Impact of Power Plant Development on Viewscapes – A Literature Review

Submitted to:

Alberta Utilities Commission

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1. Introduction

The Alberta Utilities Commission (AUC) has been directed by the Government of Alberta through the Order in Council 171/2023 to conduct an inquiry into "the ongoing economic, orderly and efficient development of electricity generation in Alberta." The terms of reference of the Order in Council outlines five areas of inquiry that must be evaluated, including:

A. Considerations on development of power plants on specific types or classes of agricultural or environmental land.

B. Considerations of the impact of power plant development on Alberta's pristine viewscapes.

C. Considerations of implementing mandatory reclamation security requirements for power plants.

D. Considerations for development of power plants on lands held by the Crown in Right of Alberta.

E. Considerations of the impact the increasing growth of renewables has to both generation supply mix and electricity system reliability.

The inquiry will include evidence submissions from interested parties and the ultimate findings, observations, and/or considerations for options resulting from the inquiry will be submitted by the AUC to the Minister of Affordability and Utilities in a final report.

The AUC has engaged Nichols Applied Management (Nichols) to support its effort in this inquiry through a detailed literature review and discussion related to inquiry area B, the impact of power plant development on Alberta's pristine viewscapes.[1] The approach to this work included a review of relevant literature related to the impacts of various types of electricity development on viewscapes.

The balance of this report is laid out as follows:

- **Section 2**: Background on electricity development in Alberta, as well as electricity development and viewscape impacts.
- **Section 3**: An overview of our approach to the literature review.
- **Section 4**: Findings from the literature review.
- **Section 5**: Conclusions and discussion of opportunities for future work.

[1] We acknowledge that several terms related to a particular field of view have been adopted in the literature (e.g., view, viewshed, viewscape). While these terms may differ in their technical definition (see Inglis et al. 2022), we refer to "viewscape" as, generally, an observer's field of view.

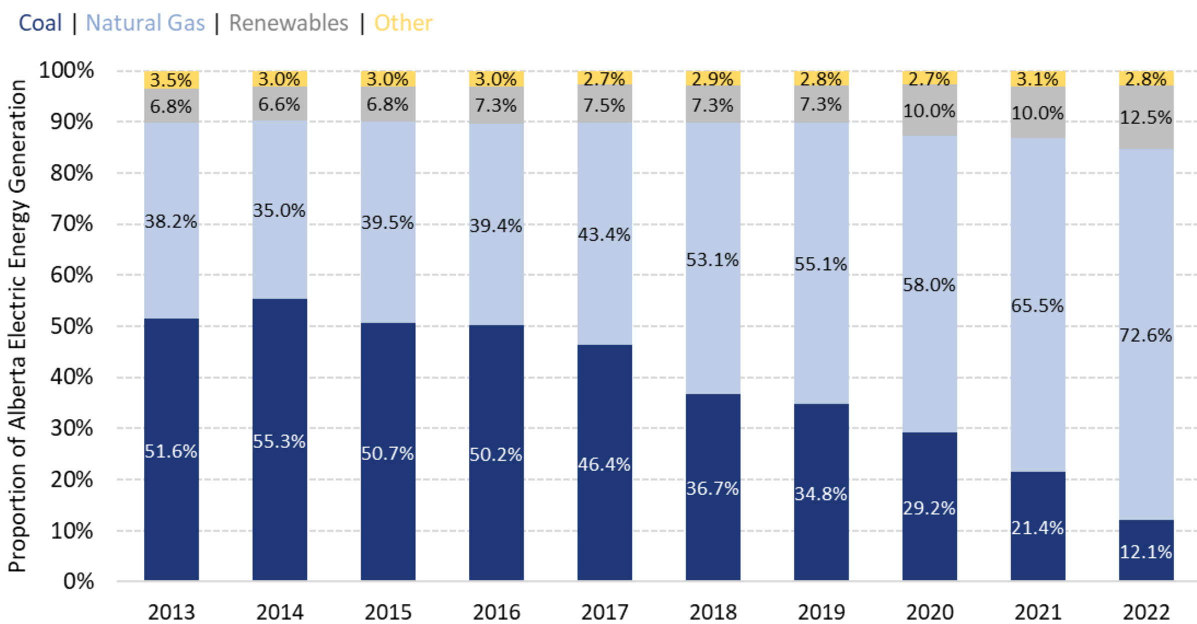
2. Background

Electricity generation in Alberta has evolved over the last several decades, as has the appearance of electricity generation infrastructure on the landscape. Below we provide a high-level overview of Alberta's electricity generation mix (Section 2.1), types of electricity infrastructure in Alberta (Section 2.2), and electricity development and its impact on viewscapes (Section 2.3).

2.1 Electricity Generation in Alberta

Historically, electricity generation in Alberta has been dominated by fossil fuels, namely coal and natural gas. Before 2017, coal supported over 50% of the province's electricity generation (Figure 2-1). As the province has transitioned away from coal there has been an increasing reliance on natural gas as well as renewable electricity sources including wind, solar, and hydro. It is expected that this trend will continue as coal-powered electricity is phased out completely by the end of 2023 (Government of Alberta 2023). Today, natural gas is the dominant source of electricity, generating roughly three-quarters of the province's electricity (Figure 2-1). Renewable electricity production has grown in recent years as well. In 2022, renewable generation sources provided roughly 12.5% of the province's electricity, exceeding coal generation for the first time in the province's history.

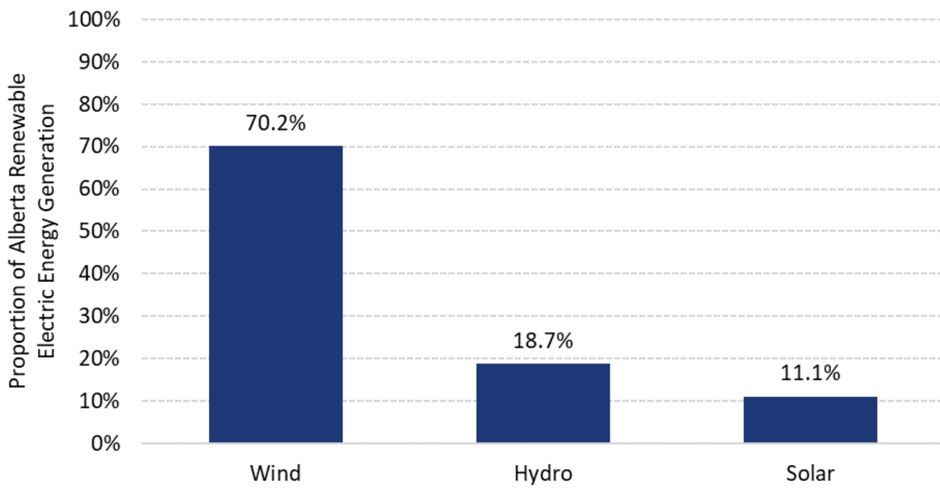
Figure 2-1 Alberta Electricity Generation by Source, 2013-2022



Source: AUC 2023.
Notes:
-"Other" generation sources include biogas/biomass, as well as fuel oil and waste heat.
-Renewables include wind, solar, and hydro. This is in keeping the AESO definition of renewables in the 2022 Annual Marketing Statistics Report (AESO 2022).

Over 70% of the province's renewable electricity generation comes from wind (Figure 2-2), while hydro and solar generation make up relatively smaller proportions (18.7% and 11.1%, respectively).

Figure 2-2 Alberta Renewable Electricity Generation by Source, 2022



Source: AUC 2023.

2.2 Electricity Infrastructure

Electricity infrastructure can vary significantly depending on the source, as different sources generate electricity in fundamentally different ways. Below, we discuss the various types of electricity infrastructure seen in Alberta, including traditional electricity generation (i.e., fossil fuel generation sources), renewable electricity generation, and electricity transmission.

