Impact Assessment & Project Appraisal 2022

Impact assessment for renewable energy development: analysis of impacts and mitigation practices for wind energy in western Canada

Camila Martins Godinho
Department of Geography & Planning, University of Saskatchewan, Canada,
camila.martins0103@gmail.com

Bram Noble[+]
Department of Geography & Planning, University of Saskatchewan, Canada, b.noble@usask.ca,
ORCID: 0000-0002-8575-2281

Greg Poelzer
School of Environment & Sustainability, University of Saskatchewan, Canada,
greg.poelzer@usask.ca, ORCID: 0000-0003-3023-6471

Kevin Hanna
Centre for Environmental Assessment Research, The University of British Columbia, Canada
kevin.hanna@ubc.ca, ORCID: 0000-0001-6955-3103

[+]corresponding author b.noble@usask.ca

Author Pre-print Version

Abstract

Impact assessment can play an important role in global energy transition, delivering knowledge to identify and manage the impacts of renewable energy projects. Yet, there are enduring concerns about IA’s efficacy for renewable energy development. Based on content analysis of IA applications for wind energy development in Canada, this paper examines the environmental and social impacts typically assessed across wind energy projects and the mitigation solutions proposed. Results indicate considerable imbalance between biophysical versus social impacts, including mitigation solutions. IAs include far more solutions for managing biophysical impacts than social ones, with impact-to-mitigation ratios of 1:4.3 and 1:1.3 respectively. Most mitigations focus on impact minimisation, followed by avoidance, and are often vague and imprecise regarding the timing, methods of implementation, and responsibility. Notwithstanding common impacts, mitigation actions that were common across projects were too vague or imprecise to support transferable practice to find efficiencies in assessment. Improved understanding the impacts of renewable energy projects and mitigation solutions, and learning from one project to the next, are foundational to advancing the role of IA the transition to renewable energy.

Keywords: impact assessment; mitigation hierarchy; wind energy; renewable energy; energy transition

Introduction

Renewable energy will play a major role in society's response to global climate change and meeting Paris commitments to reduce greenhouse gas (GHG) emissions (Milliken et al. 2021). The International Renewable Energy Agency estimates that renewables could supply up to 80% of the world's electricity by 2050 (IRENA 2021), but full integration of renewables in fossil fuel-dominated energy systems will require new, and possibly different, infrastructure for energy production, transmission, and distribution (Bataille et al. 2015; Potvin et al. 2017). Renewable energy may be central to a low carbon future, but renewable energy infrastructure is not without potentially adverse environmental and social impacts that need to be identified and mitigated (Geißler et al. 2013; Hanna et al. 2019).

Impact assessment (IA) is an important regulatory tool used globally to predict, evaluate, and identify ways to manage the potential impacts of development projects. Practitioners, the public, and decision-makers rely on IA to provide information about the potential impacts of a project and viable mitigation solutions – information that is essential to supporting informed and efficient decisions. However, IA has long been criticized for the 'quality' of information it provides about a project's impacts and mitigation solutions, namely a bias toward biophysical over social impact considerations (Orenstein et al. 2019; Vanclay 2020), vague or non-committal mitigation actions (Tinker et al. 2005; Jacob et al. 2016), and a focus on making adverse impacts less severe over seeking impact avoidance or amplifying positive outcomes (João et al. 2011; Larsen et al. 2018). The scholarly and policy communities have also been critical of IA for operating in silos, whereby proponents develop IA information from the ground up for each individual project (Expert Panel 2017), rather than learn from the typical impacts and mitigations of previous projects. Thiessen et al. (2020) argue that there is limited evidence of explicit knowledge sharing and learning about impacts and mitigation solutions across IA applications to improve future projects, realize process efficiencies, and better manage expected and unanticipated impacts (Doelle & Critchley 2015; Dutta et al. 2021).

Arguably, a primary role of IA in the global energy transition is delivery of the knowledge that governments, practitioners, communities, and project proponents need to efficiently identify and effectively manage the impacts of renewable energy projects. Yet, there are concerns about the efficacy of IA for renewable energy (Hanna et al. 2019) and even concerns about IA processes stifling renewable energy projects (Fischer et al. 2020; Macintosh et al. 2018; Smart et al. 2014; Schumacher 2017). Notwithstanding a growing literature on the impacts of renewable energy projects (Geißler et al. 2013; Hanna et al. 2019; Larinier 2018; Phylip-Jones & Fischer 2013), most of which has focused on the

European context, the role of IA as a supporting tool for renewable energy development has received considerably less attention (Da Silva et al. 2019; McMaster et al. 2021). IA must ensure proper evaluation of the potential impacts of renewable energy projects, but it must not undermine efficient energy transition (Geißler et al. 2013; McMaster et al. 2021). Understanding the typical impacts of renewable energy developments and the nature of the mitigation solutions proposed, and learning from one project to the next, are thus foundational to advancing the effectiveness and efficiency of IA for renewable energy project reviews.

This paper contributes to the growing scholarship on IA for renewable energy by examining the environmental and social impacts typically assessed across renewable energy project IA reviews and the nature and characteristics of the mitigation solutions proposed. The focus is onshore wind energy developments in western Canada, a main source of growth in new electricity generation in the country. In doing so, this paper identifies the impacts that practitioners and other actors can expect when such projects are proposed, and for which mitigation solutions should be anticipated. Although focused on current IA practice in western Canada, the paper offers several important findings and lessons that are broadly applicable to informing IA practice for renewable energy transition.

Study area and methods

The electricity system in Canada is based largely on hydropower sources (59.6%), followed by nuclear power (14.8%), natural gas (9.4%), coal (7%), and wind (5.1%). A small per cent is generated by biomass (1.7%), solar (0.6%), and petroleum (1.3%) sources (NRC 2021). The industrial and residential sectors represent the largest demand for electricity (CER 2021). To address the urgency of climate change, Canada has developed, among other policies and instruments, the Pan-Canadian Framework on Clean Growth and Climate Change (Government of Canada 2016), focused on clean technologies to guarantee the growth of Canada's energy and resource sector and to reduce GHG emissions (Potvin et al. 2017). Included among Canada's key actions and commitments are pricing carbon emissions and transitioning energy systems away from fossil fuel-based electricity production to renewables-based generation (Potvin et al. 2017). Although Canada's electricity system is currently 80% non-emitting (Government of Canada 2017), electricity generation is still the fourth-largest source of GHG emissions in Canada (Government of Canada 2018). Canada has committed to achieving a power system that is 90% carbon free by 2030; investment in renewable sources for electricity generation is a primary means to achieve this target (Poelzer et al. 2016, Government of Canada 2017).

