Alberta's Renewable Electricity Program: Design, Results, and Lessons Learned

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Abstract

We present a case study and analysis of Alberta's Renewable Electricity Program, one of a suite of policies implemented between 2015 and 2019 to increase the share of renewable generation in the Canadian province's fossil-fuel-dominated electricity system. The program consisted of a series of reverse auctions for contracts-for-differences which provided successful proponents with a project-specific guaranteed price for power generation. We find that the Renewable Electricity Program was successful in three important ways. First, it contracted for new renewable generation at prices in the range of CA$30 to CA$43/MWh (US$23 to US$33/MWh), well below expectations and among the lowest procurement costs globally at the time. These contracts have resulted in gains *to* the government of CA$75.5 million (US$60 million) to date. Second, the program ushered new entrants into Alberta's power market, including through mandated Indigenous equity participation in one round of auctions. Third, we find that price discovery and the incentive to develop new projects provided by the program spurred privately-financed development. While the program was a success, we argue that its design did not adequately reward high-value generation, which could have become an issue in future auction rounds. We analyse design alternatives that would have improved the program's dynamic efficiency.

Keywords (1-6): renewable energy; wind energy; climate change; auction; carbon pricing; offsets

1. Introduction

In 2015, the Canadian province of Alberta pledged to phase out coal-fired electricity and to supply 30% of the province's electricity from renewable sources by 2030. When these goals were adopted, less than 10% of the province's generation came from renewable sources, while more 60% came from coal-fired facilities (Alberta Electricity System Operator (AESO), 2016a). We present a case study of one of the policies implemented to meet Alberta's goals: the Renewable Electricity Program (REP). REP was comprised of three rounds of reverse auctions which awarded government-backed, two-sided contracts-for-differences which effectively guaranteed project revenues for 20 years. Contracts for over 1360 MW of wind generation were signed under REP, at costs well below levels that government advisors and industry analysts had predicted. Our results show that, to date, REP contracts have resulted in gains *to* the government of over CA$75 million on electricity. In addition to this, we estimate that at least CA$56 million in tradeable greenhouse gas emissions credits have been surrendered to the government under the REP contracts. Thus, we estimate a cumulative surplus of over CA$130 million to date.

The REP design was informed by expert advice (Leach et al., 2015), stakeholder input (AESO, 2016b) and by global experience with renewable energy auctions (AESO, 2016c). The choice to deploy a reverse auction mechanism was consistent with global trends for government renewables procurement at the time (Anatolitis et al., 2021; Bayer, 2018; Bayer et al., 2018a, 2018b; Fitch-Roy et al., 2019; Gephart et al.,

[*] In addition to standard megawatt (MW) and megawatt-hour MWh) units, we use the following abbreviations and acronyms in this paper: 1) CA$ denotes nominal Canadian dollars. The exchange rate was approximately 1 US dollar (US$) to CA$1.30 during the time period of this study; 2) Financial instruments: contracts-for-differences (CfD) and power purchase agreements (PPA); 3) Alberta-specific acronyms: Renewable Electricity Program (REP) and the Alberta Electric System Operator (AESO); and 4) financial metrics: Levelized Cost of Electricity (LCOE).

2017; Haufe and Ehrhart, 2018; Jansen et al., 2022; Matthäus, 2020). REP's procurement through two-sided contracts for differences is most closely comparable to procurements in New York State, the United Kingdom, and Denmark, and shares common elements with procurement programs in Greece, Poland, and Hungary (Beiter et al., 2021, 2020; Szabó et al., 2020). The REP also had several notable features. First, the REP was open to most renewable generation technologies, with no technology-specific caps or quotas. Second, any financial shortfall was to be supported by revenue from carbon taxes, not through on-bill charges on electricity ratepayers. Third, in addition to a financial pre-qualification procedure, projects were only eligible they required no new transmission investment beyond that required for connection to existing infrastructure. Finally, one of the auction rounds stipulated Indigenous equity participation as a necessary condition for support.

We evaluate the cost-effectiveness and dynamic efficiency of the REP. REP's competitive auction produced costs that were among the lowest globally at the time, the lowest in Canadian history (Szabó et al., 2020, p. 15), and close to the theoretical minimum procurement cost for North American onshore wind (Stehly et al., 2020). We estimate that the procurement has resulted in surplus value to the government, but also note that the government took on substantial electricity market and climate policy risk through the REP. The surpluses earned to date are, in part, compensation for the assumption of those risks. We argue that the assumption of risks in the initial REP auction rounds assured the cost-effectiveness of the procurement; had those risks remained with project proponents, the procurement cost could have been much higher (see Jansen et al., 2022, Neuhoff et al., 2018), and the program may not have succeeded.

The REP accelerated early-stage development of prospective renewable energy projects and provided important information on the cost of renewable energy. REP led to a significant increase in the number of projects in the development queue and subsequently led to an historic increase in private power purchase agreements (PPAs) for renewable electricity. The REP also increased the diversity of actors involved in Alberta's market, including through its Indigenous equity participation requirement. Private sector projects built with Indigenous partners have followed the REP's targeted call for such partnerships.

Our analysis raises concerns about the dynamic efficiency of the REP design. The REP selected for the lowest levelized cost of electricity, but was agnostic to the value of a project's generation. This likely came at a minimal cost for the initial rounds of REP, as the procurements were relatively small compared to the overall size of the market. We find that future rounds using the same design would have been likely to procure less valuable contracts, and to erode the value of previously-supported projects. We discuss two design modifications which could have mitigated this concern in later rounds: a fixed premium to market prices and a benchmarked contract-for-differences similar to that used in the procurement of offshore wind power in New York State (New York State Energy Research and Development Authority, 2018, Appendix C. See also Beiter et al., 2021). We argue that either could have mitigated long-term inefficiencies inherent in the REP design. We also discuss potential implications of Alberta's approach to transmission and solutions for cost-allocation in future renewable electricity procurement.

The balance of the paper proceeds as follows. We first provide relevant context from Alberta's electricity market and economic conditions. We then summarize the conception, design, and implementation of the REP. We evaluate the REP in terms of static and dynamic efficiency and its compatibility with Alberta's electricity system. We end with a discussion of design alternatives and conclude with policy implications.

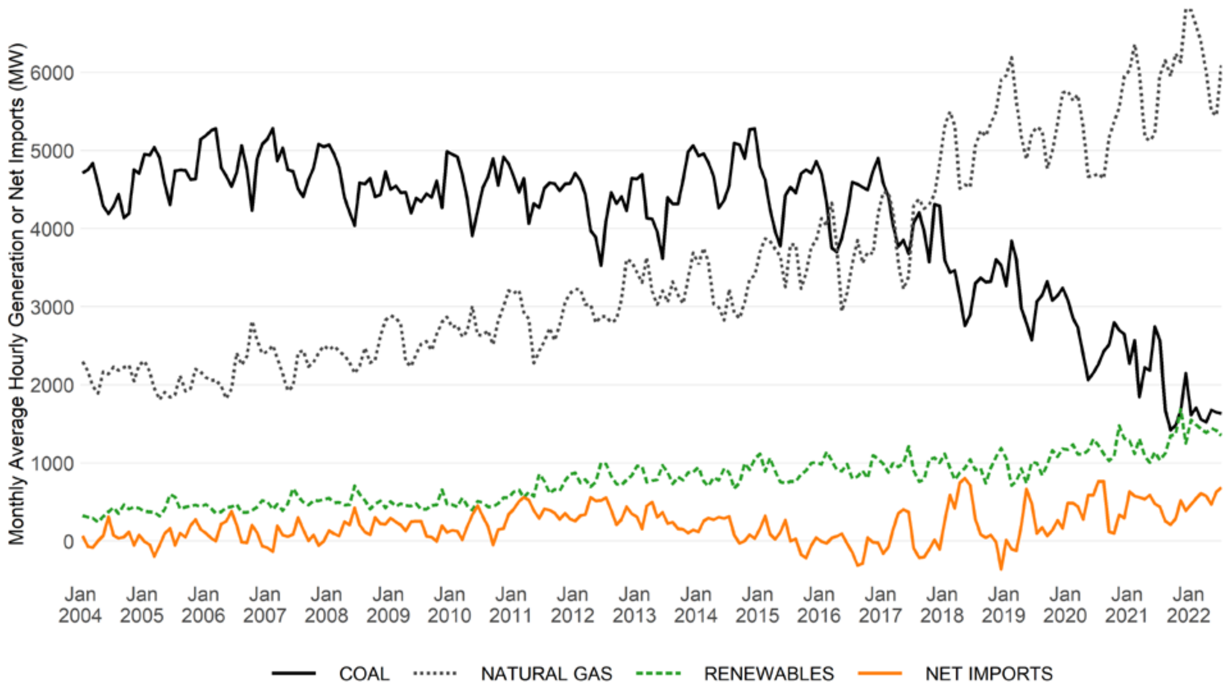

Figure 1: Alberta monthly generation by fuel and monthly net imports through July 31, 2022. Data sources: AESO via NRGStream (2022).

2. Electricity and Economic Context

2.1 Alberta's Electricity Market

Alberta has had a competitive, energy-only wholesale market for electricity since 2002 (Daniel et al., 2007). Alberta has no capacity market or equivalent opportunities for generators to receive long-term payments based on installed capacity. A separate ancillary services market operates alongside the hourly wholesale market, but does not factor into our analysis. Generators submit hourly offers from each facility and offered blocks are dispatched in increasing order by price. The pool price, received by all generators, is set based on the last offered block dispatched (AESO, 2022a).