2.2.1 Traditional Electricity Generation

Traditional electricity generation in Alberta includes both coal and natural gas sources, with power plants located throughout the province. Coal-fired electricity involves burning coal to create steam that turns a turbine to generate electricity. Coal-fired electricity generation takes place in a power plant that typically looks like a large industrial building, most often with stacks. Natural gas electricity production is similar to coal. A natural gas power plant burns fuel to create steam that turns a turbine to generate electricity. Natural gas power plants often look the same as coal power plants. In fact, throughout the province's phaseout of coal-fired power plants, some of these plants have been converted to operate on natural gas (Fletcher 2023).

2.2.2 Renewable Electricity Generation

Renewable electricity generation (i.e., wind, solar, and hydro) differs substantially from traditional electricity generation in terms of both operation and visible impacts to the landscape. Wind power is produced from blades on wind turbines that generate electricity from the wind's kinetic energy. Wind generated electricity typically involves wind farms made up of a series of wind turbines spread across the landscape. The size, scale, and density of both turbines themselves and wind farms can vary substantially. For example, the AUC recently approved a large-scale wind farm in southeastern Alberta in 2022 that will be comprised of 83 wind turbines dispersed across 7,080 hectares of farmland (Underwood 2022). Another proposed project in Northern Alberta is set to have 27 wind turbines across roughly 2,800 hectares (ABO Wind 2023). Much of the wind power in Alberta has been developed in the southern portion of the province where windy conditions are common.

Solar power involves the use of photovoltaic cells (i.e., solar panels) that generate electricity from solar energy. Photovoltaic cells are installed as "rooftop solar" on a relatively small scale directly on residential and non-residential buildings, or on a larger-scale in the form of solar farms on the landscape. Solar farms, which have developed throughout the province, involve the installation of steel piles upon which photovoltaic cells are attached. Unlike wind turbines within a wind farm, photovoltaic cells within a solar farm are less dispersed, meaning this infrastructure has a relatively denser visible footprint. For example, the Travers Solar Project, which is one of the largest solar farms in all of North America, extends across roughly 1,335 hectares of land and includes 1.3 million solar panels, each measuring 1.2 by 1.8 meters (Dunn 2021).

Hydropower takes advantage of the kinetic energy of flowing water; this can be achieved through the management of water using dams or reservoirs, as well as "run-of-the-river" projects that divert moving water from rivers. Hydropower facilities can vary substantially in terms of their size, ranging from large dams/reservoirs to "micro-hydro" projects. Hydropower facilities, including both reservoir and run-of-the-river facilities, have been developed throughout the province.

2.2.3 Electricity Transmission

Alberta hosts roughly 26,000 km of transmission lines that deliver power to residents and businesses throughout the province (AESO 2023). Electricity transmission and distribution infrastructure generally consists of transmission towers, utility poles, power lines, and substations of varying size and scale. Transmission towers, also called pylons, are typically large, lattice-style structures made of steel that connect overhead powerlines and carry high-voltage electricity to sub-stations. Sub-stations are facilities that host equipment used to convert high-voltage electricity to lower voltages for distribution. Utility poles distribute lower-voltage electricity through overhead powerlines to final customers; these poles are often smaller in scale compared to transmission towers. Because of the interconnected nature of electricity transmission infrastructure, this infrastructure is visible across the province.

2.3 Electricity Infrastructure and Viewscapes

Site selection for energy infrastructure in Alberta is often a contentious issue. The development of energy infrastructure (including electricity infrastructure) can impact not only the land upon which it is sited, but other relevant stakeholders (e.g., neighboring land-uses, visitors to the area, etc.) (Brinkley and Leach 2019). Community-opposition to electricity infrastructure development (both non-renewable and renewable) is common due to concerns related to a number of real or perceived negative externalities imposed by electricity infrastructure. Visual, noise, health, and environmental impacts are frequently cited as major concerns. Generally, opposition to new electricity infrastructure development with respect to visual, noise, and health concerns is concentrated to those residing within a relatively close proximity to the infrastructure. Even when residents of a given community are generally in support of the development, opposition can still arise when the planned development is in close proximity to residents because of the aforementioned externalities, like viewscape impacts (Cohen et al. 2014).

In Alberta, the impact of renewable electricity installations on natural vistas has been recently noted as a potential barrier to stakeholder support (Patel and Parkins 2023). Indeed, concerns with respect to the viewscape impacts of electricity generating infrastructure have been cited for all manner of electricity generation including traditional (Davis 2011), wind (Vyn 2018), solar (Maddison et al. 2023), and hydro (Bohlen and Lewis 2009).

As viewscape amenities can be considered non-market goods (i.e., not traded in an established market), quantifying the value of these amenities can be challenging. There are two general approaches to quantifying the value of non-market goods through primary research:

- The **revealed preference (RP)** approach involves examining transactions in a market to infer a value for a non-market good that is related to the transaction but not explicitly traded. For example, one can examine the price associated with a market good (e.g., housing prices) to infer values for non-market goods related to the purchase of that market good (e.g., viewscape amenities).
- The **stated preference (SP)** approach involves designing surveys or choice experiments in which participants are asked to express their willingness to pay (WTP) for non-market assets or amenities that are not traded in markets. Stated preference approaches may also ask respondents to express their WTP to avoid a negative externality (e.g., impeded viewscapes due to some development).

The most frequently employed approach to estimate the value of negative externalities associated with electricity infrastructure is the analysis of local property values (an RP approach). This approach, known as hedonic regression analysis (or hedonic modelling), allows analysts to quantify whether and to what extent electricity infrastructure influences nearby housing prices, thereby revealing if there are societal preferences associated with living in close proximity to the infrastructure. Hedonic analysis has been used extensively to understand how the presence of an externality (e.g., visual impacts, noise, nearby amenities) can influence property values. Hedonic analysis has been used specifically in relation to electricity infrastructure, including both electricity generation infrastructure and transmission/distribution infrastructure.

Conceptually, hedonic analysis contemplates real property (e.g., a house) as a bundle of individual attributes that make up the overall product. Each attribute (e.g., square footage, number of bedrooms, high efficiency heating, proximity to schools etc.) has a specific value that contributes to the overall value of the home. Therefore, understanding how a single attribute affects a home's market value requires a full examination of how the home's entire suite of attributes contributes to the price of the home.

A properly conducted hedonic analysis uses statistical tests to establish the significance and magnitude of the relationships between specific attributes and the market value of good in question. The relationships between attributes and the good's market value can be categorized as being either:

- statistically significant (i.e., there is a relationship between one attribute and a positive or negative change in price), or
- indistinguishable from random variation (i.e., no statistically significant relationship between an attribute and a price change).

It should be noted that a hedonic study that examines the impact of an externality requires a rich data set that provides:

- information regarding transactions of properties before and after some externality is established, or
- information regarding transactions of properties in two separate but similar groups of properties with one group subject to the externality and the other not.

The general approach to a hedonic regression analysis is to:

- postulate a series of explanatory variables that may contribute to a change in the dependent variable (i.e., home price),
- compile a dataset of market transactions or property values that includes sufficient data regarding the specific product attributes to allow for a robust estimation of results, and

- regress the home attributes (e.g., square footage, number of bedrooms, view of a power plant etc.) on the market price of the home and use statistical tests to identify the significance and magnitude of any impacts a particular attribute may have on the market price of the home.

With respect to electricity infrastructure, attribute variables may be created that describe a property's distance to a piece of infrastructure or whether or not the infrastructure is within view of the property. The effect of this attribute on a property's value (all else held equal) can then be estimated. It is important to note that hedonic modelling of property values with respect to electricity infrastructure does exclusively evaluate the viewscape impact of electricity development on nearby properties. At a high level, the introduction of electricity infrastructure on the landscape has the potential to affect prices in local housing markets in a number of ways, including:

- Downward pressure on property values can manifest due to the development of nearby electricity infrastructure related to the following disamenities:
  - obstructed or changed visual aesthetics for those properties which are within direct view of the infrastructure,
  - noise impacts for those properties which are within earshot of the infrastructure (should noise be emitted), and
  - real or perceived impacts regarding the risks to human health due to proximity to the infrastructure.
- Upward pressure on property values can manifest due to the development of nearby electricity infrastructure to the degree that:
  - amenities are created by the infrastructure (e.g., greenspace from a transmission line), or
  - employment opportunities created by the infrastructure and its economic activity cause in-migration to the community and the associated demand for housing.

