make the situation clearer, Table 3 reports the PVs of both costs and benefits of electricity exports attributed to these three wind farms. As can be seen, the incremental electricity exports arising from the electricity generated by these wind farms impose a total PV financial loss on Ontario's residents of CAD 154.99 million over the life of the wind farms. By comparison, the present value of the electricity rebates that consumers receive from the Ontario government on the costs of generation of electricity from these wind farms is CAD 229.48 million. Hence, about 68% of the value of the rebates received by Ontario's consumers arises to offset the costs of incremental wind-generated electricity that is sold to the United States and other customers of Ontario's electricity exports. It will eventually be paid for by future generations of Ontario taxpayers.

Table 3: Estimated PVs of costs and benefits of electricity exports

	Melancthon I	**Melancthon II**	**Wolfe Island**	**Total**
PV of cost of wind power exports	40.80	69.34	103.60	213.74
PV of revenues from sale of exports	13.82	17.78	27.15	58.75
Net loss from wind power exports	26.98	51.56	76.45	154.99

Note: Values are in CAD million as of 2008 adjusted at 2019 price level.

Given that there are no savings from hydro displacement, the sum of the value of gas

[18] In 2018, the estimated curtailment of both Melancthon I and II was found to be 4%, while for Wolfe Island, the curtailed output was approximately 10.2% of actual output.

displacement plus sales of exports and the OER are not enough to compensate Ontario's electricity consumers for the additional generation costs arising from the wind farms. Ontario has been suffering from surplus baseload generation in recent years, and wind generation tends to be available more intensely during off-peak night-time periods. Hence, the electricity generated during these periods has a relatively low value. During high-demand days, wind power will displace more expensive gas generation. This would provide benefits for the consumers as the total unit cost of gas generation is higher than that for wind. But the opposite is true for the hydro power plants. During low-demand days, the wind farms will displace cheaper hydro generation. There is little or no economic gain with hydro displacement.

The NPV of the government for all wind facilities in total is negative (Table 2, row 14). The wind farms impose a total annual loss of CAD 192.46 million on the governments in Canada. An annual loss of CAD 19.87 million is inflicted on the federal government. This loss is due to the payments from the federal government under the incentive programmes. The largest portion of the total government loss ($\frac{188.68}{192.46}$, or 98%) is to the Ontario government. The Ontario rebate programme generates annual costs of CAD 229.48 million and it is clear that the revenue sources of the government (income taxes) cannot cover this cost of the promotion of renewable energy in Ontario. The only beneficiary seems to be the municipality governments that receive the amenities fees and taxes other than income tax (Table 2, row 12).

The total annual environmental benefits obtained due to the gas generation displacement by wind power generation in Ontario are equal to CAD 116.87 million (Table 2, row 15). These environmental benefits represent only 11% of the negative net economic PV of these wind projects. At the same time, the environmental benefits due to the export of electricity from Ontario to the United States are CAD 41.90 million annually (row 16). By subsidizing these incremental exports, Ontario residents are indirectly providing assistance to the United States in order for it to meet its environmental CO2-reduction targets. Globally, the electricity generated through these wind farms in Ontario provides CAD 158.77 million of benefit due to the reduction in CO2 emissions (row 17). Comparing the total environmental benefits with the net economic PV of wind power generation in Ontario (only 16% of Ontario's economic losses) shows that investments in these wind farms cannot be justified by their global environmental impacts.

These three wind farms account for 398 MW of the total 5,076 MW of wind farms installed generation capacity. Furthermore, the average capacity factor of these three wind farms in 2018 was 27%, which is exactly the same as the average capacity factor (27%) of all Ontario's wind farms (IESO Reliability Outlook, 2019). Hence, the results from this sample of wind farms may provide a basis for an estimation of the economic performance of the entire set of wind farms. These three wind farms, with a total capacity of 398 MW, are incurring an economic loss of 1,019.88 CAD million. Thus, if the total installed wind capacity of 5,076 MW had approximately the same capital cost per MW, the expected present value of the economic loss would be about ($\frac{5{,}074}{398} * 1,019.88$) 13 CAD billion. These estimates of the economic losses are consistent with the financial losses to consumers reported in the Annual Report of the Office of the Auditor General of Ontario (2015).

Considering the harmful impacts of wind power for consumers, governments and the Canadian economy reinforces the criticism of government policies such as the GEGEA (Trebilcock, 2017). This study suggests that the policies as they apply to wind farms have failed to deliver their objectives cost-effectively. Our findings show that those policies have an adverse effect on the economy and have led to a dramatic rise in the size of the GA component of electricity prices in Ontario. This issue has also been addressed by the Office of the Ontario Auditor General (2015). Unfortunately, at this point in time there is not much room to undo the effects of past policies until the current set of PPA contracts have expired.