Alberta's market has been and remains dominated by fossil fuels, as shown in Figure 1. Coal's share of generation had declined from 79% in 2002 to below 63% in 2015 when the REP was designed, and accounted for only 31% of generation by 2021 (AESO 2011, 2016a, 2022b). Coal generation has been replaced by natural-gas-fired generation and, more recently, by renewable generation. Renewables (wind, hydro, and solar) accounted for less than 3% of generation in 2002 and 9% of generation in 2015, but accounted for 14.3% of net-to-grid generation in 2021 (AESO 2011, 2016a, 2022b). Renewable generation is poised to increase with over 6600 MW of wind projects and over 11,000 MW of solar projects seeking connection to the Alberta grid as of August, 2022 (AESO, 2022f). If even a small share of these projects reach commercial operation, that will represent a substantial increase to the 2389MW of wind and 977MW of solar generating capacity currently installed.

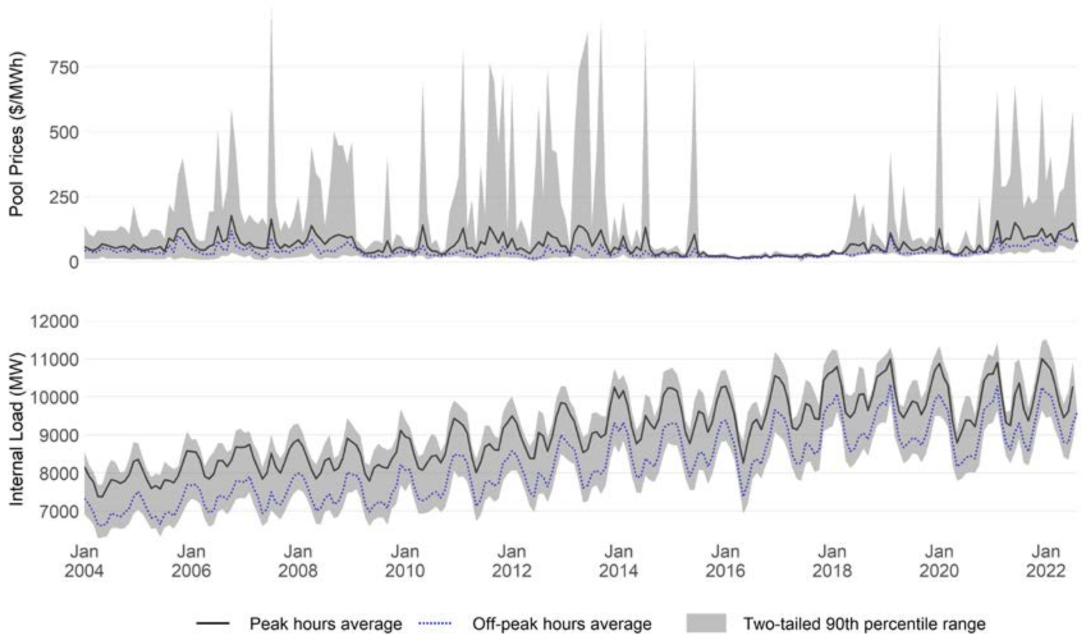

Figure 2: Prices and Internal Load in Alberta's Wholesale Power Market. Data source: AESO (2022c).

Trade plays a small role in Alberta's market. Three interties to British Columbia, Saskatchewan, and Montana have a combined effective capacity of less than 1500 MW, roughly 13% of Alberta's peak load. Trade typically accounts for approximately 5% of annual energy sales (AESO, 2022b).

Market electricity prices range between regulatory limits of CA$0 and CA$1000/MWh. Market prices since 2004, along with the 5th through 95th percentile monthly ranges are shown in Figure 2. The period in which the REP was proposed, designed, and implemented (2015-2017) featured the lowest power prices since the wholesale market was restructured in the early 2000s. This price depression resulted from the combined effects of an economic downturn, discussed further below, and from the commissioning of a large combined-cycle natural gas plant in mid-2014. The small size and relative isolation of Alberta's electricity system mean that prices are affected significantly by small changes in market conditions, and the 2015-2017 period saw significant shocks to both supply and load.

Market revenues for renewable generation depend on the correlation between a facility's generation profile and market prices. Historically, as shown in Figure 3, average revenues for wind generation have fallen well-below market average prices due to most capacity being installed in the same wind regime. Utility-scale solar, on the other hand, has historically realized premiums to market prices. Thus, different contract structures (e.g. price-firming contracts vs. price premia) will have different implications for the two most prevalent renewable generation options for Alberta. Premia and/or discounts to market prices are likely to change as installed renewable generating capacity rises, as has been seen in other regions (Brown and O'Sullivan, 2020).

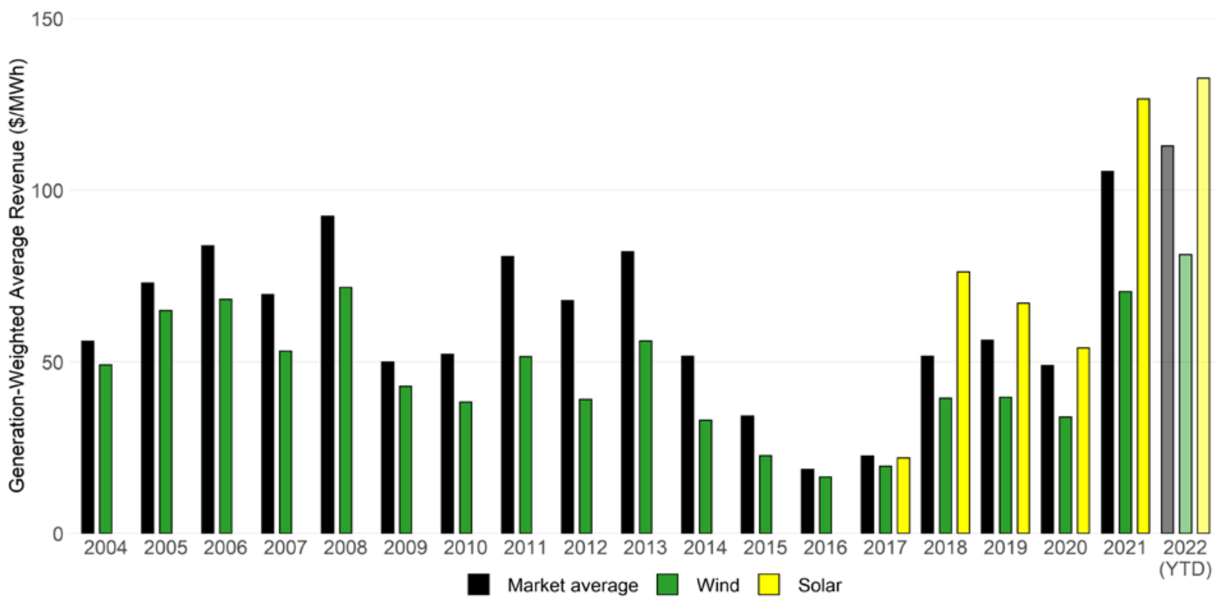

Figure 3: Average revenue for the Alberta market and for wind and solar generation, 2004-2022. Note that 2022 year-to-date average values through July 31, 2022 are shown with lighter fill. Data sources: AESO via NRGStream (2022).

Two other characteristics of Alberta's electricity system are relevant to the policies we discuss. First, Alberta's annual peak load and peak average monthly demand occur in the winter months. This impacts renewable energy policy since neither wind nor solar generation match winter peak loads well (AESO, 2022b, pp. 23 and 28). Second, all generators connected to the Alberta grid receive the same hourly price (i.e. there is a single nodal price), and Alberta has neither transmission congestion pricing nor transmission rights. New generators are responsible for a connection charge, and that connection charge may be increased if regional upgrades to the transmission system are required to accommodate specific new generation (Government of Alberta, 2007, secs. 8, 28, 29).

2.2 Economic and Political Background

The state of Alberta's economy was a significant factor in many of the REP design and implementation decisions made between 2015 and 2018. Alberta's economy and its government's fiscal balance are heavily dependent on oil and gas production. A significant downturn in oil prices began in late 2014, and plunged the province into a deep recession within a year, with the contraction enduring until 2017. Most economic indicators had not recovered to pre-recession levels before the onset of the COVID-19 pandemic in 2020 (For detailed economic data, see Government of Alberta, 2022a).

These economic conditions constrained the design of the province's renewable energy policy in 4 ways. First, the province's fiscal situation made increased program spending more challenging. Second, the economic hardships increased concerned about on-bill impacts of electricity market changes even as electricity prices hit historic lows (see, for example, Varcoe, 2016). Third, since electricity prices were likely to rise regardless of renewable energy policies, there was a political imperative that renewable energy procurement not be blamed for higher future bills (for related evidence, see Aklin, 2021, or Stokes, 2015). Finally, the adverse economic conditions meant that a large renewable energy build-out could be framed as an opportunity for short-term economic stimulus and long-term economic diversification (Alberta New Democratic Party, 2015, p. 6).

A provincial election in May of 2015 ended 45 years of centre-right government in Alberta, and handed power to the centre-left New Democratic Party (NDP) of Alberta. The new government had made significant promises concerning climate change mitigation and energy (Alberta New Democratic Party, 2015). Similarly, the election of Prime Minister Justin Trudeau in October of 2015 assured that Canada would take more aggressive federal action on climate change: Trudeau's platform pledged a national carbon price and measures to accelerate renewable energy (Liberal Party of Canada, 2015, pp. 39–42). This political evolution set the stage for major changes to climate and energy policy in Alberta.