As such, hedonic modelling of electricity infrastructure impacts on nearby property values can certainly inform questions related to viewscape impacts of this infrastructure, but the results of this type of analysis will also include other real or perceived impacts (e.g., noise, health, etc.). Stated preference methods have also been used to estimate the value of externalities created by electricity infrastructure, although to a lesser extent than hedonic analysis.

3. Methods

Inquiry area "B" of the Order in Council requires that the AUC gather and provide information to the Government of Alberta with respect to "Considerations of the impact of power plant development on Alberta's pristine viewscapes." Conducting primary research through hedonic regression analysis or an SP survey was outside the scope of this work due to the time and resources required to execute a hedonic or SP study properly. Instead, we conducted a detailed review of published studies that explore the impacts of power plant development on viewscapes.

For the purposes of this literature review, we take the term "power plant" to mean electricity generating infrastructure in order to capture generation activities that would not necessarily be referred to as "power plants" (e.g., wind turbines, solar panels, etc.). Furthermore, we focus on commercial electricity generating activities, thereby excluding small-scale generation like rooftop solar installations.

As noted in Section 2.1, the primary sources of electricity in Alberta include natural gas, coal, wind, solar, and hydro. We note that the potential property value impacts of nearby hydropower facilities are relatively more complex than traditional power plants or wind and solar infrastructure. Hydropower facilities that involve the installation of dams can result in the creation of an artificial reservoir, generally considered an amenity for nearby properties due to the appealing visual or recreational opportunities it may afford. While hydropower generation still requires the development of a power plant facility that may have viewscape impacts, the limited literature on this subject is focused primarily on property values near dam sites more generally (Lewis et al. 2008; Bohlen and Lewis 2009) and is less relevant to the narrative of power plants and their potential impacts on viewscapes. As such, we exclude hydropower generation from this literature review. Furthermore, while the focus of the literature review is on electricity generation, we also provide some high-level discussion on the literature associated with viewscapes and electricity transmission activities.

The focus of our literature review was on studies that seek to quantify the impact of power plant development on property values through hedonic analysis. As discussed above, hedonic modelling of electricity infrastructure impacts on nearby property values can provide valuable narrative with respect to viewscape impacts of this infrastructure. However, we reiterate that the results of these types of studies often include other real or perceived externalities of power plant development (e.g., noise, health, etc.). In addition, while the SP literature on power plant development and viewscapes is much sparser as compared to the hedonic literature, relevant studies that relied on SP techniques were included in the review as well. Studies examined were limited to published, peer-reviewed studies to ensure that the data and information being relied upon were robust and quality-controlled. Studies were reviewed and summarized in terms of their:

- context,
- methods,
- results, and
- relevance to the Alberta setting.

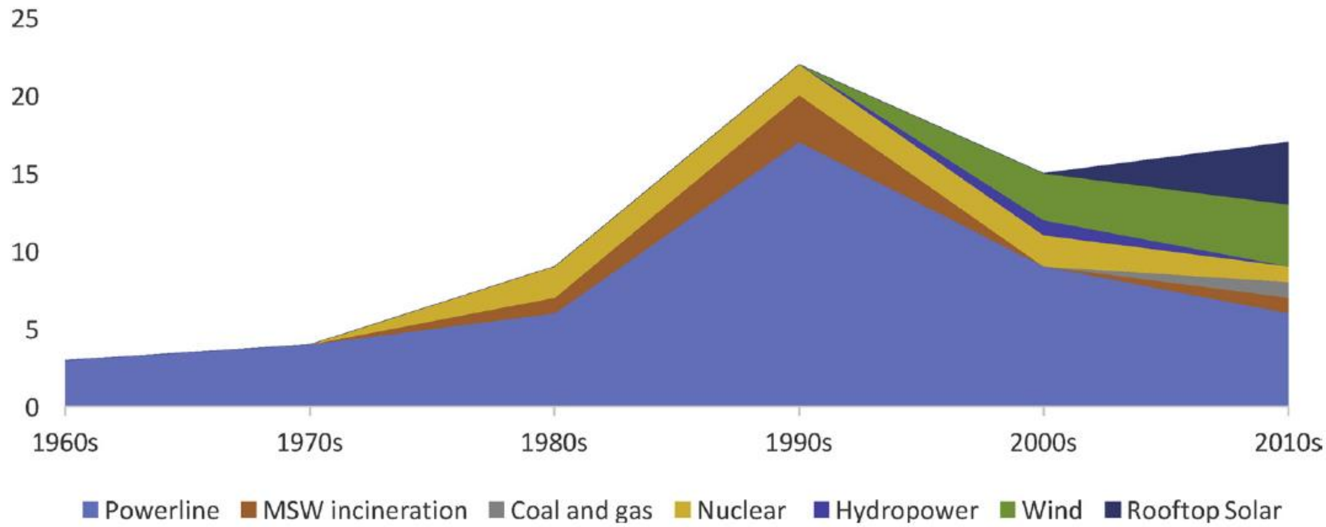
The literature review was conducted through desktop research by employing search engines for peer-reviewed work and reviewing the citations of relevant studies. Key search words included: hedonic, stated preference, willingness to pay, property value, power plant, wind, solar, electricity, view, viewscape, and viewshed. We acknowledge that several terms related to a particular field of view have been adopted in the literature (e.g., view, viewshed, viewscape). While these terms may differ in their technical definition (see Inglis et al. 2022), we refer to “viewscape” as, generally, an observer’s field of view. Furthermore, we rely on literature that uses a mix of terminology related to views, not just “viewscape”, as noted above. We endeavoured to include the foremost and most relevant published studies in our literature review. Factors such as citation count and recency were considered.

Finally, at the request of the AUC, we also reviewed the literature for studies that explore the viewscape impacts of development (of electricity infrastructure or otherwise) that occurs in close proximity to areas that are considered notable in some way (e.g., National/Provincial Parks, World Heritage Sites, etc.).

4. Findings

In a recent meta-analysis conducted by Brinkley and Leach (2019), the authors created an inventory of studies that have explored the impact of energy supply infrastructure on property values (Figure 4-1). The majority of studies have focused on electricity transmission infrastructure (i.e., powerlines). In terms of electricity generating infrastructure, there has been an increasing interest in renewable electricity generation, particularly wind and rooftop solar, with less focus on traditional electricity generation such as coal and gas.[2]

Figure 4-1 Studies on Energy Supply and Property Values, 1960s-2010s



Source: Adapted from Brinkley and Leach (2019).
Notes:
-MSW = municipal solid waste.

The results of our literature review suggest a similar trend to Brinkley and Leach (2019). There has been a rapid growth in wind energy projects in Canada and elsewhere across the world. With the growth in wind energy development there has also been vocal public concern regarding the potential impacts of wind projects on local residents, leading to a growing body of literature on wind energy infrastructure and its potential impacts on property values. Comparatively, there are fewer hedonic studies related to traditional electricity generating infrastructure and other renewables, such as solar farms.

The findings from our literature review are provided below in Sections 4.1 to 4.4.

4.1 Traditional Electricity Generation

The literature with respect to traditional power plants (i.e., coal and natural gas) and their impacts on property values is relatively sparse. We reviewed four studies that employed a hedonic model to estimate the impact of traditional power plants on nearby housing markets (Table 4-1). A detailed summary of each study and its findings, including the estimated magnitude of impacts, can be found in Appendix A.

[2] Again, the focus of this literature review is on commercial electricity generation infrastructure; as such, we exclude small-scale activities like rooftop solar.