Wind energy is the main source of new generation in Canada (CANWEA 2020). In 2019, total installed wind capacity was 13,414 megawatts (MW), an increase from 444 MW in 2004 (CANWEA 2020) (Table 1). In 2018 alone, wind energy capacity increased by 566 MW. Wind energy investments are more attractive, in part, because technology and installation costs have decreased by about 70% since 2009 (CANWEA 2019), making wind energy among the lowest cost option for new electricity development without subsidies. Canada has the potential to provide one-third of its electricity from wind energy without compromising grid reliability (GE Energy 2016), and the National Energy Board has projected that wind energy could represent 27% of new power generation between 2017 and 2040. Western Canada (Alberta, British Columbia, Manitoba, Saskatchewan) is well positioned to increase its investment in wind energy, with some of the strongest wind resources in the country. In 2018, Saskatchewan approved six new wind energy initiatives, including a 56-turbine project that will generate 177 MW. Wind energy is the second most important new electricity source in Alberta, with five new wind energy projects in recent years representing $1.2 billion of private investment (Government of Alberta 2019). British Columbia and Manitoba are investing in wind energy projects to bundle with hydropower sources that currently dominate the energy mix (CANWEA 2019). Across Canada, over 300 communities have benefited from wind energy project installations (CANWEA 2019).

Table 1. Renewable energy (electrical generation) and wind energy capacity.

Region	Total electric generation – all sources[1]	Wind energy[2]	
	MWh	*# projects*	*Installed capacity (MW)*
Canada	640,087,117	301	13,413
Alberta	77,161,279	38	1,685
British Columbia	69,080,321	9	713
Manitoba	31,712,590	4	258
New Brunswick	13,531,316	6	314
Newfoundland	43,633,614	4	55
Nova Scotia	10,171,478	78	616
Northwest Territories	758,875	1	9.2
Nunavut	194,366	0	--
Ontario	156,110,747	94	5,436
Prince Edward Island	648,300	10	204
Québec	212,780,155	47	3,822
Saskatchewan	23,826,226	8	241
Yukon	477,850	2	0.8

[1] All sources includes fossil fuels, hydroelectric, nuclear, wind, solar, and other. Includes electric producer utilities and other industries producing power that are not part of the electric power generation, transmission, and distribution industry. Statistics Canada Table 25-10-0020-01 https://www.statcan.gc.ca/eng/start. [2] Canadian Wind Energy Association, Installed Capacity https://canwea.ca/wind-energy/installed-capacity/

Impact assessment for wind energy projects

Impact assessment in Canada at the federal level is legislated under the *Impact Assessment Act.* The federal act applies only to projects for which there is federal jurisdiction and are found on the Physical Activities Regulations: SOR/2019-285. These are typically major infrastructure projects, including nuclear, trans-boundary oil and gas, and hazardous waste disposal, or projects on federal lands. Most all wind energy projects in Canada are assessed under provincial or territorial legislation, with federal IA applying only in cases where projects are located offshore or in a national park or nationally designated wildlife area (McMaster et al. 2021).

The majority of IAs in western Canada, including for wind energy projects, are under provincial jurisdiction: *Environmental Assessment Act* (British Columbia), *Environmental Protection and Enhancement Act* (Alberta), *The Environmental Assessment Act* (Saskatchewan), and *The Environment Act* (Manitoba). British Columbia's IA process is triggered based on several factors, including the characteristics of the proposed project such as its production capacity, geographical location, potential impacts, and the type of industry (SBC 2018). For most energy projects, the IA trigger is based on generation capacity (i.e., a nameplate capacity of 50 MW or more); for wind energy projects the IA trigger is based on the number of turbines and their location (Table 2).

Table 2. Impact assessment legislation and requirements for wind energy in western Canada.

Province	British Columbia	Alberta	Saskatchewan	Manitoba
Legislation	*Environmental Assessment Act (EAA)* (SBC 2018 c.51)*	*Environmental Protection and Enhancement Act (EPEA)* (RSA E-12, 2000)	*The Environmental Assessment Act (EAA)* (S.S. 1979-80 c.E-10.1)	*The Environment Act* (SM 1987-88 c.26)
Applicable IA regulations	Reviewable Projects Regulation B.C. Reg. 67/2020	Environmental Assessment Regulation (112/93; 89/2013); Activities Designation Regulation 276/2003; 125/2017)		Classes of Development Regulation (E125 – M.R. 164/88); Licensing Procedures Regulation (E125 – M.R. 163/88)
IA trigger for wind energy projects	Wind facilities with 15 or more turbines; or with at least one turbine located in water and a total of 10 or more turbines.	≥1 MW (Discretionary Activity)	Case by case basis	>10 MW

* BC Environmental Assessment Act (SBC 2002 c.43) was updated and replaced by Environmental Assessment Act 2018 (SBC 2018, c. 51) that came into force in December 2019. All IAs included in this research were for projects assessed under the previous Act. Source: Table based on McMaster et al. (2021)

In Alberta, IA is part of the larger *Environmental Protection and Enhancement Act, 2000,* which includes a list of mandatory and exempt activities under associated regulations. A project proponent is required to submit a project description to determine if a project will require assessment. Projects smaller than 1 MW are exempt, whereas those greater than 1 MW are subject to full IA review at the discretion of the regulatory authority (McMaster et al. 2021). In Saskatchewan, IA is discretionary and determined on a case-by-case basis based on indicative guidance regarding public concern, pre-emptive resource use, and the likelihood of significance adverse effects, among others; there is no project list and no defined thresholds. Manitoba requires IA licensing for project's that are designated in IA regulations. For all energy projects, the threshold requiring that a proponent submit a project application for IA screening is 10 MW.

Data collection and analysis

The public IA registries in each jurisdiction were searched to identify completed assessments for wind energy projects. A total of 17 wind energy project IAs were identified post-2006: Alberta (n = 7), British Columbia (n = 6), Manitoba (n = 2), and Saskatchewan (n = 2). This sample captures only those wind energy projects subject to regulatory IA *and* included in the IA registries. Project IA reports typically include the project's technical assessment, management plans, accompanying technical reports to support the IA, and regulatory approval conditions. A preliminary scan of the sample revealed that documentation for five of the projects were incomplete, containing the project description but no technical assessment report or management plans, thus 12 projects were selected for further review (Table 3).