2.3 Renewable Energy Policy Design Background

In June of 2015, the Alberta government appointed an expert panel to advise on climate change policy, energy efficiency, renewable energy procurement, and coal-fired electricity phase-out plans (Government of Alberta, 2015).[1] The Panel recommended procuring sufficient renewable energy to supply 30% of the province's electricity by 2030 through technology-neutral reverse auctions for fixed premia to electricity revenues (Leach et al., 2015, p. 50). A regime similar to that recommended by the panel was, for example, adopted in Denmark's 2018 Technology Neutral Tender (González and Kitzing, 2019). The panel's recommendations were informed by previous Canadian renewable electricity policies including the Clean Power Call in British Columbia (BC Hydro, 2010), feed-in-tariff programs implemented in Ontario (Yatchew and Baziliauskas, 2011), and wind energy procurements in Quebec in 2008 and 2013 (Government of Quebec, 2013). The panel was concerned that administratively-set feed-in tariffs would be more costly than a competitive procurement (see Shrimali et al., 2016, for similar concerns). The Clean Power Call had relied on a bid adjustment mechanism to account for differing value of generated power (BC Hydro, 2010, p. 8), a role the expert panel felt could be accomplished through exposure to Alberta's competitive electricity market. The panel also recommended that the procurement be financed through carbon tax revenues in order to limit on-bill impacts for electricity consumers (Leach et al., 2015, p. 51). The panel recognized that market risk exposure might make developers more hesitant to invest than an approach that insulated them from price risk (see Dukan and Kitzing, 2021, Neuhoff et al., 2018, or Winkler et al., 2018 for a discussion of these aspects of renewable energy policy design).

The Government of Alberta subsequently directed the province's independent system operator (the AESO) to "develop and implement a plan to bring on new renewable electricity generation capacity [...] while keeping the costs of doing so as low as possible through a competitive process, such as an auction" (AESO, 2016c, p. 50). The government specified that the program should take into account the pending phase-out of coal generation, and be compatible with the existing market structure (AESO, 2016c, p. 50).

The AESO examined three potential mechanisms to offer financial support for renewable energy:

1) A fixed ($/MWh) payment, which mirrored the earlier expert panel recommendations (hereafter a *fixed premium*);
2) A two-sided contract-for-differences (*CfD*), under which contract holders would be paid (or would pay) the difference between their contract strike price and the wholesale market price; and
3) Capacity payments ($/MW) for new generating capacity (AESO, 2016c, p. 3).

[1] One of the authors of this paper, Andrew Leach, was Chair of the Climate Leadership Panel for the Government of Alberta. Another author, Tim Weis, was an advisor to the Ministers of Environment and Energy during the conception, development and implementation of the REP.

The AESO solicited input from stakeholders and commissioned a third-party review of renewable energy procurement programs from Australia, California, New York, Ontario and the United Kingdom (AESO, 2016c, p. 5) in order to inform their recommendations.

The AESO recommended the *CfD* approach (the AESO termed it an *Indexed REC*), having found it most likely to produce a competitive auction and to minimize the costs of the initial rounds of support (AESO, 2016c, p. 6). The AESO recommendations cited the United Kingdom's use of competitively-sourced renewable power supported through *CfDs* (see Kozlov, 2014, or Woodman et al., 2019), noting that the approach "removes merchant price risk for the generator and reaps other benefits such as a decrease in financing costs for these projects" (AESO, 2016c, p. 10).

The analysis supporting the AESO recommendation assumed high levelized costs for renewable energy, including expected values of CA$80/MWh for wind and CA$150/MWh for solar (AESO, 2016c, p. 20). These assumptions buttressed the AESO's concern that the *fixed premium* approach could lead to few or no bidders if the potential support was capped as recommended by the expert panel or, if support wasn't capped, the AESO worried that the program could prove excessively costly (AESO, 2016c, p. 18).

3. Renewable Electricity Program (REP) Implementation

Based on the AESO (2016c) recommendations, the Government of Alberta launched the first round of REP in March, 2017 with a call for up to 400 MW of capacity from new or expanded renewable energy facilities of a minimum size of 5MW (Government of Alberta, 2017a). Two additional rounds were launched on March 29, 2018: a 300 MW procurement reserved for projects with a minimum 25% equity position held by Indigenous communities, and a 400 MW open procurement (AESO, 2018).

The REP offered two-sided *CfDs* settled based on hourly electricity revenues relative to a strike price, with the strike price partially-indexed to annual inflation (AESO, 2017a, s. 6.3). Contracts were awarded based on strike prices proposed by pre-qualified proponents in sealed-bid, reverse auctions.

3.1 REP Contracts-for-Differences

The REP contracts provide revenue certainty for a project's power generation for a 20-year term. The revenue (R_{REP}) during the support period is determined by production (Q_t) valued at market prices (P_t^m) net of the difference between market prices and the inflation-adjusted contract strike price (P_t^s) (AESO, 2017, s. 6.2). Note that, while we denote both the market price and strike price with hourly time (t) subscripts, only market prices vary at the hourly level, while the contract strike price is adjusted annually through partial indexing to inflation.

For discount rate r and support horizon T, the net present value of revenue for the project during the REP support period is thus given by:

$$R_{REP} = \sum_{t=1}^{T} \frac{Q_t \cdot P_t^m}{(1+r)^t} + \sum_{t=1}^{T} \frac{Q_t \cdot (P_t^m - P_t^s)}{(1+r)^t} = \sum_{t=1}^{T} \frac{Q_t \cdot P_t^s}{(1+r)^t}. \qquad \textit{Eq. 1}$$

The simplified right-hand side of Eq. 1 shows that the two-sided *CfD* removes all market price risk from the developer during the support period, and effectively provides a guaranteed, partially indexed price (P_t^s) for all production (for similar derivation, see Beiter et al., 2021, p. 1498). Combining Eq. 1 with expected value of electricity market revenues beyond the support period would yield the project's *Harmonized Expected Revenue* (Jansen et al., 2020, p. 615), but such an estimate is beyond the scope of this paper. As we discuss at length in Section 5, the risk reduction from the *CfD* comes with a trade-off: lack of exposure to market prices removes any reward for projects that produce in higher-priced hours.

The developer retains production volume risk, as well as exposure to market prices beyond the period of support, and remains responsible for project construction, operating, and financing costs. Project proponents retain any tax value associated with the investment in or operation of the renewable energy facility, including provisions for accelerated depreciation, accelerated operating expense deductibility, and provisions for flow-through share structures under Canadian corporate tax legislation (for details on tax measures, see Canada Revenue Agency, 2019).

Several additional elements of the REP implementation are relevant to our analysis. First, the contracts require the sale of all electricity at market prices and prevent the sale of any related products, including a prohibition on participation in the province's ancillary services market (AESO, 2017, s. 5.2). Second, operators transfer rights to any environmental attributes including renewable energy or greenhouse gas emissions credits associated with the project to the government (AESO, 2017, s. 5.1 (a)), but remain responsible for any monitoring and reporting requirements related to environmental attributes (AESO, 2017, s. 5.2 (c)). Third, in order to qualify, prospective generators had to submit to a rigorous financial pre-qualification procedure intended to ensure that proponents were in a position to execute the project if awarded a contract. Fourth, only prospective projects requiring no additional transmission infrastructure were eligible for the REP (AESO, 2017b, pp. 11–12). Fifth, each REP round had target in-service dates and, for projects not in service within 18 months of the target date, the AESO retained the option to terminate the agreement, with the generator foregoing a CA$50,000/MW security deposit. Other conditions in the contracts deal with early in-service dates, production curtailment, force majeure, and funding from other levels of government.

3.2 REP Reverse Auction Results

On December 13, 2017, the government announced that the first REP auction had led to agreements with four proponents to install almost 600 MW of new wind generating capacity, at a capacity-weighted average strike price of CA$37/MWh (Government of Alberta, 2017b), with a range across the winning projects of CA$30.90/MWh-CA$43.30/MWh (Menzies and Marquardt, 2019, p. 16).

REP Round 2 also exceeded its procurement target, reaching agreements with five wind generation facilities totalling 363 MW of installed capacity, at a capacity-weighted average strike price of CA$38.69/MWh, with individual project strike prices ranging from CA$36.99/MWh to CA$38.97/MWh (Menzies and Marquardt, 2019, p. 16). REP Round 3 met its procurement target of 400 MW through agreements with three wind generation facilities at an average contract strike price of CA$40.14/MWh (AESO, 2018), and individual strike prices closely clustered between CA$38.60/MWh and CA$41.49/MWh.

REP projects have already materially increased installed wind generation capacity in Alberta, as shown in Figure 4. Of the twelve facilities successful in the REP, four have commenced operation and four remain on track to meet in-service milestones (See Table 1 and AESO, 2022d, 2021a, and 2018). Four projects (Sharp Hills and Buffalo Atlee 1, 2, and 3) with total capacity of 296.7 MW have terminated support agreements. The largest of these, the 248.4 MW Sharp Hills project, remains under development and signed a private-sector power purchase agreement (see TC Energy Corp., 2021). The termination of the Buffalo Atlee project support agreements was announced on August 8, 2022 and the project proponent has, as of the time of this writing, not provided an update with respect to the eventual development prospects for the project. Three additional wind projects (Rattlesnake Ridge (130MW), Whitla 2 (151MW), and Wheatland (120MW)) not funded through the REP have also been added to the grid and are shown as *Post-REP* projects in Figure 4. At least two of these projects, Rattlesnake Ridge and Whitla

2, were financed through private-sector PPAs (for Rattlesnake Ridge, see Shopify, 2022, and Bow Island Commentator, 2020; for Whitla 2, see Capital Power, 2021).

A newly-elected right-of-centre government cancelled REP on June 10, 2019 (Savage, 2019). The cancellation was not due to objections to the REP program design, but based on a view that renewables "must be able to compete on a market basis" (Legislative Assembly of Alberta, 2019, p. 1168).

Table 1: Renewable Electricity Program (REP) procurement results, adapted from AESO (2018).