Table 4-1 Reviewed Hedonic Studies – Traditional Electricity Generation Infrastructure

Authors	Journal	Location	Impact Found
Blomquist (1974)	*Land Economics*	United States (Illinois)	Negative
Davis (2011)	*The Reviews of Economics and Statistics*	United States	Negative
Khezr et al. (2021)	*Australian Journal of Environmental Management*	Australia	Negative
Eichholtz et al. (2023)	*Journal of Real Estate and Finance Economics*	Europe (Netherlands)	Mixed (negative to positive)

Of the four reviewed studies:

- Three studies found consistent evidence of significant negative impacts of traditional power plants on nearby property values under various conditions (Blomquist 1974; Davis 2011; Khezr et al. 2021).
- One study found mixed evidence (i.e., either no impact or some statistically significant impact) (Eichholtz et al. 2023).

One of the largest hedonic studies evaluating the impact of traditional power plants on property values is that of Davis (2011). Davis (2011) asserted that communities often express opposition to the siting of traditional power plants (i.e., power plants run on fossil fuels) near their homes due to the disamenities they create related to both viewscapes and noise. Using a hedonic model of property values and traditional power plant locations across the United States, the author found that housing values declined by -4% to -7% for homes within roughly 3.2 km (2 miles) of a traditional power plant (either coal or natural gas). In an earlier study by Blomquist (1974), it was asserted that the property value impact of a traditional power plant becomes more pronounced for houses closer to the plant. Specifically, for homes within roughly 3.5 km of a coal-fired power plant, an additional -0.9% price change was found for every 10% closer a home was located to the plant.

There are two recent studies that explored the impact of traditional power plants on nearby property values (Khezr et al. 2021; Eichholtz et al 2023). The conclusions from these studies are mixed. Khezr et al. (2021) found substantial negative price effects of gas and coal power plants on nearby homes in New South Wales, Australia (between -8.1% and -25% for gas and coal power plants, respectively). Conversely, Eichholtz et al. (2023) found no statistically significant impact on property values associated with coal-fired power plants; for gas power plants, statistically significant positive impacts of roughly 3.4% were found for houses within 1 km of the plant, while negative impacts of -4.5% to -5.9% were found for houses between 1 and 4 km of the plant.

Again, we note that there are a variety of disamenities associated with traditional power plants, and hedonic modelling of nearby property values can capture not only the disamenity associated with viewscape impacts, but also other impacts such as noise, health, and environmental concerns (Davis 2011).

One relevant SP study was reviewed that sought to estimate the WTP of residents to remove a nearby coal power plant in Delaware, United States (Thomson and Kempton 2018). The study found that residents were WTP $0.86 (2018 USD) per month to have the coal plant removed on the basis of its visual impacts alone (Thomson and Kempton 2018). We note that this same study looked at resident WTP to remove a single wind turbine on the basis of its visual impacts as well and found that residents were actually WTP $1.65 (2018 USD) per month to keep the turbine, suggesting there may be positive perception effects associated with renewable energy in the community studied (Thomson and Kempton 2018).

4.2 Renewable Electricity Generation

The findings from our literature review related to renewable electricity generation, specifically wind and solar, are provided in the subsections below.

4.2.1 Wind

There is a plethora of peer-reviewed literature that has examined the potential impacts of wind energy infrastructure on nearby property values. Table 4-2 below provides a list of some of the most relevant literature pertaining to wind energy development and property values. In total, 20 peer-reviewed studies from the last 15 years were examined. Study locations include Canada, the United States, Europe, and New Zealand. A detailed summary of each study and its findings, including the estimated magnitude of impacts, can be found in Appendix A.

Table 4-2 Reviewed Hedonic Studies – Wind Electricity Generation Infrastructure

Authors	Journal	Location	Impact Found
Sims et al. (2008)	*International Journal of Strategic Property Management*	Europe (United Kingdom)	None
Hoen et al. (2011)	*The Journal of Real Estate Research*	United States (9 states)	None
Heintzelman and Tuttle (2012)	*Land Economics*	United States (New York)	Mixed (negative to potentially positive)
Jensen et al. (2014)	*Land Economics*	Europe (Denmark)	Negative
Lang et al. (2014)	*Energy Economics*	United States (Rhode Island)	None
McCarthy and Balli (2014)	*International Journal of Strategic Property Management*	New Zealand	None
Vyn and McCullough (2014)	*Canadian Journal of Agricultural Economics*	Canada (Ontario)	None
Gibbons (2015)	*Journal of Environmental Economics and Management*	Europe (United Kingdom)	Negative
Hoen et al. (2015)	*Journal of Real Estate and Finance Economics*	United States (9 states)	None
Dröes and Koster (2016)	*Journal of Urban Economics*	Europe (Netherlands)	Negative
Sunak and Madlener (2016)	*Energy Economics*	Europe (Germany)	Negative
Heintzelman et al. (2017)	*Ecological Economics*	Canada and the United States	Mixed (none to negative)

Castleberry and Greene (2018)	*International Journal of Housing Markets and Analysis*	United States (Oklahoma)	None
Jensen et al. (2018)	*Energy Policy*	Europe (Denmark)	Negative
Vyn (2018)	*Land Economics*	Canada (Ontario)	Mixed (none to negative)
Skenteris et al. (2019)	*Economic Analysis and Policy*	Europe (Greece)	Mixed (none to negative)
Dröes and Koster (2021)	*Energy Policy*	Europe (Netherlands)	Negative
Joly and De Jaeger (2021)	*Land Use Policy*	Europe (Belgium)	Mixed (none to negative)
Dong and Lang (2022)	*Energy Policy*	United States (Rhode Island)	None
Eichholtz et al. (2023)	*Journal of Real Estate Finance and Economics*	Europe (Netherlands)	Negative[a]

Notes:
[a] Refers to results for wind electricity generation infrastructure.

Overall, there is a lack of consensus in the literature on the topic of wind energy infrastructure and property value impacts. Of the 20 reviewed studies:

- Seven studies found consistent evidence of significant negative impacts of wind turbines on nearby property values under various conditions (Jensen et al. 2014; Gibbons 2015; Dröes and Koster 2016; Sunak and Madlener 2016; Jensen et al. 2018; Dröes and Koster 2021; Eichholtz et al. 2023).
- Five studies found mixed evidence (i.e., either no impact or some statistically significant impact) (Heintzelman and Tuttle 2012; Heintzelman et al. 2017; Vyn 2018; Skenteris et al. 2019; Joly and De Jaeger 2021).
- Eight studies concluded there was no evidence of statistically significant impacts of wind turbines on nearby property values (Sims et al. 2008; Hoen et al. 2011; Lang et al. 2014; McCarthy and Balli 2014; Vyn and McCullough 2014; Hoen et al. 2015; Castleberry and Greene 2018; Dong and Lang 2022).

It has been suggested that studies that have not found evidence of wind turbines impacting property values may suffer from a lack of data, particularly a lack of observations of residential sales in close proximity to wind turbines (Vyn 2018). For example, Vyn and McCullough (2014) noted that their dataset included a relatively small number of property sales in close proximity to wind turbines. Furthermore, property value impacts may be difficult to capture if the impacts occur to properties that have not been sold at the time of a given study or have difficulty selling. However, there have been more recent studies that have used larger datasets, including a larger number of observations of property sales near wind turbines, that have not found statistically significant impacts of wind turbines on property values (e.g., Hoen et al. 2013; Lang et al. 2014; Castleberry and Greene 2018; Dong and Lang 2022).

Many of the studies that have found statistically significant negative impacts from wind turbines on property values were conducted in European housing markets (Gibbons 2015; Dröes and Koster 2016; Sunak and Madlener 2016; Jensen et al. 2018; Skenteris et al. 2019; Joly and De Jaeger 2021). While these markets are considered to be generally free and well-functioning, the geographical landscape within which the wind turbines are situated and potentially obstructing nearby viewscapes may differ from that of the Alberta context. Furthermore, the range of estimated impacts varies substantially. Recent work by Eichholtz et al. (2023) concluded that the negative impacts of wind turbines located within 2.5 km of a residential property is between -1.2% and -1.4% of the property value, whereas Sunak and Madlener (2016) estimated negative impacts between -9% and -14%; however, these impacts were specific to properties within close view of a high density of turbines (7 to 10 turbines within 3 km). Jensen et al. (2014) is the only reviewed hedonic study that estimated visual and noise impacts of nearby wind turbines on property values separately. The authors found that the visual impact of wind turbines resulted in a roughly -3% decline in property value for properties with a view of at least one turbine (Jensen et al. 2014).