5 Conclusion

Through the integrated investment appraisal, our findings show that the Ontario government's policy of subsidizing the production of electricity by wind farms to reduce GHG emissions has been a spectacularly costly experiment. This indicates that if there is a potential winner in this situation, it is the wind farm owners. The contract price shields the wind farm owners from both demand and price risk, for 20 years. The system operator (the IESO) has agreed to buy all power generated by the wind farms, regardless of demand conditions. The wind farms are also paid for any curtailed output. Furthermore, the purchase price of electricity is guaranteed under the contract, with a modest escalation factor based on inflation.

Overall, the net savings in fuel due to the deployment of the wind farms indicates a very poor economic return on these investments. The negative economic NPVs that are passed on to consumers and future taxpayers of Ontario are an indication of these losses. Due to the relatively low displacement factor of gas generation, it becomes almost impossible to integrate wind power into the Ontario electricity system, which is dominated by nuclear power generation. It has been a failure of policy to promote wind power investments when the generation system for the foreseeable future is dependent on nuclear baseload power. The province is currently undertaking nuclear refurbishments and requires a temporary source of electricity to fill the void left by the offline nuclear plants (D'Onofrio, 2016). Even if we assume that natural gas plus wind farm generation would be substituted for the nuclear power generation, the potential benefits of the gas displacement would still not be enough to cover the economic costs of wind power generation.

References

[1] Alberta Ministry of Energy (2019) Energy Annual Report 2018–2019.

[2] Auditor General (2011) "Electricity Sector—Renewable Energy Initiatives," 2011 Annual Report of the Office of the Auditor General of Ontario.

[3] Auditor General (2015) "Electricity Power System Planning," 2015 Annual Report of the Office of the Auditor General of Ontario.

[4] Ayodele, T., Ogunjuyigbe, A., and Amusan, T. (2016) "Wind power utilization assessment and economic analysis of wind turbines across fifteen locations in the six geographical zones of Nigeria," Journal of Cleaner Production 129, 341–49.

[5] Bahramian, P., Jenkins, G., and Milne, F. (2020) "The displacement impacts of wind power electricity generation: Costly lessons from Ontario," Development Discussion Papers 2020–22, JDI Executive Programs.

[6] Borenstein, S. (2012) "The private and public economics of renewable electricity generation," Journal of Economic Perspectives 26(1), 67–92.

[7] Buffalo Ridge II Wind Farm (2008) "South Dakota Facility Permit Application, Appendix H, Decommissioning Report," Iberdrola Renewables, Oct 2008.

[8] Canadian Hydro Developers Inc, "Annual Information Form," 2005–2008.

[9] Canadian Wind Energy Association (2019) Ontario Wind Energy Market Profile.

[10] Canadian Wind Energy Association (2020) Whitepaper on Wind Energy and the Ontario Market.

[11] Cohen, S. M., and Caron, J. (2018) "The economic impacts of high wind penetration scenarios in the United States," Energy Economics 76, 558–73.

[12] Cundiff, B. (2015) "Ontario's Coal Phase Out: Lessons Learned from a Massive Climate Achievement," Ontario Clean Air Alliance Research.

[13] D'Onofrio, Z. (2016) "Ontario-Québec electricity collaboration and interprovincial trade barriers: using the Agreement on Internal Trade to promote a more sustainable electricity sector in Canada."

[14] EIA (US Energy Information Administration) (1999) Natural Gas 1998: issues and trends. DOE/EIA-0560 (98). April 1999.

[15] Energy Information Administration (EIA). 2019. Electric Power Monthly, February 2019. Washington, DC: US Energy Information Administration.

[16] Environmental Protection Agency (EPA) FACT SHEET (2013). Social cost of carbon. Washington, DC, USA.

[17] Flyvbjerg, B. (2006) "Five misunderstandings about case-study research," Qualitative Inquiry 12(2), 219–45.

[18] Frondel, M., Schmidt, C. M., and Vance, C. (2014) "Revisiting Germany's solar cell promotion: an unfolding disaster," Economic Analysis and Policy 44(1), 3–13.

[19] Gifford, J. S., Grace, R. C., and Rickerson, W. H. (2011) "Renewable energy cost modeling: A toolkit for establishing cost-based incentives in the United States," Subcontract Report NREL/SR-6A20-51093, National Renewable Energy Laboratory.

[20] Hoppmann, J., Peters, M., Schneider, M., and Hoffmann, V. H. (2013) "The two faces of market support—How deployment policies affect technological exploration and exploitation in the solar photovoltaic industry," Research Policy 42(4), 989–1003.