REP Round	Proponent	Project	Capacity (MW)	Nearest City/Town	In-service Date	AESO ID
REP Round 1 Capacity-weighted average strike price of CA$37.00/MWh.	EDP Renewables Canada Ltd.	Sharp Hills*	248.4	Oyen	Agreement Terminated	N/A
	Enel Green Power Canada Inc.	Riverview	115	Pincher Creek	2019	RIV1
	Enel Green Power Canada Inc.	Castle Rock Ridge 2	30.6	Pincher Creek	2019	CRR2
	Capital Power Corp.	Whitla	201.6	Medicine Hat	2019	WHT1
REP Round 2 Capacity-weighted average strike price of CA$38.69/MWh.	EDF Renewables Canada Inc.	Cypress	201.6	Medicine Hat	2023_e	N/A
	Potentia Renewables Inc.	Stirling	113	Lethbridge	2023_e	N/A
	Capstone Infrastructure Corp.	Buffalo Atlee 1*	17.25	Brooks	Agreement Terminated	N/A
	Capstone Infrastructure Corp.	Buffalo Atlee 2*	13.8	Brooks	Agreement Terminated	N/A
	Capstone Infrastructure Corp.	Buffalo Atlee 3*	17.25	Brooks	Agreement Terminated	N/A
REP Round 3 Capacity-weighted average strike price of CA$40.14/MWh.	TransAlta Corp.	Windrise	207	Pincher Creek	2021	WRW1
	Potentia Renewables Inc.	Jenner 1	122.4	Brooks	2022_e	N/A
	Potentia Renewables Inc.	Jenner 2	71.4	Brooks	2023_e	N/A

$_e$ denotes estimated in-service date as expressed by project proponents.
* EDP Renewables' Sharp Hills Project Limited requested early termination of its agreement, and signed a PPA with TC Energy (TC Energy Corp., 2021). The AESO (2022d) announced on August 8, 2022 that the proponent of the Buffalo Atlee projects had requested early termination of their agreements, as the projects were not expected to achieve their required in-service date.

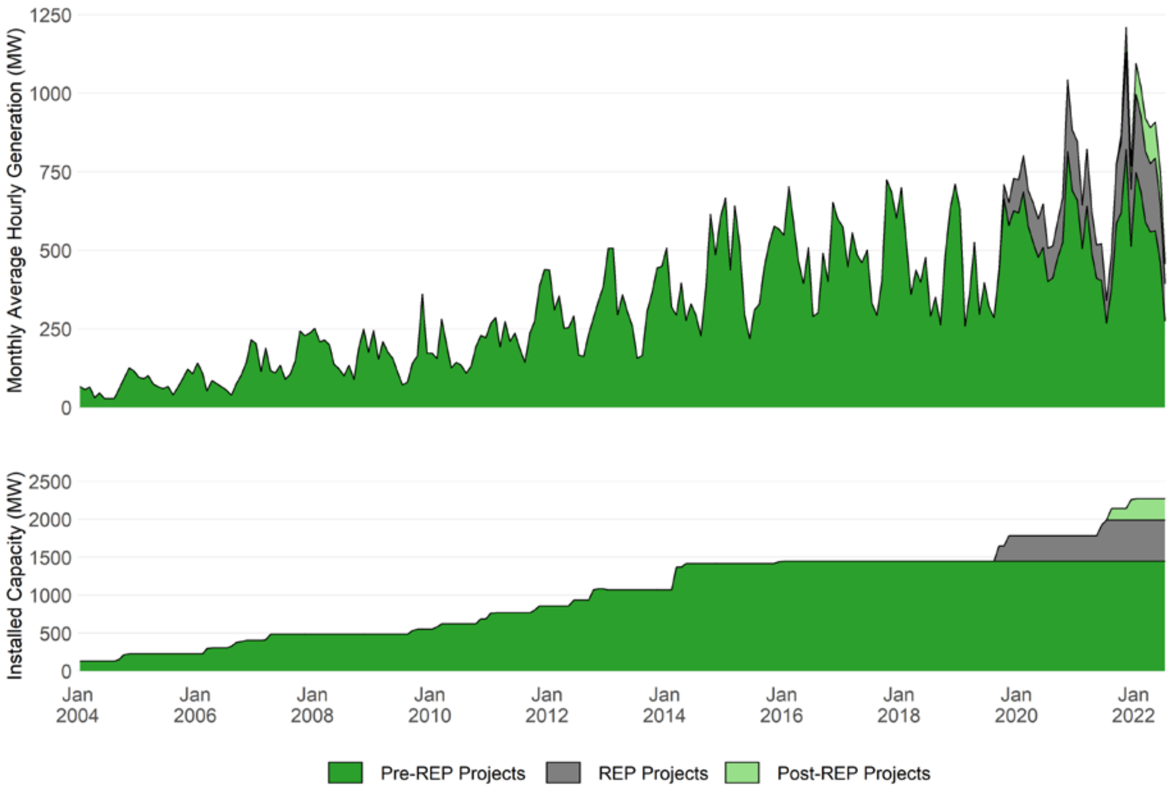

Figure 4: Alberta wind power generation and installed generating capacity by vintage. Data sources: AESO via NRGStream (2022).

4. Evaluation of Alberta's Renewable Electricity Program (REP)

4.1 Cost minimization

We first consider the static efficiency of REP, asking whether renewables were procured at the lowest possible cost (Mezősi et al., 2018; Winkler et al., 2018). The REP reverse auctions had many participants, with major global entities represented (AESO, 2018; Menzies and Marquardt, 2019). A sealed-bid auction with a large number of participants suggests, although does not prove, that the offered strike prices were close to each entity's reservation value.

REP procured 1363 MW of wind generation at a capacity-weighted strike price of CA$38.37/MWh, among the lowest procurements costs for onshore wind generation globally during the same period (Menzies and Marquardt, 2019, p. 16). REP procurement costs were less than 5% above the theoretical minimum procurement cost estimated for the best wind resources in North America (Stehly et al., 2020). And, realized costs were almost 50% lower than projected in the AESO (2016c) recommendations to the government, and much lower than private sector forecasts. For example, EDC Associates (2016) estimated that new wind generation in Alberta would have a levelized cost of almost CA$95/MWh.

The difference between expected and realized procurement costs seems to be due to a combined over-estimate of capital costs and an underestimate of wind energy capacity factors. The AESO (2016c) recommendations assumed capital costs in the range of CA$2.1-2.5 million per MW for wind generation, which corresponds to the average realized costs for projects with commercial operation dates in 2016. Projects with 2019 commercial operation dates saw significantly lower average capital costs of CA$1.7M/MW (Authors' calculations based on estimates from Berkeley Lab Electricity Markets &

Policy, 2021, converted to Canadian dollars.). The AESO (2016c) estimates also assumed a capacity factor of 35%, lower than the 36.7% average capacity factor for the REP portfolio through July 31, 2022. Correcting the AESO estimates for these differences accounts for approximately 75% of the gap between expected and realized renewable energy support costs. The balance of the cost difference can likely be explained by lower-than-expected financing costs but, since project costs were not disclosed, we can only speculate as to why costs fell below expectations.

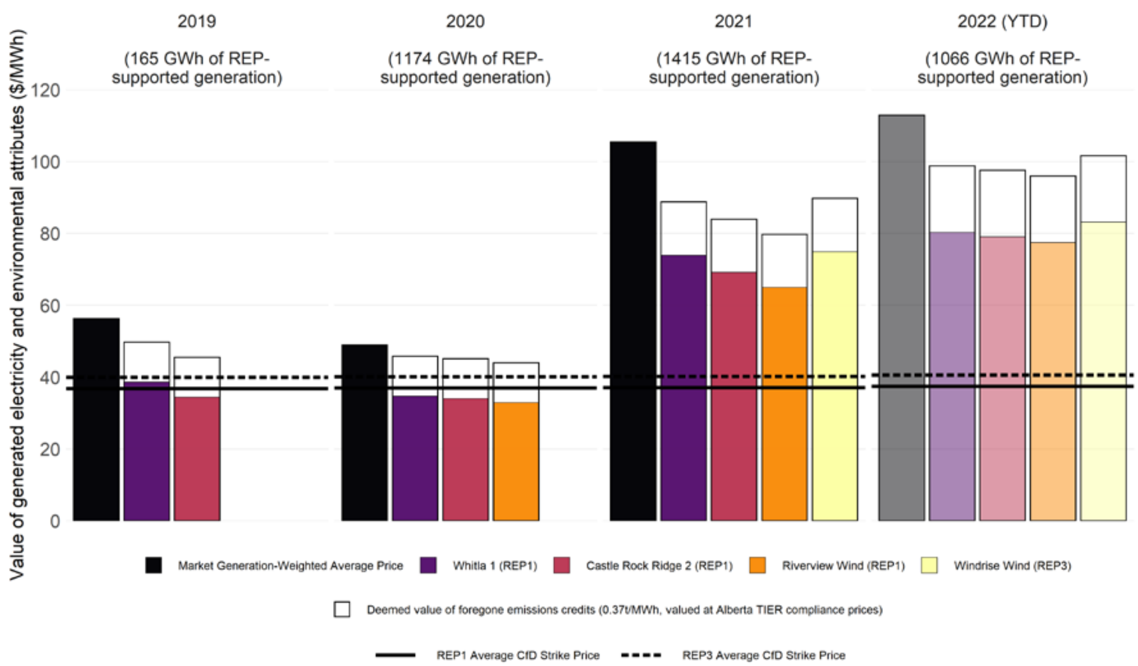

Figure 5: Value of generated electricity and deemed value of environmental attributes, REP projects. 2022 year-to-date values (lighter shaded fill) current to July 31, 2022. Data source: AESO (2022e).