Houses with views of a higher density of wind turbines have often been found as having larger property value impacts compared to houses with views of fewer turbines (Gibbons 2015; Sunak and Madlener 2016; Vyn 2018) Furthermore, taller wind turbines have been found to have a larger impact on nearby property values as compared to shorter turbines (Dröes and Koster 2016; Dröes and Koster 2021).

Some work has suggested that significant negative impacts may occur in the short-term but diminish over time as a community becomes accustomed to wind turbines (Heintzelman and Tuttle 2012; Lang 2014), although other work has found evidence of statistically significant negative impacts over longer periods (10 years) following the construction of wind turbines (Dröes and Koster 2016).

The most recent and relevant hedonic studies to the Alberta context are Vyn and McCullough (2014) and Vyn (2018), both of which examined the potential impacts of wind turbines on property values in a Canadian context (Ontario). Vyn and McCullough (2014) evaluated the impact of wind turbines on property values for both rural residential properties and farmland properties. According to the authors, wind electricity infrastructure may have a larger impact on rural residential properties, as these properties are purchased primarily for residential purposes and may be more sensitive to viewscape changes as compared to properties purchased for agricultural production (Vyn and McCullough 2014). The authors found that neither rural residential nor farmland property values were significantly impacted by nearby wind turbines. The authors acknowledged that data limitations may have played a role in the resulting lack of impacts found. Furthermore, the authors note that a lack of statistically significant results does not mean that individual properties may not still be impacted by nearby wind turbines (Vyn and McCullough 2014). The more recent work by Vyn (2018) suggested that a municipality's overall acceptance or opposition to wind energy development may play a role in the extent of impacts to nearby rural residential property values. The author found evidence of negative impacts to property values for residences within 4 km of the nearest wind turbine of -4.1% to -8.4% in municipalities that are considered unwilling hosts of wind energy. Conversely, for municipalities that are willing hosts of wind energy projects, no significant impacts to property values were found. Designation of municipalities as willing or unwilling hosts was based a list compiled by Wind Concerns Ontario, a grassroot organization that represents communities in Ontario that are opposed to wind energy development. The list compiled by Wind Concerns Ontario includes all municipalities that have formally declared themselves as unwilling hosts of wind energy, suggesting that there is a critical mass of residents in the community that oppose wind turbines (Vyn 2018).

Four SP studies that estimated WTP values associated with wind turbines and their viewscape impacts were reviewed. Thomson and Kempton (2018) undertook a SP survey to estimate resident WTP to remove a single wind turbine in a community in Delaware, United States, on the basis of its visual impacts. Residents were found to be WTP $1.65 (2018 USD) per month to keep the turbine, suggesting there may be positive perception effects associated with renewable energy in the community. We note that this same study looked at resident WTP to remove a coal plant in a community in Delaware, United States. The authors found that residents were WTP $0.86 (2018 USD) per month to have the coal plant removed on the basis of its visual impacts alone (Thomson and Kempton 2018). Ladenburg and Dubgaard (2007) and Krueger et al. (2011) both sought to estimate the value of visual disamenities associated with offshore wind farms in Denmark, Europe, and Delaware, US, respectively. Ladenburg and Dubgaard (2007) found that respondents were WTP between €46 and €122 per household per year (2007 EUR) to have the wind farm located further from the coast compared to an 8 km baseline. Krueger et al. (2011) similarly found an external visual cost associated with offshore wind farms, with annual costs estimated at up to $80 per household for turbines located roughly 1.5 km from the shore. Groothuis et al. (2008) explored the visual impacts of wind power generation on mountain views in North Carolina, US. The authors found that households would be willing to accept compensation of $23 per year (2008 USD) on average to site wind turbines within the mountain viewshed (Groothuis et al. 2008), suggesting the mountain landscape is important to residents but that compensation would allow for wind energy infrastructure development.

4.2.2 Solar

There is relatively limited literature that seeks to explore the impact of solar farms on nearby property values. We reviewed two studies that employed a hedonic model to estimate the impact of commercial solar farms on nearby residential property prices (Table 4-3). We note that the most recent of these studies (Maddison et al. 2023) asserts that there are in fact only two published studies that explore the impact of solar farms on nearby property values including their own. A detailed summary of each study and its findings, including the estimated magnitude of impacts, can be found in Appendix A.

Table 4-3 Reviewed Hedonic Studies – Solar Electricity Generation Infrastructure

Authors	Journal	Location	Impact Found
Dröes and Koster (2021)	*Energy Policy*	Europe (Netherlands)	Negative
Maddison et al. (2023)	*Land Economics*	Europe (England and Wales)	Negative

Both of the reviewed studies on the impact of solar farms on nearby housing prices suggest that solar farms have a negative impact. Furthermore, both studies find that the impact of solar farms on nearby housing prices is relatively local. Dröes and Koster (2021) find an average impact of roughly -2.6% on property prices for properties within 1 km of a solar farm, while Maddison et al. (2023) find an average impact of about -5.4% on property prices for properties within 750 m of a 5 MW solar farm.

4.3 Electricity Transmission

The impact of electricity transmission infrastructure on nearby residential property values has been a topic of great interest for many years. Given that the focus of our literature review is electricity generation infrastructure, we do not endeavour to summarize the entire relevant literature related to viewscape impacts of electricity transmission infrastructure. However, the nature in which electricity transmission lines may create a visual disamenity is highly similar to that of other electricity infrastructure (like traditional power plants, wind turbines, etc.). As such, the hedonic literature related to electricity transmission infrastructure can help inform the narrative on electricity generating infrastructure and viewscape impacts.

According to Brinkley and Leach (2019), the hedonic literature on of electricity transmission infrastructure is relatively mixed in terms of results. The authors inventoried 20 hedonic studies of electricity transmission lines and found that 11 studies concluded there are significant negative impacts to nearby property values as a result of transmission lines, while the other nine studies found no statistically significant impacts. Negative price impacts were found to be as large as -30%, although some studies have found positive price impacts to nearby homes as a result of electricity transmission lines due to the positive amenities associated with well maintained Right-of-Ways and greenspace.

4.4 Notable Viewscapes

The literature with respect to power plant development, or any kind of industrial development, and its impact on the viewscapes of notable sites (e.g., (e.g., National/Provincial Parks) is limited. With respect to the non-market valuation techniques described in this report (namely RP and SP approaches, see Section 2.3), there is one study of particular relevance to the Alberta context. As described in Section 4.2.1, Groothuis et al. (2008) explored the visual impacts of wind power generation on mountain views in North Carolina, United States. As a number of Provincial and National parks in Alberta are located near the rocky mountains, a particularly scenic area of the province, the mountain viewscapes described in Groothuis et al. (2008) may be of relevance. The authors found that households living in the area would be willing to accept compensation of $23 per year (2008 USD) on average to site wind turbines within the mountain viewshed (Groothuis et al. 2008).

Another area of literature that has explored attitudes toward development near places or regions residents consider important is the “place attachment” literature. Place attachment generally refers to emotional bonds between individuals/groups and a particular location (Devine-Wright and Howes 2010). In a study by Devine-Wright and Howes (2010), the authors explored resident attitudes to a proposed wind farm off the coast of two coastal towns in North Wales, Llandudno and Colwyn Bay. Llandudno was described as being well known for its scenic beauty, restorative environment, and associated attractiveness for tourists, while Colwyn Bay was described as being relatively more run-down. The authors were particularly interested in better understanding attitudes to the proposed wind farm in the towns with respect to resident place attachment. The study used both qualitative and quantitative methods, including group discussions and survey analysis. The authors concluded that residents of Llandudno had negative attitudes toward the proposed wind farm and a high place attachment to their town; significantly more than the residents of Colwyn Bay. The place attachment of Llandudno residents was found to be significantly correlated with negative opinions on the wind farm, particularly with respect to the viewscape impacts on what is considered a scenic, restorative, and natural environment. These results were not found for the residents of Colwyn Bay, potentially due to the relatively higher natural beauty and pristine viewscapes that exist in Llandudno (Devine-Wright and Howes 2010). Strazerra et al. (2012) came to similar conclusions in a study conducted in Italy, where the authors find that the visual impact of a wind farm is an important component to resident opposition, particularly when individuals have strong place attachment to the area.