Table 3. Wind energy project IAs selected for analysis.

Province	Project	Generating capacity* (# turbines)	Date IA filed	Distance to closest community
Alberta	Blackspring Ridge Wind	298.8 MW (167)	2009	15 km
	Bull Creek Wind Facility	29.1 MW (15)	2015	15 km
	Halkirk Wind	149.4 MW (83)	2009	2 km
	Wintering Hills	88.0 MW (55)	2009	12 km
British Columbia	Bear Mountain Wind Park	102.0 MW (34)	2007	12 km
	Cape Scott Wind Farm	99.0 MW (55)	2009	14 km
	Dokie Wind Project	144.0 MW (48)	2006	9 km
	Quality Wind	142.2 MW (79)	2010	9 km
	Thunder Mountain Wind	320.0 MW (160)	2009	18 km
Manitoba	St. Joseph Wind Farm	138.0 MW (60)	2008	2 km
	St. Leon Wind Energy I & II	120.4 MW (73)	2006	2 km
Saskatchewan	Chaplin Wind Energy	177 MW (59-118)	2013	90 km

*As per IA application technical project description.

For each project, IA documents were examined to identify and classify the types of impacts and mitigations (e.g., by receptor, project size, proponent, geography) (see Jacob et al. 2016; Peste et al. 2015). Content analysis is common in IA research for reviewing impact statements (e.g., Ball et al. 2013), often for the purpose of detecting patterns, information gaps, or emergent themes. For each project IA, the following information were extracted and categorized:

- *Valued components:* Impact statements in IA reports are typically presented by Valued Component (VC). All VCs were identified from the sample of projects and organized into common VC categories. Similar or related VCs (e.g., fish, fish habitat, riparian environment) were aggregated into a larger VC category (e.g., aquatic environments).
- *Impacts:* All predicted impacts to VCs were identified and documented for the construction and operations phase of the project
- *Impact category:* Impacts were categorized as biophysical (e.g., impacts to air, water, wildlife) or human (e.g., property values, health, well-being).
- *Mitigation action:* Where applicable, the specific impact mitigation action was identified.
- *Mitigation hierarchy:* Each mitigation action was classified based on the mitigation hierarchy (Larsen et al. 2018; Jacob et al. 2016): avoid, minimize, repair, compensate, or enhance.
- *Mitigation specificity:* A common challenge in IA practice is vagueness or imprecision of mitigation commitments (Tinker et al. 2005). Mitigation actions were classified according to their specificity (Aura Environmental 2018):

  High: The mitigation action is well described and presents information such as where the action will be taken, when, for long, how it will be done, and the responsible party.

  Medium: The mitigation action is well described but does not provide such details as timing, methods, or responsibility.

  Low: The mitigation action is only vaguely described, difficult to link to the identified impact, and does not provide any extra information to guide implementation.

Based on the above data and categorizations, analysis focused on extraction of common impacts, routine or typical mitigation actions across the sample of wind energy projects, the nature and precision of mitigation prescriptions, and impacts most often deemed to have a high likelihood of significant adverse effects and/or for which mitigations are uncertain or unproven.

Results

There was variability in IA information availability and accessibility. It took four months to secure project IA documents, as not all documents listed in public registries were available. In some cases, formal information requests to the responsible government agency were required to access documentation. In other cases, project developers were contacted for project documents when IA registries were incomplete. The format and organization of impact statements also varied, from reports presented in a consolidated document to projects with assessment results separated by theme and organized in several different formats and electronic folders or access points. Some reports presented impact and mitigation actions in sequence, while others presented impacts and mitigations in separate documents and not always explicitly linked. IA documents for projects in British Columbia were mostly complete and with detailed information, in comparison to Alberta where IA information was often incomplete or unconsolidated in the IA registry.

Impacts and mitigation actions

A total of 94 impacts to VCs were identified across the sample of IAs (see Supplemental Data: Noble 2022). The majority (50%) were identified specifically during the project construction phase; 22% during the operations phase; and 28% of the impacts identified related to both construction and operations phase. Only four project IAs included information on wind turbine decommissioning, but no impacts were identified during decommissioning that different from those impacts associated with project construction, and no IAs included a detailed decommissioning plan.

Of the 94 impacts identified, 56 were biophysical impacts and 38 were impacts to the human environment. Most human impacts identified were social or economic impacts, followed by impacts to human health, and impacts specifically affecting Indigenous communities, namely access to traditional lands or impacts to Indigenous rights. For biophysical impacts, impacts to wildlife, vegetation, and soil, followed by water resources and aquatic environments dominated.

A total of 289 mitigation actions were identified across the sample of projects. Of these, 50 mitigation actions were identified for the 38 human impacts – an impact to mitigation ratio 1:1.3. In contrast, 239 mitigation actions were identified for the 56 reported biophysical impacts – an impact to mitigation ratio 1:4.3. We observed 11 impacts to the human environemnt with no prescribed mitigation (29%), including adverse impacts to property values, housing demands, and interference with radio communications. This was compared to only four biohysical impacts with no mitigation (7%), primarily focused on sensory disturbance interfering with birds and bats and noise affecting cattle grazing. Only five of the 12 impact statements identified the potential positive impacts of wind energy projects. When identified, positive impacts were related to short-term economic opportunities through the construction and operation of a wind facility, specifically short-term employment.

Mitigation specificity

Our analysis also set out to identify impacts for which the mitigation actions were unknown or uncertain, but as indicated above there were few impacts without mitigation actions. However, results do indicate that how impacts and associated mitigation actions were presented in the project IAs varied considerably. For example, we identified several impacts with mitigation actions that were vague and not addressing the stated impact; we refer to these as “mitigation black holes” because it wasn’t possible to understand what they required. Examples include “mitigation” statements like: “consider forestry values in the design phase,” but with no explanation as to what this means, the specific impact it is addressing, who is responsible, or how to proceed. In a second example, “prepare an emergency spill response plan” was presented but with no reference to implementation or to a specific spill type or hazard.