The contracts-for-differences procured through the REP have been net positive for the government to date, driven by an increase in wholesale power prices in Alberta in 2021 and 2022 year-to-date. We estimate the value of the REP contract portfolio to date (V_{REP}) starting with the hourly surplus value generated on power sales relative to project-specific, inflation-adjusted contract strike prices ($P^s_{j,t}$), to which we add an estimate of the value of greenhouse gas emissions credits (EC) transferred to the government under the REP contracts at market carbon prices (τ_t). These are each multiplied by hourly production ($Q_{j,t}$) for each project (*j*) in each hour (*t*) from the first hour ($t_{0,j}$) in which a facility was in commercial operation, through to the end-of-day July 31, 2022 (*T*) as follows:

$$V_{REP} = \sum_{j=1}^{J} \sum_{t=t_{0,j}}^{T} Q_{j,t} \cdot \left(P^m_t - P^s_{j,t} + \tau_t \mathrm{EC}\right). \qquad \textit{Eq.2}$$

We make three important assumptions to value the portfolio of contracts using Eq. 2. First, we use the capacity-weighted average strike prices for each REP round as a proxy for project-specific strike prices ($P^s_{j,t}$), as project-specific information was not disclosed. We also assume that the lowest strike price in REP round 1 (CA$30.90/MWh) was associated with the Sharp Hills project that terminated its support agreement and, based on this assumption, we adjust the capacity-weighted average strike price for first round contracts to CA$41.36/MWh, which we apply as P^s for the remaining three round 1 projects. Finally, we estimate the value of surrendered environmental attributes based on the annual value of emissions performance credits that would have otherwise been allocated to the projects at a rate of 0.37t/MWh under Alberta's carbon pricing policy, the *Technology and Innovation Emissions Reduction Regulation* (*TIER*, 2019), multiplied by annual carbon prices established in the regulation (CA$50/tonne in 2022). This approach ignores any potential gains from the banking of credits and any other environmental attribute value which might have been generated by the projects. For example, wind projects would potentially be eligible for carbon offsets under Alberta carbon pricing legislation at higher rates per unit of production (for 2022, wind projects can generate emissions offsets at a rate of 0.52t/MWh per Government of Alberta, 2022b). Projects would also potentially have been eligible to sell into US renewable energy credit markets as was the case, for example, for two Alberta wind projects commissioned before the REP was in place (see California Public Utilities Commission, 2011). However, since we are interested in the impact on government finances, the value of the emissions credits that the government would have otherwise issued to the projects provides the most direct and relevant measure.

Under these conservative assumptions, we find that the average hourly value of energy and of the carbon emissions credits that would otherwise have been issued to these projects has consistently exceeded average contract strike prices, as shown in Figure 5. We estimate the cumulative net surplus from the energy *CfDs* at CA$75.5 million, and the cumulative deemed value of surrendered emissions credits at CA$55.9M. Thus, we estimate a cumulative surplus to government through July 31, 2022 of CA$131 million. This financial outcome contrasts with the AESO's initial estimates of net costs of CA$10 million per year to fund REP energy contract shortfalls from Round 1 alone (Varcoe, 2017).

The future value of the REP portfolio is uncertain and will depend mainly on future electricity prices, climate change policy, and the regional distribution of wind energy in Alberta. Additional wind development with generation patterns highly correlated with the REP-supported projects could compromise the surplus value of the *CfDs* as well. And, since the REP projects are located in close proximity to each other, the wind discount shown in Figure 3 may be exacerbated once all the REP projects are in operation. A precise estimate of the future value of the REP *CfDs* is beyond the scope of this analysis, but a combination of low electricity revenues and low environmental attribute valuation would be necessary to push the REP *CfD* portfolio significantly out-of-the-money for the government. The future size of the REP portfolio is also uncertain, as the Cypress (201.6 MW), Jenner (193.8MW), and Stirling (113MW) projects have not reached commercial operation at the time of writing.

Overall, the REP provided cost-effective procurement. This is confirmed by the low cost of procurement compared to both local expectations and global benchmarks, by the contracts showing a cumulative financial surplus to government to date, and by the fact that at least one project has terminated their REP support ostensibly because more lucrative financial returns were available through the private market.

4.2 Technology Neutrality

Various renewable energy generation types were eligible to participate in the REP auctions, including wind, solar, biomass, geothermal, and small hydroelectric projects and the program had no technology-specific caps or carve-outs. Some low emissions generation options including large hydro and nuclear were not eligible, so the REP was not strictly technology-neutral.

Despite being open to multiple technologies, the design of the REP was such that it was most likely to procure wind generation, while utility-scale solar generation or other renewable projects were less likely to succeed. The REP auctions considered only the offered *CfD* strike prices in choosing between projects, which is roughly equivalent to comparing projects' levelized costs of electricity (LCOE). At the time of the three REP rounds, the LCOE of wind was far below that of biomass, hydro, and geothermal globally

(Lazard, 2016). While utility-scale solar LCOE was competitive with wind in some regions in North America, only wind projects were successful under the REP. This is likely due to the design of the REP support contract: solar power generally commands a premium to pool prices in Alberta (see Figure 3), but the REP did not consider the value of generated electricity in choosing between projects, and so negated the value advantage of solar generation over wind. REP also restricted eligibility to projects requiring no new transmission investment, and so the fact that Alberta had invested substantially in new transmission to support future wind development (Alberta Utilities Commission, 2009) may have offered a further advantage to wind projects, although many of the province's best solar resources are also within the area served by the transmission capacity expansion.

Design alternatives including the *fixed premium* considered by the AESO and/or technology-specific carve-outs or caps could have broadened the mix of successful generation sources. Technology-specific policies have been used extensively, for example for offshore wind procurements (Jansen et al., 2022) or for on-shore renewables in Denmark (González and Kitzing, 2019). We discuss design choices which could have provided more advantages for dispatchable renewable generation or technologies like solar which currently follow peak market prices more closely in Section 5.

4.3 Long-term Efficiency

The results above suggest that the efficiency of the procurement could have eroded in later rounds and/or at larger cumulative levels of procurement if the design had remained unchanged. However, given that only three rounds of REP procurement took place before its early termination in 2019, long-term efficiency issues were less likely to materialize.

Because the two-sided *CfD* removes any link between project revenues and market prices (see the right-hand side of Eq. 1), the REP design offered no assurance that projects with the highest value, as opposed to the lowest cost, would be selected. Other support programs, for example BC's Clean Power Call (see BC Hydro, 2010), have employed administrative adjustments to reflect the expected value of generated electricity in reverse-auction procurements.

Similarly, the REP design creates the potential for a dynamic interaction effect whereby future rounds of procurement could have made current REP contracts less valuable – a pecuniary policy externality. Consider a hypothetical example in which future rounds of REP had offered similar *CfDs*, again attracting the lowest levelized cost projects regardless of location. As the best wind resources in Alberta are concentrated in a few regions of the province (see Treasury Board of Canada Secretariat, 2022), generation from new projects likely would be highly correlated with that of existing projects including those supported through the REP. The construction of new facilities in regions with existing plants would drive down the average value of generated electricity for all facilities in the region, thereby both eroding the value of the *CfDs* associated with those projects and the value of *CfDs* from previous REP rounds.

The transmission connection capacity constraint that was included in REP provides some protection against this dynamic inefficiency, as transmission capacity may limit the amount of generation that can be sited in the same region. However, over the long term, the AESO is mandated to forecast the likely location of future generation and to ensure the availability of sufficient transmission infrastructure, and so any dynamic efficiency gains from this constraint would likely be transitory.

The direct, long-term impact of the three REP rounds on renewable generation in Alberta is significant, with a substantial increase in installed – the REP is expected to support the installation of over 1000 MW of wind capacity, or almost 40% of the province's forecast total for 2023 (AESO, 2021b). REP also had two key indirect effects which amplified its impact on renewable energy deployment in Alberta: REP drew more projects into the development queue and demonstrated the viability of renewable energy at low prices, which combined to spur substantial private PPA activity before and after the REP was cancelled. From 2015 to 2019, the capacity of wind projects in the AESO development queue increased five-fold (AESO 2022f). While some of these projects are supported under the REP, many have secured or are seeking private PPAs. REP's low procurement costs spurred interest on the demand side of the private PPA market as well. Prior to 2019, only 44MW of private renewable energy PPAs had been completed in Alberta. Since 2019, almost 2000 MW of private renewable PPAs have been signed in Alberta (Business Renewables Canada, 2022).

In our discussion below, we argue that different contract structures could have improved the long-term efficiency of the REP by better recognizing differing value across projects.

4.4 Actor diversity

Renewable program objectives often reach beyond issues of cost and efficiency, for example targeting economic development through local content requirements (Böhringer et al., 2012; Johnson, 2016; Probst et al., 2020; Rodrik, 2014; Sahoo and Shrimali, 2013; Stokes, 2013).

One of the objectives of the REP was to increase the participation of Indigenous communities in Alberta's electricity sector. Renewable energy projects have been proposed as a potential pathway to reconciliation with Indigenous Communities in Canada,[2] because they contribute to the interlinked goals of a just transition away from fossil fuels, climate change mitigation, and economic development (Henderson, 2013; Scott, 2020). Indigenous communities face a number of barriers to participation through development and ownership of renewable energy projects (Krupa, 2012), and so Hoicka., et. al. (2021) advocate for enabling equity ownership by Indigenous communities. REP's second round procurement required 25% Indigenous equity partnerships. While the lack of operational data precludes a direct comparison of the value of the projects selected in the last two REP rounds, the slightly lower capacity-weighted strike prices in the second round (CA$38.69/MWh, vs CA$40.14/MWh in Round 3) suggest that minimal or no additional costs were imposed through the Indigenous equity requirement.

The REP appears to have inspired similar private sector Indigenous partnerships. The Athabasca Chipewyan First Nation (ACFN) partnered in a 67.6 MW solar project (Kiehlbauch, 2021), and oil sands producer Cenovus developed a solar project in partnership with the Cold Lake First Nations (Cenovus, 2021). While we cannot attribute these project agreements specifically to the REP, the price discovery provided by the REP projects and the engagement of Indigenous partners in the renewable energy industry in Alberta was likely an important driver.