[21] Independent Electricity System Operator (IESO) (2016) "2017 FIT Price Review, Background Information."

[22] Independent Electricity System Operator (IESO) (2018) "Electricity Pricing: Global Adjustment Costs."

[23] Independent Electricity System Operator (IESO) (2019) "Reliability Outlook, An adequacy assessment of Ontario's electricity system."

[24] Jenkins, G. P. (1999) "Evaluation of stakeholder impacts in cost-benefit analysis," Impact Assessment and Project Appraisal 17(2), 87–96.

[25] Jenkins, G., Kuo, C., and Harberger, A. (2011) "Discounting and alternative investment criteria," Chapter 4 in Cost-Benefit Analysis for Investment Decisions, IDEAS page for this paper.

[26] Jenkins, G. P., Baurzhan, S. (2018). Evaluation of the Economic Performance of Hydropower Developments Supported by the World Bank Group 1975 to 2015 (No. 2018-06). JDI Executive Programs.

[27] Kennedy, S. (2005) "Wind power planning: assessing long-term costs and benefits," Energy Policy 33(13), 1661–75.

[28] Lu, X., Tchou, J., McElroy, M. B., and Nielsen, C. P. (2011) "The impact of Production Tax Credits on the profitable production of electricity from wind in the U.S.," Energy Policy 39(7), 4207–14.

[29] Natural Resources Canada (2008) "ecoENERGY for Renewable Power Program, Terms and Conditions".

[30] Ontario Energy Board (OEB) (2019). Regulated Price Plan Price Report.

[31] Ontario Society of Professional Engineers (OSPE) (2014) "The Real Cost of Electrical Energy," Energy Policy Presentation, OSPE Energy Task Force.

[32] Ontario Society of Professional Engineers (OSPE) (2017) "Empower Ontario's Engineers to Obtain Opportunity. An Analysis of Ontario's Clean Electricity Exports," report prepared by the OSPE.

[33] Peters, M., Schneider, M., Griesshaber, T., and Hoffmann, V. H. (2012) "The impact of technology-push and demand-pull policies on technical change–Does the locus of policies matter?" Research Policy 41(8), 1296–308.

[34] Rosenbloom, D., Berton, H., and Meadowcroft, J. (2016) "Framing the sun: A discursive approach to understanding multi-dimensional interactions within socio-technical transitions through the case of solar electricity in Ontario, Canada," Research Policy 45(6), 1275–90.

[35] Rowlands, I. H. (2005) "Envisaging feed-in tariffs for solar photovoltaic electricity: European lessons for Canada," Renewable and Sustainable Energy Reviews 9(1), 51–68.

[36] Rowlands, I. H. (2007) "The development of renewable electricity policy in the Province of Ontario: the influence of ideas and timing," Review of Policy Research 24(3), 185–207.

[37] Salci, S., and Jenkins, G. P. (2018) “An economic analysis for the design of ipp contracts for grid-connected renewable energy projects,” Renewable and Sustainable Energy Reviews 81, 2410–20.

[38] Songsore, E., and Buzzelli, M. (2015) “Wind energy development in Ontario: A process/product paradox,” Local Environment 20(12), 1428–51.

[39] Staffell, I., and Green, R. (2014) “How does wind farm performance decline with age?,” Renewable Energy 66, 775–86.

[40] Stokes, L. C. (2013) “The politics of renewable energy policies: The case of feed-in tariffs in Ontario, Canada,” Energy Policy 56, 490–500.

[41] TransAlta Corporation, “Annual Report,” 2008–2018.

[42] Treasury Board of Canada Secretariat (2007) “Canadian Cost-Benefit Analysis Guide: Regulatory Proposals.”

[43] Trebilcock, M. (2017) “Ontario’s Green Energy Experience: Sobering Lessons for Sustainable Climate Change Policies,” C.D. Howe Institute E- Brief, August 2017.

[44] UK Energy Research Centre (2006) “The Costs and Impacts of Intermittency: An assessment of the evidence on the costs and impacts of intermittent generation on the British electricity network.”

[45] US Department of Energy (2017) “Overview of CHP Technologies,” Combined Heat and Power Technology Fact Sheet Series.

[46] US Energy Information Administration (EIA) (2018) “Electric Power Annual 2016”.

[47] Wind Concerns Ontario (2018) “Wind power profits don’t stay in Ontario”.

[48] Winfield, M., and Dolter, B. (2014) “Energy, economic and environmental discourses and their policy impact: The case of Ontario’s Green Energy and Green Economy Act,” Energy Policy 68, 423–35.

[49] Xia, F., and Song, F. (2017) “Evaluating the economic impact of wind power development on local economies in China,” Energy Policy 110, 263–70.