5. Conclusions and Opportunities for Future Work

Quantifying the impacts of power plant development on viewscapes is a complex endeavour as viewscapes are considered non-market goods for which market data and information are not readily available. Economic valuation of non-market goods, like viewscapes, is typically undertaken through RP or SP methods. With respect to the disamenities associated with electricity generating infrastructure, including viewscape impacts, the bulk of the literature has focused on RP methods, specifically hedonic analysis of nearby property values. As such, this literature review focused predominantly on hedonic studies of electricity generating infrastructure. In addition, while the SP literature on power plant development and viewscapes is much sparser as compared to the hedonic literature, relevant studies that rely on SP techniques were included in the review as well.

5.1 Conclusions

The RP and SP literature related to traditional and renewable electricity generation infrastructure development and its impact on viewscapes is relatively mixed. With respect to traditional power plants, the literature suggests that these plants may reduce the value of nearby homes up to several kilometers away as a result of disamenities imposed by a plant, including (but not limited to) visual impacts. Arguably the most comprehensive and relevant of the reviewed studies on traditional power plants was Davis (2011). This study, which was conducted in a North American context (the US), found that housing values declined by -4% to -7%for homes within roughly 3.2 km of a traditional power plant (either coal or natural gas).

With respect to renewable electricity, there have been numerous studies evaluating the impact of renewable electricity infrastructure (primarily wind turbines) on nearby property values as a means to explore potential real or perceived disamenities, including viewscape impacts. Overall, there is a lack of consensus with respect to the impacts of wind electricity infrastructure on property values. While a number of studies find statistically significant and negative impacts of wind turbines on nearby housing prices, there are many studies that find no statistically significant impact. Of the studies that do find significant impacts, the range of impacts on housing prices varies substantially, from anywhere from a -1% impact to -14% depending on a variety of factors such as proximity to a turbine, density of turbines within view of a property, turbine size, municipal acceptance, etc. Only two studies exist that examine the impacts of solar farms on nearby housing markets, both of which find significant negative impacts on properties in very close proximity to a solar farm (less than 1 km).

The most relevant of the reviewed studies on renewable electricity infrastructure were Vyn and McCullough (2014) and Vyn (2018), both of which examined the potential impacts of wind turbines on property values in a Canadian context (Ontario). Vyn and McCullough (2014) found no statistically significant impacts of wind turbines on nearby residential or farmland property values. However, the more recent work by Vyn (2018) suggested that a municipality's overall acceptance or opposition to wind energy development may play a role in the extent of impacts to nearby property values. The author estimated the impacts of wind turbines on nearby property values for two groups of municipalities in which one group is considered "willing hosts" to wind development and the other group is considered "unwilling hosts." Designation of municipalities as willing or unwilling hosts was based a list compiled by Wind Concerns Ontario, a grassroot organization that represents communities in Ontario that are opposed to wind energy development. The list compiled by Wind Concerns Ontario includes all municipalities that have formally declared themselves as unwilling hosts of wind energy. This declaration is made by municipal governments and suggests that there is a critical mass of residents in the community that oppose wind turbines (Vyn 2018). Other municipalities in the Vyn (2018) study that have not formally declared themselves as unwilling hosts are considered willing hosts. The author found evidence of negative impacts to property values (-4.1%

to -8.4%) in municipalities that are considered unwilling hosts to wind energy. Conversely, for municipalities that are considered willing hosts to wind energy, no significant impacts to property values were found.

The influence of a community's overall perception to various types of electricity development may indeed play an important role in how viewscape changes are perceived following power plant development. Further to Vyn's (2018) findings, an SP study by Thomson and Kempton (2018) found that residents of a community in Delaware, US were willing to pay $1.65 (2018 USD) to keep the nearby wind electricity generation infrastructure (a single turbine) based on visual impacts alone. Conversely, the study found that residents of a separate community were willing to pay $0.86 (2018 USD) per month to have the coal plant removed due to the visual impacts it imposed (Thomson and Kempton 2018). The results of Thomson and Kempton (2018) and Vyn (2018) suggest that attitudes toward viewscape changes associated with power plants may be influenced by resident perceptions of various electricity generating sources in a community. As the mix of electricity generation sources continues to change in Alberta, it is possible that attitudes toward viewscape changes will change over time as well.

There is limited literature with respect to viewscape impacts of development near particularly notable areas (such as National Parks). Groothuis et al. (2008) explored the visual impacts of wind power generation on mountain views in North Carolina, US. The authors found that households would be willing to accept compensation of $23 per year (2008 USD) on average to site wind turbines within the mountain viewshed (Groothuis et al. 2008). As a number of Provincial and National parks in Alberta are located near the rocky mountains, a particularly scenic area of the province, the mountain viewscapes described in Groothuis et al. (2008) may be of relevance. Another area of literature that has explored attitudes toward development near places or regions residents consider important is the "place attachment" literature. Some work in this area has suggested that residents with a particular place attachment to a scenic region may have negative attitudes towards electricity infrastructure development as compared to those with relatively weaker place attachment to their surroundings (Devine-Wright and Howes 2010; Strazerra et al. 2012). However, there appears to be is insufficient RP or SP literature to suggest that the development of power plants near what may be considered notable sites in Alberta would differ in terms of viewscape impacts relative to other areas of the province.

We emphasize that this literature review was focused on the potential impacts of power plant development on viewscapes to the extent possible. We acknowledge that the non-market valuation studies reviewed in this work may include perceptions and values with respect to other real or perceived impacts of power plants (e.g., noise, health, etc.). To this point, the potential viewscape impacts associated with various types of electricity generation in Alberta should be considered one piece of the narrative regarding the province's energy future, along with a variety of other important trade-offs that must be considered.

5.2 Opportunities for Future Work

Given the relatively mixed results of this literature review, it would appear that the impacts of electricity generation infrastructure on viewscapes, as estimated by RP and SP valuation approaches, are location specific. Indeed, as suggested by Vyn (2018), this may be a result of the role that community acceptance of various types of electricity generation plays in the resulting impacts of this infrastructure. At the time of writing, no RP or SP studies exploring preferences around electricity generation infrastructure (viewscape changes) have been conducted in Alberta. There has also been limited research on the effects of electricity generation infrastructure on mountain viewscapes, an important category of Alberta scenery. The province would indeed benefit from primary analysis to better understand the preferences and values of Albertans with respect to electricity generation and its potential impact on Alberta viewscapes. Research that focuses on potential impacts of electricity generation on mountain viewscapes in Alberta would also represent an important contribution to the literature on this topic.

We note that undertaking a hedonic analysis to explore the impact of power plants on property values in Alberta as a means to better understand viewscape preferences would require a substantial amount of data. Hedonic analyses of property values typically require data over a long time period (e.g., 5-10 years). Ideally, data that would need to be compiled would include:

- property values (ideally sales transactions) for a study area of interest,
- details with respect to property characteristics (e.g., square footage, number of bedrooms, lot size, etc.),
- power plant locations, and
- power plant proximity and visibility to properties.

What is of particular importance is having sufficient data for property values in relatively close proximity or with particularly impacted views of a power plant; this has been a noted limitation of previous hedonic work (e.g., Vyn and McCullough 2014). The extent to which the required data are available in Alberta will influence the feasibility of undertaking this type of analysis in the future. Alternatively, SP approaches would likely be feasible given sufficient time and resources.