5. Discussion

The REP was a successful procurement, in particular with respect to minimizing costs and spurring additional development. The positive fiscal flows to the government stand in contrast to many historical renewable support policies (Aklin, 2021; Beck et al., 2018; Stokes, 2015, 2013). However, REP *CfDs* also insulated project revenues from market prices. While this design is simple and easy to understand for developers, financial partners, and the public, it rewards low cost rather than high value projects. This is exacerbated by the Alberta market's lack of nodal pricing and/or transmission congestion charges which each act to mute other signals of value that might otherwise influence project development decisions.

[2] Reconciliation is used here as has become accepted in Canada: to describe a process of recognition of past harms and transformation of relationships between Indigenous communities and the settler state (The Truth and Reconciliation Commission of Canada, 2015).

Given only three REP auctions were held, it is likely this deficiency had minimal impact on the efficiency of the program, as the lowest cost projects were likely to be among the highest net benefit projects. The benefits of the simplicity of the design likely outweighed any efficiency costs, and was thus appropriate for the initial stages of procurement. However, if more REP auction rounds had been held, the exclusive focus on cost would likely have resulted in lower net benefits from future project agreements and the erosion of value from existing REP agreements. Below, we discuss potential modifications to similar future programs that would improve the selection of high-value projects.

5.1 Relying on the Market

A *fixed premium*, as recommended by Alberta's expert panel, would see renewable developers receive market prices (P_t^m) for their production plus a project-specific per-unit premium (P_t^a) allocated through a competitive reverse auction. With a *fixed premium*, the market price acts as a signal of value while the auction selects projects which generate value at the lowest cost. Using similar notation to (Eq. 1), the revenue under a *fixed premium* over the period of support is given by:

$$R_P = \sum_{t=1}^{T} \frac{Q_t \cdot P_t^m}{(1+r)^t} + \sum_{t=1}^{T} \frac{(Q_t \cdot P_t^a)}{(1+r)^t} = \sum_{t=1}^{T} \frac{Q_t \cdot (P_t^m + P_t^a)}{(1+r)^t} \qquad \text{Eq. 3}$$

This design, similar to that implemented in one tranche of New York's offshore wind power procurement (Beiter et al., 2020, p. 11) and in Denmark, Spain, Estonia and Slovenia (Kitzing et al., 2012), rewards the value of generation insofar as it is reflected in market prices, but leaves more revenue risk with the proponent than the REP *CfD* approach. This increased risk exposure would likely increase the rate of return required by investors and lead to higher procurement costs (Kitzing, 2014; Kitzing and Weber, 2014; Neuhoff et al., 2018), but would also reward technology-specific advantages such as the market premium for solar energy shown in Figure 3.

5.2 Recognizing relative value: a *benchmarked CfD*

A contract structure, which we term a *benchmarked contract-for-differences* (hereafter, *bCfD*), offers a middle ground between the risk transfer of the traditional *CfD* and the energy value recognition of the *fixed premium*. Rather than settling against a project's realized revenues, a *bCfD* settles against a benchmark, for example the average revenue from all renewable generation. This instrument allows the government to assume market-wide risks while leaving more project- or technology-specific risks with the proponent. Instruments of this type have been used, for example, in one tranche of New York's offshore wind procurement (the Index OREC detailed in New York State Energy Research and Development Authority, 2018, Appendix C, and discussed in Beiter et al., 2020, p. 55, is a form of *bCfD*). The revenue from a project with a *bCfD* is given by:

$$R_{bCfD} = \sum_{t=1}^{T} \frac{Q_t \cdot P_t^m}{(1+r)^t} + \sum_{t=1}^{T} \frac{Q_t \cdot (P_t^s - P_t^b)}{(1+r)^t} \qquad \text{Eq. 4}$$

Equation 4 is similar to that for the REP *CfD* (Eq. 1), except that it reflects settlement against the benchmark (P_t^b) rather than against market prices in the second term. By rearranging the terms in Eq.4, we can express the expected revenues under a *bCfD* as the sum of the revenues from the REP *CfD* design (the first term is equivalent to the simplified right-hand side of Eq. 1) and an incremental *beat the benchmark* incentive in the second term:

$$R_{bCfD} = \sum_{t=1}^{T} \frac{Q_t \cdot P_t^s}{(1+r)^t} + \sum_{t=1}^{T} \frac{Q_t \cdot (P_t^m - P_t^b)}{(1+r)^t} \qquad \text{Eq. 5}$$

The *bCfD* retains some exposure to market prices, with the nature and degree of risk mitigation defined by the choice of benchmark. The *bCfD* allows a regulator to more carefully tailor economic incentives to match particular policy goals or to take account of other market characteristics. For example, in the case of a market like Alberta's with no locational marginal pricing, a *bCfD* using regional average monthly renewables revenues as the benchmark could provide similar economic incentives, and would likely lead to more regionally-balanced development of renewables than REP's *CfD* approach.

5.3 Accounting for Transmission Costs

Before REP was implemented, Alberta substantially increased transmission capacity, including new infrastructure serving the windiest regions of the province (Alberta Utilities Commission, 2009). This new infrastructure, similar to the Competitive Renewable Energy Zones in Texas (Dorsey-Palmateer, 2020), created opportunities and challenges. Existing infrastructure allowed for lower incremental costs on generators or rate-payers to integrate new renewables, and likely contributed to the development of new, potential projects. On the other hand, large increases in transmission tariffs resulting from the overall transmission investment were inevitable, and would be coincident with (and perhaps blamed on) renewables procurement. Both were factors in the decision to constrain REP support to be available only to projects which leveraged existing infrastructure and did not require new investment in transmission.

The early cancellation of REP meant that program designers did not have to wrestle with two key policy questions: how to reward generation that has more value given existing transmission constraints and how to take account of implications for the transmission network in future procurements.

An assessment of transmission implications could be integrated into the procurement designs discussed above through an application of the bid adjustment used in BC's Clean Power Call (see BC Hydro, 2010). The bid adjustment applied an administratively-assessed transmission adder, along with other premia or penalties, to a project's reverse auction bid, with the adjusted bids used to rank projects in the reverse auction. In Alberta, which has no congestion pricing and a single nodal price, such an administrative adjustment could be used to inform a dynamically efficient procurement as part of a reserve auction for support via REP-style *CfDs*, or for support via a *fixed premium* or a *bCfD* as proposed above.

The early investment in transmission to support future wind development in Alberta was important to REP's success, just as the Competitive Renewable Energy Zones in Texas have facilitated expansion of wind production there (Dorsey-Palmateer, 2020). However, it seems impractical to separate transmission investment from renewables procurement entirely. Allowing transmission implications to be valued in the procurement will be more dynamically efficient than limiting support only to projects which do not necessitate additional investment. However, procurements with simultaneous addition of transmission and generation may come at the expense of timely expansion of the renewable fleet.

6. Conclusion and policy implications

Alberta's REP used a reverse-auction-based procurement to award contracts-for-differences on electricity revenues in return for the surrender of environmental attributes. It delivered a cost-effective procurement of renewable power, and lead directly to a nearly 50% increase in installed wind capacity in the province. Substantial private-sector development followed REPs demonstration of the low cost of renewable power.

The REP design featured a relatively simple structure, provided price transparency, attracted a large number of potential projects into the development queue, and had program objectives and attributes that were easy to communicate to the public. The REP, and particularly the targeted Indigenous equity participation in Round 3, added new participants to the Alberta market. The indirect effects of the REP continue to be felt today despite the program's cancellation after only three auction rounds.

Despite this success, we find that improvements could have been made to the REP design to assure dynamic efficiency. We suggest alternatives that would provide more incentive for developers to seek out the highest net value projects, rather than an exclusive focus on projects with the lowest levelized costs. Our proposed alternatives would have provided more protection against the erosion of value in existing projects than did the REP design. However, we recognize that our suggested alternative designs introduce risks that may have resulted in less project development, less competitive auctions, less transparency, and potentially higher cost of procurement. We also suggest that lessons from previous procurements in BC could have been applied under the REP as an alternative to a binary rule that precluded projects requiring new transmission investments. Our proposed alternatives do not unconditionally dominate the REP design, but offer regulators options to more carefully apportion procurement risks and rewards, and to maximize value while also minimizing costs.

The REP design is well-suited either to an initial deployment of renewable energy support programs in a new market, or to the support of new or emerging technology in mature renewables markets. The REP design allows the government to take on market and policy risks, while leaving project execution risk with the developer. This design has a demonstrated record of attracting new potential projects into the market, and provides public price discovery for renewable energy sources which, in Alberta's case at least, has spurred development far beyond the projects directly supported by REP.

References

Aklin, M., 2021. Do high electricity bills undermine public support for renewables? Evidence from the European Union. Energy Policy 156, 112400. https://doi.org/10.1016/j.enpol.2021.112400

Alberta Electric System Operator, 2022a. Complete set of ISO rules [WWW Document]. AESO. URL https://www.aeso.ca/rules-standards-and-tariff/iso-rules/complete-set-of-iso-rules/ (accessed 5.16.22).

Alberta Electric System Operator, 2022b. 2021 Market Statistics Report [WWW Document]. AESO. URL https://www.aeso.ca/assets/Uploads/market-and-system-reporting/2021-Annual-Market-Stats-Final.pdf (accessed 5.13.22).

Alberta Electric System Operator, 2022c. AESO Actual Forecast Report Servlet [WWW Document]. AESO. URL http://ets.aeso.ca/ets_web/ip/Market/Reports/ActualForecastReportServlet?contentType=html (accessed 5.16.22).

Alberta Electric System Operator, 2022d. Renewable Electricity Program (REP) Rounds 2 and 3 Update [WWW Document]. AESO. URL https://www.aeso.ca/assets/REP-Round-2-and-3-Update_August-8-2022.pdf (accessed 8.9.22).