Based on our analysis, four distinct patterns of impact-mitigation relationships emerged. First, a specific impact is identified, and one or more specific mitigation actions presented for addressing that impact (Table 4). For example, a specific impact statement regarding riparian habitat is presented, for which multiple and specific mitigation actions are proposed – specific in the sense that their implementation could likely be verified by a regulatory authority via project follow-up and auditing procedures. Second, an impact is only generally stated but specific mitigation actions are proposed. For example, a general statement is made about the possibility of a hazardous fuel spill during construction, but with no specification of risk or characterization of the impact to receiving environment; yet specific mitigation actions are identified to respond to a potential spill. Third, a specific impact is identified, for example the specifics of sediment loading in a nearby waterbody due to cleared vegetation, but the associated mitigation action is only vaguely described, such as reference to site revegetation but with no further details as to the area to be revegetated, the time frame, or specific strategy to address sediment delivery. Finally, an impact is vaguely identified, such as the potential for soil disturbance but with no specific driver, and the mitigation prescribed, minimize soil disturbance, is equally vague and likely could neither be verified nor serve to inform impact management actions.

Government guidelines or “consulting specific agencies” were mentioned as a mitigation action for 20 identified impacts across different impact statements. These included, for example, “adherence to CanWEA Best Practices for Transmission Line Setbacks” and “practices outlined in DFO Operational

Statement for Maintenance of Riparian Vegetation in Existing Rights-of-Way.” Government guidelines have several actions describing how to address an effect. Those actions can range from consultation to very detailed actions as described in specific regulations. Although referring to government guidelines is a common practice in IA, for the scope and purpose of this research there was no subsequent analysis of the nature or specificity of instructions set out in those various regulations.

Table 4. Example of impact statements and mitigation actions.

Specific impact statement ▪ Project construction (i.e., site clearing and road access) may cause direct disturbance to riparian habitat in the project’s construction zone.	***Specific mitigation commitment*** ▪ A minimum setback of 15 m from non-fish bearing watercourses, and 20 m from fish bearing watercourses will be established during construction. ▪ Best management practices identified in federal Department of Fisheries and Oceans’ Operational Statement for Maintenance of Riparian Vegetation in Existing Rights-of-Way will be followed.
Generic impact statement ▪ There can be hazardous material spills.	***Specific mitigation commitment*** ▪ On-site fuel storage tanks will be double-walled and equipped with drip trays to avoid spills when refueling equipment.
Specific impact statement ▪ Increased surface runoff at the turbine site during construction will increase sediment loading to nearly streams during construction.	***Generic mitigation commitment*** ▪ Conduct revegetation.
Generic impact statement ▪ Potential for soil disturbance during construction.	***Generic mitigation commitment*** ▪ Minimize soil disturbance.

Mitigation hierarchy

Mitigation actions were classified following the mitigation hierarchy and based on specificity. Most mitigation actions across the sample of IAs were focused on impact minimization – i.e., making a potentially adverse impact less severe. For biophysical impacts, 184 (77%) mitigation actions emphasized impact minimization, followed by avoidance (n = 38, 16%), repair (n= 15, 6%), and compensation (n =2; 1%) (Table 5). For impact to the human environment, 45 (90%) of the proposed mitigation actions focused on impact minimization, three (6%) on avoidance, and two (4%) on compensation. No repair measures were identified for potential impacts to the human environment. For both biophysical and human impacts compensation measures were relatively infrequent. When identified, compensation measures were described as monetary compensation, but no specifics were provided. There were no clear enhancement strategies identified for positive impacts.

Most mitigation actions identified (73%) were described with low specificity (n = 210), whereby the specific actions were only vaguely described, difficult to associate to a specified impact prediction, and with limited to no information regarding implementation. This was followed by mitigations described with medium specificity (n = 67, 23%), where the mitigation action itself is sufficiently described and associated with the impact, but implementation timing, methods and responsibility are lacking. Only 4% of mitigation actions (n = 12) met our criteria for high specificity, where the mitigation action itself clear as are the implementation details and responsibilities. For biophysical impacts, 161 (67%) of the mitigation actions were classified as low specificity, followed by 66 (28%) as medium specificity, and 12 (5%) as high specificity. For impacts to the impact environment, 49 of the 50 mitigation actions identified were classified as low specificity.

Table 5. Biophysical mitigation actions classified by mitigation hierarchy and mitigation specificity.

Mitigation hierarchy		**Specificity of mitigation action**			**Total**	**%**
		High	*Medium*	*Low*		
Biophysical environment	Avoid	3	7	28	38	16%
	Minimize	9	54	121	184	77%
	Repair	0	5	10	15	6%
	Compensate	0	0	2	2	1%
	Total	**12**	**66**	**161**	**239**	**100%**
Human Environment	Avoid	0	1	2	3	6%
	Minimize	0	0	45	45	90%
	Repair	0	0	0	0	0
	Compensate	0	0	2	2	4%
	Total	**0**	**1**	**49**	**50**	**100%**

Common impacts and mitigation solutions

The common, or most frequently identified, impacts for both biophysical and human environments, were organized based on the VCs identified and the impacts to those VCs. See Supplemental Data (Noble 2022) for a complete listing of impacts and mitigations by VC. A "common" impact simply means that the impact is found in 50% or more of project impact statements in which the VC is identified. For example, the impact "increased levels of dust" associated with the VC "air quality" is identified in all 12 projects, and the VC "air quality" is also identified in all 12 projects. "Disturbance to archaeological sites" is found in only 6 project IAs but is still considered a common impact because the VC "archaeological resources" was included in only 5 projects. In contrast, impacts to livestock were identified in only one project; however, the VC "agricultural land and resources" was included in seven of the 13 projects; thus, impacts to livestock was not considered a common impact.

Biophysical VCs tended to be more common across projects when compared to human VCs. The VCs air quality, terrain stability, and hydrology were identified in all 12 project IAs. For the human environment, the most common VCs are transportation, demographic and health, and heritage resources. Biophysical

VCs also presented more common impacts across wind energy projects, such as increased dust emissions, surface water contamination, and bird collisions. Fewer common impacts were identified across human VCs, namely temporary impacts such as increased traffic and need for local accommodations during project construction (Table 6).

The same criterion for defining common impacts was applied to mitigation actions. To be considered common, the mitigation action needed to be identified in 50% or more of project IAs in which the VC and common impacts are identified. Results indicate that while the project IAs shared a considerable number of common impacts, the number of common mitigation actions proposed across projects is low. For biophysical impacts, 15 common mitigation actions were identified. The VC “air quality” captured the most common mitigation actions (n = 5). In contrast, only 5 mitigation actions were identified as common for impacts to human VCs (Table 6).