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Appendix A. Detailed Hedonic Literature Summaries

Table A-1 Hedonic Studies, Detailed – Traditional Electricity Generation Infrastructure

Authors (Journal)	Location	Impact Found	Summary	Findings	Citation Count[a]
Blomquist 1974 (Land Economics)	United States (Illinois)	Negative	This study estimated the impact of proximity to the Winnetka Power Plant in Illinois on nearby housing price using a hedonic model. The power plant of interest was a coal-fire power plant.	The author found statistically significant and negative impacts of the coal-fired power plant on nearby property values. For homes within roughly 3.5 km of the plant, prices are estimated to decline by about -0.9% for every 10% closer a home is to the plant.	115
Davis 2011 (The Review of Economics and Statistics)	United States	Negative	The author used a hedonic model to estimate the impact of power plants using fossil fuels on nearby property values. The dataset included property values for 205,000 homes near 92 power plants across the United States between 1993 and 2000. Unlike most hedonic studies, this study used housing values from self-reported census data as opposed to property sales data.	The author found statistically significant and negative impacts of traditional power plants on nearby property values. For houses within roughly 3.2 km of a power plant, values were estimated to decrease by roughly -4% to -7%.	302

Authors (Journal)	Location	Impact Found	Summary	Findings	Citation Count[a]
Khezr et al. 2021 (Australasian Journal of Environmental Management)	Australia	Negative	Using hedonic modelling, this study sought to estimate the effect of fossil fuel-fired power plants (including coal and natural gas plants) on the value of nearby properties in New South Wales, Australia. The dataset employed included over 102,000 residential property transactions in New South Wales in 2011. Data included property proximity to coal and natural gas power plants.	The authors found statistically significant and negative impacts of traditional power plants on nearby property values. For houses within 30 km of a coal power plant, housing prices were found to be discounted by up to -25%. For gas power plants, price discounts of up to -8.1% were found for houses within 20 km of the plant.	0
Eichholtz et al. 2023 (Journal of Real Estate and Finance Economics)	Europe (Netherlands)	Mixed	The authors use a hedonic analysis to estimate the impacts of traditional and renewable electricity generation infrastructure on nearby property values, including coal and natural gas power plants. Electricity infrastructure included coal, gas, wind, and biomass generation infrastructure. The entire dataset used in the study included roughly 2.3 million property transactions, including almost 10,779 transactions within 2.5 km of a coal-fired power plant, and 152,093 within 2.5 km of a gas power plant.	The authors found no statistically significant impact associated with coal-fired power plants on nearby property values. For gas-fired power plants, the authors found that properties within 1 km of the plant experience a price increase of roughly 3.4% on average, while properties between 1 km and 4 km of a gas plant experience price decreases of -4.5% to -5.9%.	2

Notes:
We note that lower citation counts for Khezr et al. (2021) and Eichholtz et al. (2023) are likely due to the recency of these studies as well as the relatively limited literature related to hedonic analysis of traditional power plants in general.
[a] Citation counts are reported from Google Scholar at the time of this writing.

Authors (Journal)	Location	Impact Found	Summary	Findings	Citation Count[a]
Sims et al. 2008 (International Journal of Strategic Property Management)	Europe (United Kingdom)	None	The authors employed a hedonic pricing model to examine the potential impact of a wind farm on local residential property values in Cornwall, United Kingdom. The dataset used in the study included 201 property transaction observations for properties within 0.5 miles (0.8 km) of a 16-turbine wind farm.	The study found no statistically significant impacts associated with property values near the wind farm. Neither the distance to the wind farm nor the number of wind turbines visible to a property had a significant impact on property sale prices.	142
Hoen et al. 2011 (The Journal of Real Estate Research)	United States (9 states)	None	This study employed a hedonic pricing model using a dataset of roughly 7,500 sales of single-family homes across 9 states. The analysis evaluated impacts associated with both proximity and view of wind turbines.	The authors found no statistically significant impact of the wind turbines on nearby property values .	160
Heintzelman and Tuttle 2012 (Land Economics)	United States (New York)	Mixed (none to potentially positive)	Using a dataset comprised of over 11,000 property transactions across three counties in northern New York, the authors conducted a hedonic analysis to examine the potential impacts of wind energy facilities on nearby property values. Of the entire dataset, 461 observations included property sales within 3 miles (4.8 km) of a wind turbine, of which 59 were within 1 mile (1.6 km).	The study's findings are mixed. In two of the three counties, wind turbines are found to have statistically significant negative impacts of up to -14.5% to -15.8% on property values, whereas in the third county, the authors found either no impact or potentially positive impacts under certain model specifications.	218

Authors (Journal)	Location	Impact Found	Summary	Findings	Citation Count[a]
Jensen et al. 2014 (Land Economics)	Europe (Denmark)	Negative	This study sought to estimate the impacts of both visual and noise pollution from wind turbines on nearby residential properties using hedonic analysis. The dataset employed included 12,640 transactions of single-family homes over the 2000 to 2011 period across 20 municipalities in Denmark.	The authors found that the visual impact of wind turbines resulted in a roughly 3% decline in property values.	140
Lang et al. 2014 (Energy Economics)	United States (Rhode Island)	None	The authors used a large dataset of over 48,500 residential property transactions within 5 miles (8 kms) of a wind turbine site, over 3,200 of which were within 1 mile (1.6 km) of a site in Rhode Island. Using hedonic modelling, the authors estimated the impacts of wind turbines over various periods of time in terms of proximity, viewshed, and contrast with surrounding development to nearby property values.	The authors found no statistically significant impacts of wind turbines on nearby property values across a variety of model specifications that were tested. No impacts were found in either the post-public announcement phase or the post-construction phase.	140
McCarthy and Balli 2014 (International Journal of Strategic Property Management)	New Zealand	None	This study focused on a small township hosting roughly 900 dwellings and located within 8 km of two windfarms. The authors employed a hedonic analysis using 945 property transactions between the 1995 and 2009 period. The study captured both the distance of properties to a wind turbine as well as the visibility of turbines from a property.	The authors found no statistically significant impact of the wind turbines on nearby property values.	14

Authors (Journal)	Location	Impact Found	Summary	Findings	Citation Count[a]
Vyn and McCullough 2014 (Canadian Journal of Agricultural Economics)	Canada (Ontario)	None	The authors estimated the impacts of wind turbines in a township in southern Ontario on nearby residential and farmland property values. The analysis examined both the impact of turbine proximity as well as turbine visibility. A hedonic approach was taken in the study, using a dataset of over 5,400 residential property sales and over 1,500 farmland sales.	Neither residential nor farmland property values were found to be significantly impacted by nearby wind turbines.	78
Gibbons 2015 (Journal of Environmental Economics and Management)	Europe (United Kingdom)	Negative	This study used hedonic modelling to estimate the potential impacts of wind farm visibility on nearby residential property values in England and Wales. A dataset of almost 38,000 housing price observations was used, with turbines potentially visible for 36,000 of those observations.	Statistically significant negative impacts to residential property values were found. Estimated impacts were found to average a price decrease of 5% to 6% for properties within 2 km of wind turbines, declining to roughly -2% for those between 2 km and 4 km, and not quite -1% by 14 km (the limit of likely turbine visibility). Smaller wind farms were found to have relatively smaller impacts to property values, while larger wind farms (20+ turbines) were found to reduce prices by about -12% for properties within 2 km.	265