Alberta Electric System Operator, 2022e. Hourly Metered Volumes by Generating Asset [WWW Document]. AESO. URL https://www.aeso.ca/assets/Uploads/Hourly-Metered-Volumes-by-Generating-Asset.csv (accessed 8.10.22).

Alberta Electric System Operator, 2022f. Connection project reporting [WWW Document]. AESO. URL https://www.aeso.ca/assets/Uploads/project-reporting/August-2022-Project-List.xlsx (accessed 5.13.22).

Alberta Electric System Operator, 2021a. REP Round 1 Update [WWW Document]. AESO. URL https://www.aeso.ca/assets/Uploads/market/REP-Round-1-Update-Final-002.pdf (accessed 4.27.22).

Alberta Electric System Operator, 2021b. 2021 Long Term Outlook [WWW Document]. AESO. URL https://www.aeso.ca/assets/Uploads/grid/lto/2021-Long-term-Outlook.pdf (accessed 5.9.22).

Alberta Electric System Operator, 2018. REP results [WWW Document]. AESO. URL https://www.aeso.ca/market/renewable-electricity-program/rep-results/ (accessed 4.27.22).
Alberta Electric System Operator, 2017a. Renewable Energy Support Agreement, REP Round 1 [WWW Document]. AESO. URL https://aeso.ca/assets/Uploads/REP-Round-1-RESA-Execution-Version-As-Approved-by-Minister-of-Energy.pdf (accessed 5.9.22).
Alberta Electric System Operator, 2017b. Request for Qualifications For The First Renewable Electricity Program Competition [WWW Document]. AESO. URL https://www.aeso.ca/assets/Uploads/Request-for-Qualifications-for-REP-Round-1.pdf (accessed 8.8.22).
Alberta Electric System Operator, 2016a. AESO 2015 Annual Market Statistics [WWW Document]. AESO. URL https://www.aeso.ca/assets/listedfiles/2015-Annual-Market-Stats-WEB.pdf (accessed 5.13.22).
Alberta Electric System Operator, 2016b. Renewable Electricity Program Update to Stakeholders [WWW Document]. AESO. URL https://www.aeso.ca/assets/Uploads/Combined-REP-next-steps-and-questionnaire-summary.pdf (accessed 8.6.22).
Alberta Electric System Operator, 2016c. Renewable Electricity Program Recommendations [WWW Document]. AESO. URL https://www.aeso.ca/assets/Uploads/AESO-RenewableElectricityProgramRecommendations-Report.pdf (accessed 4.26.22).
Alberta Electric System Operator, 2011. 2010 Annual Market Statistics [WWW Document]. AESO. URL https://www.aeso.ca/market/market-and-system-reporting/annual-market-statistic-reports/ (accessed 8.6.22).
Alberta New Democratic Party, 2015. 2015 Election Platform [WWW Document]. via Alberta Politics. URL https://albertapolitics.ca/wp-content/uploads/2015/10/Alberta-NDP-Election-Platform-2015-.pdf (accessed 4.26.22).
Alberta Utilities Commission, 2009. Needs Identification Document Application: Southern Alberta Transmission System Reinforcement.
Anatolitis, V., Breitschopf, B., Brückmann, R., Dukan, M., Ehrhart, K.-M., Fitch-Roy, O., Geipel, J., Hanke, A.-K., Jimeno, M., Kitzing, L., Marquardt, M., Menzies, C., Resch, G., Szabo, L., Wigand, F., Winkler, J., Woodman, B., 2021. Auctions for Renewable Energy Support II - First insights and results of the Horizon2020 project AURES II full 28.
Bayer, B., 2018. Experience with auctions for wind power in Brazil. Renewable and Sustainable Energy Reviews 81, 2644–2658. https://doi.org/10.1016/j.rser.2017.06.070
Bayer, B., Berthold, L., Moreno Rodrigo de Freitas, B., 2018a. The Brazilian experience with auctions for wind power: An assessment of project delays and potential mitigation measures. Energy Policy 122, 97–117. https://doi.org/10.1016/j.enpol.2018.07.004
Bayer, B., Schäuble, D., Ferrari, M., 2018b. International experiences with tender procedures for renewable energy – A comparison of current developments in Brazil, France, Italy and South Africa. Renewable and Sustainable Energy Reviews 95, 305–327. https://doi.org/10.1016/j.rser.2018.06.066
BC Hydro, 2010. Clean Power Call RFP Process [WWW Document]. BC Hydro. URL https://www.bchydro.com/content/dam/hydro/medialib/internet/documents/planning_regulatory/acquiring_power/2010q3/cpc_rfp_process_report.pdf (accessed 8.8.22).
Beck, M., Rivers, N., Wigle, R., 2018. How do learning externalities influence the evaluation of Ontario's renewables support policies? Energy Policy 117, 86–99. https://doi.org/10.1016/j.enpol.2018.02.012
Beiter, P., Heeter, J., Spitsen, P., Riley, D., 2020. Comparing Offshore Wind Energy Procurement and Project Revenue Sources Across U.S. States (No. NREL/TP-5000-76079). National Renewable Energy Lab. (NREL), Golden, CO (United States). https://doi.org/10.2172/1659840
Beiter, P., Kitzing, L., Spitsen, P., Noonan, M., Berkhout, V., Kikuchi, Y., 2021. Toward global comparability in renewable energy procurement. Joule 5, 1485–1500. https://doi.org/10.1016/j.joule.2021.04.017

Berkeley Lab Electricity Markets & Policy, 2021. Land-Based Wind Market Report.
Böhringer, C., Rivers, N.J., Rutherford, T.F., Wigle, R., 2012. Green Jobs and Renewable Electricity Policies: Employment Impacts of Ontario's Feed-in Tariff. The B.E. Journal of Economic Analysis & Policy 12. https://doi.org/10.1515/1935-1682.3217
Bow Island Commentator, 2020. Rattlesnake Ridge Wind project announces corporate partner. Bow Island Commentator. URL https://bowislandcommentator.com/news/2020/07/22/rattlesnake-ridge-wind-project-announces-corporate-partner/ (accessed 8.10.22).
Brown, P.R., O'Sullivan, F.M., 2020. Spatial and temporal variation in the value of solar power across United States electricity markets. Renewable and Sustainable Energy Reviews 121, 109594. https://doi.org/10.1016/j.rser.2019.109594
Business Renewables Canada, 2022. Deal Tracker [WWW Document]. BRC. URL https://businessrenewables.ca/deal-tracker (accessed 5.11.22).
California Public Utilities Commission, 2011. E-4390 Final Redacted Resolution [WWW Document]. URL https://docs.cpuc.ca.gov/published/Final_resolution/130227.htm (accessed 5.10.22).
Canada Revenue Agency, 2019. Income Tax Folio S3-F8-C2, Tax Incentives for Clean Energy Equipment [WWW Document]. URL https://www.canada.ca/en/revenue-agency/services/tax/technical-information/income-tax/income-tax-folios-index/series-3-property-investments-savings-plans/series-3-property-investments-savings-plan-folio-8-resource-properties/income-tax-folio-s3-f8-c2-tax-incentives-clean-energy-equipment.html (accessed 8.9.22).
Capital Power, 2021. Capital Power announces long-term renewable power purchase agreement with Dow [WWW Document]. Capital Power. URL https://www.capitalpower.com/media/media_releases/capital-power-announces-long-term-renewable-power-purchase-agreement-with-dow/ (accessed 8.10.22).
Cenovus, 2021. Cenovus to buy renewable power from Cold Lake First Nations, Elemental Energy partnership [WWW Document]. Cenovus. URL https://www.cenovus.com/news/news-releases/2021/2021-07-22-Cenovus-to-buy-renewable-power-from-Cold-Lake-First-Nations-Elemental-Energy-partnership.html (accessed 5.13.22).
Daniel, T., Doucet, J., Plourde, A., 2007. Electricity Restructuring: The Alberta Experience, in: Electric Choices: Deregulation and the Future of Electric Power. Rowman & Littlefield.
Dorsey-Palmateer, R., 2020. Transmission costs and the value of wind generation for the CREZ project. Energy Policy 138, 111248. https://doi.org/10.1016/j.enpol.2020.111248
Dukan, M., Kitzing, L., 2021. The impact of auctions on financing conditions and cost of capital for wind energy projects. Energy Policy 152, 112197. https://doi.org/10.1016/j.enpol.2021.112197
EDC Associates, 2016. Renewables Subsidies in Alberta: REC vs PPA Market.
Fitch-Roy, O.W., Benson, D., Woodman, B., 2019. Policy Instrument Supply and Demand: How the Renewable Electricity Auction Took over the World. Politics and Governance 7, 81–91. https://doi.org/10.17645/pag.v7i1.1581
Gephart, M., Klessmann, C., Wigand, F., 2017. Renewable energy auctions – When are they (cost-)effective? Energy & Environment 28, 145–165. https://doi.org/10.1177/0958305X16688811
González, M.G., Kitzing, L., 2019. Auctions for the support of renewable energy in Denmark.
Government of Alberta, 2022a. Economic Dashboard [WWW Document]. URL https://economicdashboard.alberta.ca/ (accessed 5.13.22).
Government of Alberta, 2022b. Methodology for the electricity displacement factor [WWW Document]. URL https://open.alberta.ca/publications/methodology-for-the-electricity-displacement-factor (accessed 8.11.22).
Government of Alberta, 2017a. New jobs, investment to come from renewables [WWW Document]. Government of Alberta. URL https://www.alberta.ca/release.cfm?xID=4653114186F9D-D960-29D3-F989FD2E0A0F0DF6 (accessed 4.27.22).