Table 6. Most common impacts with most common mitigation actions

Biophysical VCs and mitigation actions					
Valued component	*# projects*	*Common impacts*	*Common mitigations*	*Mitigation hierarchy*[1]	*Mitigation specificity*[2]
Air quality	12	Increases levels of dust	Application of dust suppressants	MI	M
			Limiting vehicle speeds	MI	L
		Increased level of fugitive emissions and GHGs	Operating equipment at optimum rated loads	MI	L
			Minimizing vehicle trips (i.e. coordinate worker trips)	MI	L
			Routine equipment maintenance	MI	L
Terrain	12	Increased erosion and sedimentation	Re-vegetating areas	RE	L
		Changes to natural drainage	Maintain natural drainage patterns	AV	L
		Risk of accidental spills causing soil contamination	Prepare/implement emergency spill response plan	?	?
Hydrology	9	Surface water contamination from spills and releases	Prepare/implement emergency spill response plan	?	?
Vegetation	8	Habitat fragmentation/ loss	Minimize vegetation clearing	MI	L
		Introduction of exotic plant species in the project area	Equipment and vehicles cleaned before entering site	MI	L
Wildlife & wildlife habit	8	Increased bird collision and disorientation with turbines	Use of lightning system	MI	L
		Increasing batt mortality by collision with turbines	Use of lightning system	MI	L
Aquatic environments	7	Contamination due to run-off and spills	Prepare/implement emergency spill response plan	MI	L
		Disturbance or loss of riparian habitat affecting aquatic life	Vegetation removal will be minimized and disturbance of vegetation and soils near surface waters will be minimized	MI	L

Human VCs and mitigation actions					
Valued component	*# projects*	*Most common impacts*	*Most common mitigation action*	*Mitigation hierarchy*	*Specificity*
Transportation	10	Increased local traffic	Creating a traffic management plan	MI	L
Demography & health	8	Increased demand on local temporary accommodations	Adopt hire local strategies	MI	L
Recreation	7	Disrupt outdoor recreation activities	Advise recreational groups issues related to safety and routing of trials	MI	L
Heritage resources	6	Archeological site disturbance	Conduct an archeological survey before construction	MI	L
Indigenous lands	6	Loss of use of traditional areas and traditional use sites	Conduct consultation and consider other traditional use sites	MI	L

[1] Mitigation hierarchy: MI = minimize; AV = avoid; RE = repair; C = compensate

[2] Specificity of mitigation: H = high; M = medium; L = low; ? = mitigation "black hole"

Discussion

Results identified 94 predicted impacts of wind energy projects from 12 IA reports. Of these, 56 were biophysical impacts and 38 impacts to the human environment. Most impacts were associated with the construction phase of wind energy projects and concerned impacts to such matters as dust emissions, erosion and sedimentation, and changes to natural drainage patterns. A total of 289 mitigation actions were identified, with the majority (83%) for biophysical impacts. For 11 of the identified impacts to the human environment no mitigation actions were suggested; compared to only four biophysical impacts without a prescribed mitigation. For both biophysical and human impacts, most mitigation actions focused on impact minimization, followed by avoidance, and repairing or restoring. No compensation measures were identified for human impacts. Results also demonstrate that although IAs are considered "public records" and should be easy to access, in practice this often proves difficult. Similar challenges to obtaining public IA documentation were reported by Ball et al. (2013) for projects impacting water resources and all conducted under federal jurisdiction.

Shifting attention to impacts on the human environment

Each of the four western Canadian provinces included in this research have their own legislations and regulations for conducting IA. In each of those provincial acts and regulations, the assessment process is described as encompassing environmental, social, cultural, and economic effects that might be generated by a project. However, results of this research indicate a considerable imbalance in practice between the attention given to biophysical impacts versus impacts to the human environment for wind energy developments – a ratio of 1:1.4 based on the sample of projects reviewed. This is not surprising as several authors have discussed the biophysical focus of IA practice (Hanna et al. 2019). Larsen et al. (2018), for example, report that impacts to the human environment are rarely analyzed in-depth in comparison to biophysical impacts, and often not properly addressed during the IA process for energy projects. They go on to report that in many cases there is a gap between public concerns about human impacts and the focus of project assessments. Tinker et al. (2005) and Jacob et al. (2016) also showed more focus on biophysical impacts in IAs, demonstrating that they are also typically explored with more clarity and diversity when compared to human impacts. Vanclay (2020) and Parsons (2020) argue that proponents are focused on technocratic design in their project management frameworks and are often unfamiliar with the social sciences, indicating a need to increase the awareness of IA practitioners on the significance of social issues. This explanation is not new, however, as Burdge (2002) previously noted that consultation efforts in IA are often misunderstood by technical practitioners to be the same as the assessment of social impacts.

The emphasis on biophysical impacts may be problematic in IAs for renewable energy projects, if they are considered at the expense of impacts to the human environment. If IA is to help facilitate renewable energy transition, human impacts and mitigation solutions cannot be superficially addressed or not addressed at all (Dendena & Corsi 2015). Renewable energy projects are known to generate social concerns and impacts to the human environment have become the center of conflict for many renewable energy projects (Larsen et al. 2018; Johansen 2021; Simla & Stanek 2020). Colvin et al. (2016), for example, identify several human impacts associated with wind farm development in Australia; whilst Szpak (2019) report on the concerns raised by Sammi reindeer herders in northern Sweden about the impacts of wind energy projects on their livelihood. Such impacts to the human environment of course are not unique to wind energy projects and extend to other renewable sources including biogas and solar (Kaldellis et al. 2013).

If IAs provide only limited attention to social impacts and mitigation solutions, conflicts can emerge between local communities or land users and project proponents, risking delays in a project's acceptance and approval and even stifling renewable energy project development (Martinez & Komendantova 2020).

Improving mitigation actions

Considering the imbalance of biophysical to human impact considerations, most mitigation actions identified in the sample of IAs were also for biophysical impacts. A total of 289 mitigation actions were identified in the 12 IAs analyzed, of which 239 were presented for the 56 biophysical impacts identified; versus 50 mitigation actions identified across 38 human impacts. Given the ratio of impacts to mitigations, results suggest that IAs present far more alternatives for managing biophysical impacts than social ones. This is problematic, as discussed in the previous section, as unmitigated social concerns can play a big part social conflicts and delays to project approvals (Gorayeb et al. 2018; Szpak 2019).