Government of Alberta, 2017b. Alberta renewables auction record-setting success [WWW Document]. Government of Alberta. URL https://www.alberta.ca/release.cfm?xID=511572D67D28E-C09C-E3E6-BA37A772B4C34AF6 (accessed 4.27.22).
Government of Alberta, 2015. Province takes meaningful steps toward climate change strategy [WWW Document]. Government of Alberta. URL https://www.alberta.ca/news.aspx (accessed 4.26.22).
Government of Alberta, 2007. Electric Utilities Act, Transmission Regulation, Alta Reg 86-2007.
Government of Quebec, 2013. Regulation respecting a 450-megawatt block of wind energy, O.C. 1149-2013, 6 November 2013, Gazette Officielle du Quebec, November 13, 2013, Vol. 145, No. 46A.
Haufe, M.-C., Ehrhart, K.-M., 2018. Auctions for renewable energy support – Suitability, design, and first lessons learned. Energy Policy 121, 217–224. https://doi.org/10.1016/j.enpol.2018.06.027
Henderson, C., 2013. Aboriginal Power: Clean Energy and the Future of Canada's First Peoples. Rainforest Editions, Erin, ON.
Hoicka, C.E., Savic, K., Campney, A., 2021. Reconciliation through renewable energy? A survey of Indigenous communities, involvement, and peoples in Canada. Energy Research & Social Science 74, 101897. https://doi.org/10.1016/j.erss.2020.101897
Jansen, M., Beiter, P., Riepin, I., Müsgens, F., Guajardo-Fajardo, V.J., Staffell, I., Bulder, B., Kitzing, L., 2022. Policy choices and outcomes for offshore wind auctions globally. Energy Policy 167, 113000. https://doi.org/10.1016/j.enpol.2022.113000
Jansen, M., Staffell, I., Kitzing, L., Quoilin, S., Wiggelinkhuizen, E., Bulder, B., Riepin, I., Müsgens, F., 2020. Offshore wind competitiveness in mature markets without subsidy. Nat Energy 5, 614–622. https://doi.org/10.1038/s41560-020-0661-2
Johnson, O., 2016. Promoting green industrial development through local content requirements: India's National Solar Mission. Climate Policy 16, 178–195. https://doi.org/10.1080/14693062.2014.992296
Kiehlbauch, P., 2021. ACFN Green Energy LP [WWW Document]. Greenplanet Energy Analytics. URL https://gpenergyanalytics.ca/acfn-green-energy/ (accessed 5.13.22).
Kitzing, L., 2014. Risk implications of renewable support instruments: Comparative analysis of feed-in tariffs and premiums using a mean–variance approach. Energy 64, 495–505. https://doi.org/10.1016/j.energy.2013.10.008
Kitzing, L., Mitchell, C., Morthorst, P.E., 2012. Renewable energy policies in Europe: Converging or diverging? Energy Policy, Renewable Energy in China 51, 192–201. https://doi.org/10.1016/j.enpol.2012.08.064
Kitzing, L., Weber, C., 2014. Support Mechanisms for Renewables: How Risk Exposure Influences Investment Incentives. https://doi.org/10.2139/ssrn.2505976
Kozlov, N., 2014. Contracts for difference: risks faced by generators under the new renewables support scheme in the UK. The Journal of World Energy Law & Business 7, 282–286. https://doi.org/10.1093/jwelb/jwu016
Krupa, J., 2012. Identifying barriers to aboriginal renewable energy deployment in Canada. Energy Policy 42, 710–714. https://doi.org/10.1016/j.enpol.2011.12.051
Lazard, 2016. Lazard's Levelized Cost of Energy Analysis, Version 10.0 [WWW Document]. Lazard. URL https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf (accessed 5.3.22).
Leach, A., Adams, A., Cairns, S., Coady, L., Lambert, G., 2015. Climate leadership : Report to Minister [WWW Document]. Government of Alberta. URL https://open.alberta.ca/publications/climate-leadership-2015 (accessed 4.26.22).
Legislative Assembly of Alberta, 2019. Hansard, 30th Leg, 1st Sess, June 25, 2019.
Liberal Party of Canada, 2015. 2015 Election Platform: New plan for a strong middle class [WWW Document]. URL https://liberal.ca/wp-content/uploads/sites/292/2020/09/New-plan-for-a-strong-middle-class.pdf (accessed 5.13.22).
Matthäus, D., 2020. Designing effective auctions for renewable energy support. Energy Policy 142, 111462. https://doi.org/10.1016/j.enpol.2020.111462

Menzies, C., Marquardt, M., 2019. Auctions for the support of renewable energy in Alberta, Canada [WWW Document]. AURES. URL http://aures2project.eu/wp-content/uploads/2020/02/AURES_II_case_study_Canada.pdf
Mezősi, A., Szabó, L., Szabó, S., 2018. Cost-efficiency benchmarking of European renewable electricity support schemes. Renewable and Sustainable Energy Reviews 98, 217–226. https://doi.org/10.1016/j.rser.2018.09.001
Neuhoff, K., May, N., Richstein, J.C., 2018. Renewable Energy Policy in the Age of Falling Technology Costs.
New York State Energy Research and Development Authority, 2018. Order Establishing Offshore Wind Standard and Framework for Phase 1 Procurement [WWW Document]. NYSERDA. URL https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BDC668418-0AE2-4274-AF2B-7350D58C961C%7D (accessed 8.9.22).
NRGStream Data Service [WWW Document], 2022. URL https://www.nrgstream.com/ (accessed 5.16.22).
Probst, B., Anatolitis, V., Kontoleon, A., Anadón, L.D., 2020. The short-term costs of local content requirements in the Indian solar auctions. Nat Energy 5, 842–850. https://doi.org/10.1038/s41560-020-0677-7
Rodrik, D., 2014. Green industrial policy. Oxford Review of Economic Policy 30, 469–491. https://doi.org/10.1093/oxrep/gru025
Sahoo, A., Shrimali, G., 2013. The effectiveness of domestic content criteria in India’s Solar Mission. Energy Policy 62, 1470–1480. https://doi.org/10.1016/j.enpol.2013.06.090
Savage, S., 2019. Minister of Energy’s Letter to AESO re: REP [WWW Document]. AESO. URL https://www.aeso.ca/assets/Uploads/GoA-REP-32469signed-letter.pdf (accessed 4.27.22).
Scott, K., 2020. Reconciliaton and Energy Democracy. Canadian Journal of Program Evaluation 34. https://doi.org/10.3138/cjpe.6844
Shopify, 2022. Hold Onto Your Hats—Things Are About to Get Windy at Shopify. We’re Powering All North American Home Offices With Wind Energy. [WWW Document]. Shopify. URL https://news.shopify.com/hold-onto-your-hats-things-are-about-to-get-windy-at-shopify-were-powering-all-north-american-home-offices-with-wind-energy (accessed 8.10.22).
Shrimali, G., Konda, C., Farooquee, A.A., 2016. Designing renewable energy auctions for India: Managing risks to maximize deployment and cost-effectiveness. Renewable Energy 97, 656–670. https://doi.org/10.1016/j.renene.2016.05.079
Stehly, T., Beiter, P., Duffy, P., 2020. 2019 Cost of Wind Energy Review.
Stokes, L.C., 2015. Electoral backlash against climate policy : a natural experiment on retrospective voting and local resistance to public policy (Thesis). Massachusetts Institute of Technology.
Stokes, L.C., 2013. The politics of renewable energy policies: The case of feed-in tariffs in Ontario, Canada. Energy Policy 56, 490–500. https://doi.org/10.1016/j.enpol.2013.01.009
Szabó, L., Bartek-Lesi, M., Dézsi, B., Diallo, A., Mezősi, A., Wigand, F., Anatolitis, V., 2020. Auctions for the support of renewable energy: Lessons learnt from international experiences – Synthesis report of the AURES II case studies [WWW Document]. AURES II. URL http://aures2project.eu/wp-content/uploads/2021/06/AURES_II_D2_3_case_study_synthesis_report.pdf
TC Energy Corp., 2021. EDP Renewables and TC Energy Execute Long-Term Agreement to Add a 297-Megawatt Wind Farm to Alberta [WWW Document]. GlobeNewswire. URL https://perma.cc/Z8ZW-6Z53 (accessed 4.27.22).
Technology Innovation and Emissions Reduction Regulation, 2019. , Alta Reg 133-2019.
The Truth and Reconciliation Commission of Canada, 2015. Canada’s Residential Schools: The History, Part 1 Origins to 1939. McGill-Queen’s University Press, Montreal, Kingston, London, Chicago.
Treasury Board of Canada Secretariat, 2022. Canadian Wind Turbine Database - Open Government Portal [WWW Document]. URL https://open.canada.ca/data/en/dataset/79fdad93-9025-49ad-ba16-c26d718cc070 (accessed 5.13.22).

Varcoe, C., 2017. Alberta nabs cheap renewable power price, but faces $10-million annual subsidy [WWW Document]. Calgary Herald. URL https://calgaryherald.com/business/energy/varcoe-alberta-nabs-cheap-renewable-power-price-but-faces-10-million-annual-subsidy (accessed 5.10.22).
Varcoe, C., 2016. Alberta's push to renewables looks good, but is the price right? [WWW Document]. Calgary Herald. URL https://calgaryherald.com/business/energy/varcoe-albertas-push-to-renewables-looks-good-but-is-the-price-right (accessed 8.8.22).
Winkler, J., Magosch, M., Ragwitz, M., 2018. Effectiveness and efficiency of auctions for supporting renewable electricity – What can we learn from recent experiences? Renewable Energy 119, 473–489. https://doi.org/10.1016/j.renene.2017.09.071
Woodman, B., Fitch-Roy, O., Dézsi, B., Szabó, L., Wigand, F., Anatolitis, V., 2019. Auctions for the support of renewable energy in the UK [WWW Document]. AURES II.
Yatchew, A., Baziliauskas, A., 2011. Ontario feed-in-tariff programs. Energy Policy, Special Section: Renewable energy policy and development 39, 3885–3893. https://doi.org/10.1016/j.enpol.2011.01.033