Results also show that most impact mitigation actions identified in IAs for wind energy projects are vague and imprecise in terms of the timing of implementation, how the mitigation will be implemented, who is responsible for implementation, and specific locations or extent of the mitigation action, among others. This is not unique to the wind energy sector; these challenges have been identified by scholars and across different sectors (e.g., Carley et al. 2011; Morrisson-Saunders & Arts 2005; Noble & Storey 2004; Larsen et al. 2018). Impact mitigation statements need to be precise such that project proponents and regulators can follow-up on mitigation, understand how it was implemented, and verify its effectiveness. Larsen et al. (2018), for example, discuss how mitigation actions are not always clear when it comes to essential information such as implementation methods, responsibility, or what the mitigation is aiming to protect. Furthermore, the lack of clarity in mitigation can mislead the public and stakeholders about the confidence placed in mitigation solutions and result in implementation of mitigation actions that are less than certain (Larsen et al. 2018). Gorayeb et al. (2018) explains that conflicts increased for a wind farm project in Ceara, Brazil, due to misunderstandings between proposed mitigation actions to address impacts, in this case on residential property, and the values and expectations of the local community. If mitigations are presented as tools to address impacts but those mitigation are unclear, it is difficult to not only manage the actual impacts but also to ensure trust in the project and its management when un-mitigated impacts occur. This can create uncertainty about the impacts of wind energy projects and reduce confidence in mitigation measures when they are proposed during IA processes.

Implications for mitigation hierarchy

Most of the mitigation actions identified from the sample of IAs were focused on impact minimisation, for both biophysical and human impacts, followed by avoidance and repair. Tinker et al. (2005) and Jacob et al. (2016) argue that minimization of impacts is usually the preferred action for both IA authorities and project developers. However, many authors have criticized IA for focusing on making adverse impacts “less severe” as opposed to creating benefits or avoiding adverse impacts (Pope et al. 2013; Jacob et al. 2016; Squires & Garcia 2018). Tallis et al. (2015) argue that this is often seen as a reactive approach to project management, and that much greater attention should be given to avoiding impacts earlier in the project planning and design process. Joao et al. (2011) agree, arguing that IA needs to be a “proactive agent” and that while minimization is indeed sometimes a necessity, as not all impacts can be avoided, greater attention should also be given to improving environmental and social outcomes through project design.

It is understandable to an extent that IA focuses largely on reducing the intensity of impacts given limitations to how certain effects can be addressed or avoided at the time a wind energy project is proposed. Limitations do exist for project developers on where wind turbines can be placed due to land use zoning or operational efficiency. This research shows a small number of avoidance measures for both biophysical and human impacts. It may also be that avoidance measures are discussed in the early stages of the project design (Tinker et al. 2005). According to Tallis et al. (2015), avoidance measures are best discussed upfront in the project design process, during feasibility studies, indicating that many avoidance measures may already considered before the IA process is implemented. This may explain why IA reports, such as the ones analyzed in this research, do not include a high number of avoidance-based mitigations.

Compensation measures for adverse impacts, the least desirable option in the mitigation hierarchy, were present only in small numbers in this research – only 1% of mitigation actions for biophysical impacts, and 4% for human impacts. When compensation measures were identified, they were primarily monetary. Absent from the sample of IAs reviewed, however, was a focus on opportunities to create or enhance the potential positive impacts associated with wind energy development, whether in the form of emissions reduction, energy costs, or energy availability and reliability.

Learning across IAs to reduce transaction costs

A challenge to IA in supporting energy transition is delivery of the knowledge that governments, practitioners, proponents, and communities need to plan for and manage the impacts of renewable energy projects. Understanding the impacts of wind energy projects that can be expected when such projects are proposed, and for which clear mitigation solutions should be anticipated, is thus important for informed and efficient IA reviews. However, our results suggest limited learning across IAs – over time and across jurisdictions – a challenge that is not limited to wind energy projects (Wong et al. 2019; Sheate & Partidario 2010). Results show several common impacts across the sample of IAs reviewed, but considerable inconsistency in mitigation actions – including similar impacts and impact contexts but with no mitigation actions identified. The mitigation actions that were common across projects for similar impacts were typically vague or imprecise actions. The lack of commonality in mitigations may be attributed in part to project-specific context; however, Doelle & Critchley (2015) argue that the impacts identified during renewable energy projects and their mitigations actions are rarely new.

For each wind energy project IA proponents (and regulators) need to develop the IA process from the ground up, which may lead to a slow, inefficient, and frustrating IA process (Expert Panel 2017). The lack of learning across IAs can also raise uncertainties for project developers and communities regarding potential impacts, and how they will best be managed, leading to tension between stakeholders. Of use to IA practitioners, regulators, and impacted communities may be a reference guide of the typical impacts of wind energy projects and alternative mitigation actions, including information about impact uncertainties and mitigation effectiveness. This could be a living document, maintained by a government responsible authority, and electronically updated after the follow-up process to convey to future project proponents and communities the anticipated impacts and efficacy of mitigation actions. In Canada, this may be the responsibility of IA jurisdictional authorities or a national organization, such as the Canadian Council of Ministers of the Environment or the Canadian Wind Energy Association (McMaster et al. 2021), but IA practice would benefit globally from an international knowledge sharing forum of wind energy impacts and mitigations.

That said, results of this research also indicate a need to not only improve such communications across projects but also to improve the clarity and specificity of both impact predictions and mitigation actions within project IAs (see Table 4). If information about typical impacts and mitigation actions are to be shared, it is important that the information available is clear enough that it is in informative to the next project. Vague impact statements and imprecise mitigation actions is unfortunately an enduring concern in IA practice (Noble & Storey 2004; Tinker et al. 2005).

Conclusion

Renewable energy projects have an important role to play in meeting GHG emissions reduction targets (Bataille et al. 2015), but renewable energy projects can still generate adverse impacts that need to be identified and effectively mitigated. This research explored the impacts of renewable energy projects, specifically onshore wind energy, and their mitigation solutions, providing knowledge to government, project proponents, and the public to inform IA application and aid energy transition decisions. Ultimately, the results of this research may be used to help regulators make more informed decisions about wind energy projects, provide proponents with guidance on better practice for identifying and managing impacts, and enable communities to better understand what they can expect from project developments. An enduring concern, however, is the limited attention to impacts and mitigation solutions for the human environment, and the often vague and imprecise nature of mitigation actions for what may be considered typical project impacts. This research focused on a small sample of IAs for onshore wind energy in western Canada. Although onshore wind energy is the primary source of renewables growth in

Canada, a deeper analysis of mitigation actions is needed and across a broader sample of IAs and renewable energy technologies to allow researchers to identify mitigation options and evaluate, coupled with follow-up assessments to evaluate the effectiveness of mitigation measures for addressing the typical or anticipated impacts of renewable energy projects. Finally, research is needed to address the challenges to sharing information across IAs, including improvements to impact statements and mitigation specificity, and to develop the tools and instruments to facilitate knowledge sharing for IA in the renewable energy sector.

Funding details

This research was supported by the Social Sciences and Humanities Research Council of Canada, grant numbers 435-2018-0008 and 895-2019-1007.

Disclosure statement

The authors declare no conflict of interest.

Data availability

Supplemental data that support the findings of this study are openly available in Mendeley Data, V1, doi:10.17632/nzt7pk3kt2.1.

References

Aura Environmental 2018. High quality assessment input: Current challenges, key principles, and recommendations. Report prepared for Yukon Major Projects Management Office. C00041169. *AURA*: Saskatoon, SK.

Ball MA, Noble BF, Dubé MG. 2013. Valued ecosystem components for watershed cumulative effects: an analysis of environmental impact assessments in the South Saskatchewan River watershed, Canada. *Integrated Environmental Assessment and Management 9*(3): 469-479.

Bataille C, Sawyer D, Melton N. 2015. Pathways to deep decarbonization in Canada. Ottawa ON: SDS Network, Institute for Sustainable Development, and International Relations.

Burdge R. 2002. Why is social impact assessment the orphan of the assessment process? *Impact Assessment and Project Appraisal* 20(1): 3-9. https://doi.org/10.1080/14615517.2019.1692585.

Canadian Wind Energy Association [CANWEA] 2019. Western Canada, and of "renewable" opportunity. Retrieved from: https://windenergyevent.ca/news/western-canada-land-of-renewable-opportunity/

Canadian Wind Energy Association [CWEA] 2020. Canadian Wind Energy Association. [accessed 2022 June 3] https://canwea.ca/.

Carley S, Lawrence S, Brown A, Nourafshan A, Benami E. 2011. Energy-based economic development. *Renewable and Sustainable Energy Reviews* 15(1): 282-295.

Canada Energy Regulator. 2021. Provincial and territorial energy profiles. Retrieved from: https://www.cer-rec.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/index-eng.html

Colvin R, Witt G, Lacey J. 2016. How wind became a four-letter word: Lessons for community engagement from a wind energy conflict in King Island. Australia. *Energy Policy 98*: 483-494.

Dendena B, Stefano C. 2015. The environmental and social impact assessment: a further step towards an integrated assessment process. *Journal of Cleaner Production* 108: 965-77.

Doelle M, Critchley R. 2015. The role of strategic environmental assessments in improving Scotia. *McGill International J of Sustainable Development Law and Policy* 11(1):87-114.

Dutta N, Noble B, Poelzer G, Hanna K. 2021. From project impacts to strategic decisions: Recurring issues and concerns in wind energy. *Environmental Management* 68(4): 591-603.

Expert Panel. 2017. Building common ground: A new vision for impact assessment in Canada. Ottawa ON: CEAA.

Fischer D, Lochner P, Annegarn H. 2020. Evaluating the effectiveness of strategic environmental assessment to facilitate renewable energy planning and improved decision-making: A South African case study. *Impact Assessment and Project Appraisal* 38(1): 28-38.

GE Energy Consulting. 2016. Pan-Canadian Wind Integration Study (PCWIS). Prepared for Canadian Wind Energy Association (CanWEA). https://canwea.ca/wp-content/uploads/2016/07/pcwis-fullreport.pdf

Geißler G, Köppel J, GuntherP. 2013. Wind energy and environmental assessments - a hard look at forerunners' approaches: Germany and the United States. *Renewable Energy* 51:71-78.

Gorayeb A, Brannstrom C, De Andrade Meireles A, De Sousa Mendes J. 2018. Wind power gone bad: Critiquing wind power planning processes in northeastern Brazil. *Energy Research & Social Science* 40: 82-88.

Government of Alberta. 2019. Climate leadership plan progress peport 2017-18. Retrieved from: https://open.alberta.ca/dataset/83285ecd-dbbe-4b6f-a1a2-ceaebf289fa3/resource/f6b4da5f-76d7-4ed2-9fd7-9a133c323440/download/clp-progress-report-2017-18-final.pdf

Government of Canada. 2016. Pan-Canadian Framework on Clean Growth and Climate Change: Canada's plan to address climate change and grow the economy. *Environment and Climate Change Canada*, Gatineau, Quebec

Government of Canada. 2017. Environmental and regulatory reviews: Discussion paper. Ottawa ON: Her Majesty the Queen in Right of Canada: Ottawa. Retrieved from: https://www.canada.ca/content/dam/themes/environment/conservation/environmental-reviews/share-your-views/proposed-approach/discussion-paper-june-2017-eng.pdf

Government of Canada. 2018. Powering our future with clean electricity. Retrieved from: https://www.canada.ca/en/services/environment/weather/climatechange/climate-action/powering-future-clean-energy.html

Hanna K, McGuigan E, Noble B, Parkins J. 2019. An analysis of the state of impact assessment research for low carbon power production: Building a better understanding of information and knowledge gaps. *Energy Research and Social Science* 50:116-128.

IRENA. 2021. Renewable energy: A key climate solution. International Renewable Energy Agency. https://www.irena.org/climatechange/Renewable-Energy-Key-climate-solution.

Jacob C, Pioch S, Thorin S. 2016. The effectiveness of the mitigation hierarchy in environmental impact studies on marine ecosystems: A case study in France. *Environmental Impact Assessment Review* 60:83–98.

João E, Vanclay F, den Broeder L. 2011. Emphasising enhancement in all forms of impact assessment: introduction to a special issue. *Impact Assessment and Project Appraisal* 29(3):170–180.

Johansen K. 2021. Blowing in the wind: A brief history of wind energy and wind power technologies in Denmark. *Energy Policy* 152:112139. https://doi.org/10.1016/j.enpol.2021.112139

Kaldellis JK, Kapsali M. 2013. Shifting towards offshore wind energy—Recent activity and future development. *Energy Policy* 53: 136–148. https://doi.org/10.1016/j.enpol.2012.10.032

Larinier M. 2008. Fish passage experience at small-scale hydro-electric power plants in France. *Hydrobiologia* 609(1): 97-108.

Larsen SV, Kørnøv L, Christensen P. 2018. The mitigation hierarchy upside down – a study of nature protection measures in Danish infrastructure projects. *Impact Assessment and Project Appraisal*, 36(4): 287-293 doi: 10.1080/14615517.2018.1443260

Macintosh A, Gibbons P, Jones J, Constable A, Wilkinson D. 2018. Delays, stoppages and appeals: An empirical evaluation of the adverse impacts of environmental citizen suits in the New South Wales land and environment court. *Environmental Impact Assessment Review* 69: 94-103.

McMaster R, Noble BF, Poelzer G, Hanna K. 2020. Wind energy environmental assessment requirements and processes: an uneven landscape. *Impact Assessment and Project Appraisal* 39(1): 11-23. https://doi.org/10.1080/14615517.2020.1815271

Milliken L, White T, Fisher A. 2021. Countering climate change with renewable energy technologies. Federation of American Scientists: Washington DC. https://fas.org/blogs/sciencepolicy/

Morrison-Saunders A, Arts J. 2005. Learning from experience: emerging trends in environmental impact assessment follow-up. *Impact Assessment and Project Appraisal* 23(3): 170-74.

Noble BF, Storey K. 2004. Towards increasing the utility of follow-up in Canadian EIA. *Environmental Impact Assessment Review* 25: 163-180.

Noble BF. 2022. Wind energy impact assessment valued components impacts and mitigations. Mendeley Data, V1, doi:10.17632/nzt7pk3kt2.1.

Natural Resources Canada [NRC] 2021 Renewable energy facts. Retrieved from: https://www.nrcan.gc.ca/science-and-data/data-and-analysis/energy-data-and-analysis/energy-facts/renewable-energy-facts/20069

Orenstein R, Westwood E, Dowse S. 2019. Effect characterization in social impact assessment: a scan of current practice. *Impact Assessment and Project Appraisal* 37(1): 48-56.

Parsons R. 2020. Forces for change in social impact assessment. *Impact Assessment and Project Appraisa*l 38(4): 278-286 https://doi.org/10.1080/14615517.2019.1692585

Peste F, Paula A, da Silva L et al. 2015. How to mitigate impacts of wind farms on bats? A review of potential conservation measures in the European context. *Environmental Impact Assessment Review* 51: 10-22.

Phylip-Jones J, Fischer TB. 2013. EIA for wind farms in the United Kingdom and Germany. *Journal of Environmental Assessment Policy and Management* 15(2). Doi: 10.1142/S1464333213400085

Pope J, Bond A, Morrison-Saunders A, Retief F. 2013. Advancing the theory and practice of impact assessment: setting the research agenda. *Environmental Impact Assessment Review* 41: 1-9.

Potvin C, Burch S, Layzell D, Meadowcroft J, Mousseau N, Dale A, Henriques I, Margolis L, Matthews D, Paquin D, Ramos H, Sharma D, Sheppard S, Slawinski N. 2017. Re-energizing Canada: Pathways to a low carbon future. Ottawa, ON

Schumacher K. 2017. Large scale renewable energy project barriers: Environmental impact assessment streamlining efforts in Japan and the EU. *Environmental Impact Assessment Review* 65:100-110.

Sheate WR, Partidario MR. 2010. Strategic approaches and assessment techniques—Potential for knowledge brokerage towards sustainability. *Environmental Impact Assessment Review* 30(4): 278–288. https://doi.org/10.1016/j.eiar.2009.10.003

Simla T. Stanek W. 2020. Influence of the wind energy sector on thermal power plants in the Polish energy system. *Renewable Energy* 161:928-938. https://doi.org/10.1016/j.renene.2020.07.122

Smart DE, Stojanovic TA, Warren CR. 2014, Is EIA part of the wind power planning problem? *Environmental Impact Assessment Review* 49: 13-23

Squires D, Garcia S. 2018. The least-cost biodiversity impact mitigation hierarchy with a focus on marine fisheries and bycatch issues. *Conservation Biology* 32: 989–997. doi: 10.1111/cobi.1315

Social Sciences and Humanities Research Council of Canada [SSHRC] 2017. Advancing knowledge on collaborative and sustainable energy and natural resource development in Canada: Insights and opportunities for knowledge mobilization and future research. Ottawa ON: Social Sciences and Humanities Research Council of Canada. http://www.sshrc-crsh.gc.ca/society-societe/community-communite/ifca-iac/02-natural_resources_report-ressources_naturelles_rapport-eng.pdf

Szpak A. 2019. Relocation of Kiruna and construction of the Markbygden wind farm and the Saami rights. *Polar Science* 22: 100479.

Tallis H, Kennedy C, Ruckelshaus M, Goldstein J, Kiesecker J. 2015. Mitigation for one & all: An integrated framework for mitigation of development impacts on biodiversity and ecosystem services. *Environmental Impact Assessment Review* 55: 21-34.

Thiessen B, Noble B, Hanna K. 2020. Analysis of Impact Assessment Practice and Mitigation for Shipping Activity in the Eastern Canadian Arctic. *Arctic* 73(2): 221–239. https://doi.org/10.14430/arctic70471

Tinker L, Cobb D. Bond A, Cashmore M. 2005. Impact mitigation in environmental impact assessment: paper promises or the basis of consent conditions? *Impact Assessment and Project Appraisal* 23(4): 265-280, DOI:10.3152/147154605781765463

Vanclay F. 2020. Reflections on social impact assessment in the 21st century. *Impact Assessment and Project Appraisal* 38(2): 126-131. https://doi.org/10.1080/14615517.2019.1685807

Wong L, Noble B, Hanna K. 2019. Water quality monitoring to support cumulative effects assessment and decision making in the Mackenzie Valley, Northwest Territories, Canada. *Integrated Environmental Assessment and Management* 15(6): 988-999.