Authors (Journal)	Location	Impact Found	Summary	Findings	Citation Count[a]
Hoen et al. 2015 (Journal of Real Estate and Finance Economics)	United States (9 states)	None	Using hedonic modelling, the authors examined the impact of wind facilities on nearby residential properties. The dataset was made up of over 50,000 residential property sales that were within a 10-mile proximity of a wind facility. Data were collected across 9 states for various time periods related to turbine construction including post-announcement/pre-construction and post-construction. Of the entire dataset, about 1,200 observations were within 1 mile (1.6 km) of an existing or future turbine location, 376 of which were within 1 mile (1.6 km) of an existing wind turbine location.	The authors concluded that wind turbines had no statistically significant impact on nearby residential prices in either the post-construction or post-announcement/pre-construction phases.	161[b]
Dröes and Koster 2016 (Journal of Urban Economics)	Europe (Netherlands)	Negative	The authors employed a hedonic analysis to examine the potential impact of wind turbines on sale prices of nearby residential properties in both urban and rural areas of the Netherlands. Impacts were evaluated for various time periods before and after the construction of the wind turbines.	Statistically significant negative impacts to residential property values were value. The results of the study indicate that on average, house prices decline by approximately -1.4% following the construction of a wind turbine within 2 km from the property. Impacts were found to occur in years leading up to the construction of a turbine and were found to be larger for taller turbines and for properties in urban areas as compared to rural areas. The authors also found that negative impacts were still statistically significant 10 years after the wind turbine had been constructed.	167

Authors (Journal)	Location	Impact Found	Summary	Findings	Citation Count[a]
Sunak and Madlener 2016 (Energy Economics)	Europe (Germany)	Negative	This study used a hedonic model to examine the visual impact of wind farms on local semi-urban property prices near three medium-sized cities in North Rhine-Westphalia, Germany. The study incorporated specific visual impact criteria including the distance of the property to the wind farm, the number of visible turbines from the property, as well as the view angle from the property. The dataset included property sales pre-wind farm construction (1,236 sales) as well as sales post-wind farm construction (905 sales).	Statistically significant negative impacts to property values were found for properties deemed to have medium to extreme views of a wind farm (i.e., an average of 7 to 10 turbines visible at a distance of 1.1 km to 3.1 km). Impacts were found to range from -9% to -14%. The number of visible turbines and distance to the turbines played a large role in the resulting impacts to property values, as properties with marginal to minor view impacts (i.e., a view of 3 turbines or fewer from a distance of at least 3.5 km) were not found to have significantly lower property values.	166
Heintzelman et al. 2017 (Ecological Economics)	Canada and the United States	Mixed (none to negative)	The authors evaluated the impacts of a wind farm along the Canadian border on nearby property values within both Canada and the United States. A dataset 6,017 single-family residential property transactions in New York and 2,262 in Ontario. Both proximity to a wind turbine and visibility of a wind turbine were evaluated in the analysis.	Statistically significant negative impacts were found for properties located in close proximity to and/or within view of a wind turbine in New York. No statistically significant impacts were found for properties in Ontario.	13
Castleberry and Greene 2018 (International Journal of Housing Markets and Analysis)	United States (Oklahoma)	None	The authors developed a hedonic analysis to estimate the impact of wind farms on local residential property prices across five counties in Western Oklahoma. The analysis relied on a dataset of roughly 23,000 residential and non-residential property transactions.	Neither residential nor non-residential property values were found to be significantly impacted by nearby wind turbines.	17

Authors (Journal)	Location	Impact Found	Summary	Findings	Citation Count[a]
Jensen et al. 2018 (Energy Policy)	Europe (Denmark)	Negative	This study employed a hedonic model to examine the impact of both on-shore and off-shore wind turbines on property values of nearby homes in Denmark. The dataset used for the Study included 8,865 observations of property sales, over 4,900 of which were within 3 km of at least one wind turbine.	Statistically significant negative impacts to property values within 3 km of on-shore wind turbines were found. The estimated marginal impact of an additional wind turbine within 3 km of a residential property was -0.2% to -1.1%. Off-shore wind turbines, located about 9 km from nearby properties in the dataset, were not found to have statistically significant impacts on property values.	70

Authors (Journal)	Location	Impact Found	Summary	Findings	Citation Count[a]
Vyn 2018 (Land Economics)	Canada (Ontario)	Mixed (none to negative)	The author examined whether the amount of local support or opposition to wind energy projects influences the impacts of wind turbines on residential property values. Specifically, the study estimated the average impacts of wind turbines on nearby property values in southern Ontario, comparing impacts between two groups of municipalities based on whether they generally support or oppose wind energy. A hedonic modelling approach was taken in the study, using a dataset of over 22,000 residential property sales, 300 of which were sales within 1 km of a wind turbine post-construction.	Statistically significant negative impacts to property values were found in municipalities that generally oppose wind energy for properties located up to 4 km from the nearest wind turbine during both the project announcement and post-construction periods. Estimated impacts ranged between -4.1% to -8.4% and were not found to be declining with distance from the turbine. Turbine density was also found to have a statistically significant impact on property values. For municipalities that are generally unopposed to wind energy projects, no significant impacts to property values were found.	23
Skenteris et al. 2019 (Economic Analysis and Policy)	Europe (Greece)	Mixed (none to negative)	Using a hedonic analysis, the authors estimated the impact of wind facilities on surrounding residential properties on two Greek islands. The dataset used for this study included 1,800 transactions of single-family homes near 17 wind power generation facilities on the two islands of interest.	The authors found statistically significant and negative impacts of wind generation infrastructure on nearby property values of up to -14.4% on one island in their study, and no statistically significant impacts on the other island.	16

Authors (Journal)	Location	Impact Found	Summary	Findings	Citation Count[a]
Dröes and Koster 2021 (Energy Policy)	Europe (Netherlands)	Negative	The authors used a hedonic model to explore the effect of wind turbines and solar farms on house prices in the Netherlands. The dataset included over 3 million residential property transactions for the wind turbine analysis. The authors specifically explored the impact of wind turbine height on nearby property values.	The authors found statistically significant negative impacts of wind turbines on nearby property values. Overall, the development of a wind turbine was found to reduce local housing prices by -1.8%. Impacts were not found for properties located more than 2.25 km from a turbine, and impacts were found to be more substantial (-5.4%) for turbines taller than 150m.	41
Joly and De Jaeger 2021 (Land Use Policy)	Europe (Belgium)	Mixed (none to negative)	In this study, the authors used a hedonic model to estimate the impact of wind turbines on residential property values in two markets within Flanders, Belgium. The study's dataset included over 207,000 property transactions across the two housing markets that occurred between 2004 and 2017.	The authors found that, before the financial crisis of 2008, there was no statistically significant impact of wind farms on nearby property values. However, following the financial crisis, statistically significant and negative impacts ranging from -2.8% to -6.4% were found for properties within 1 to 3 km of a wind turbine.	5
Dong and Lang 2022 (Energy Policy)	United States (Rhode Island)	None	The authors evaluated the impacts of an off-shore wind farm in Rhode Island on mainland property values by means of hedonic analysis. A dataset of over 11,000 property transactions over the 2005-2020 period was used, and spatial modelling was conducted to assess property views of turbines.	The authors concluded that off-shore wind farm had no statistically significant impact on mainland property values.	5

Authors (Journal)	Location	Impact Found	Summary	Findings	Citation Count[a]
Eichholtz et al. 2023 (Journal of Real Estate Finance and Economics)	Europe (Netherlands)	Negative[c]	The authors undertake a hedonic analysis to estimate the impacts of traditional and renewable electricity generation infrastructure on nearby property values, including wind energy infrastructure. Electricity infrastructure included coal, gas, wind, and biomass generation infrastructure. The entire dataset used in the study included roughly 2.3 million property transactions, including almost 186,000 transactions within 2.5 km of a wind turbine.	The authors found statistically significant and negative impacts of wind generation infrastructure on property values within 2.5 km of a turbine. Housing prices were found to decline by up to -1.4% in rural areas, and -1.2% in urban areas.	2

Notes:
[a] Citation counts are reported from Google Scholar at the time of this writing.
[b] Hoen et al. (2015) was published as both a peer-reviewed journal article (97 citations) and a report (64 citations).
[c] Refers to results for wind electricity generation infrastructure.

Table A-3 Hedonic Studies, Detailed – Solar Electricity Generation Infrastructure

Authors (Journal)	Location	Impact Found	Summary	Findings	Citation Count[a]
Dröes and Koster 2021 (Energy Policy)	Europe (Netherlands)	Negative	The authors used a difference in difference hedonic price model to explore the effect of wind turbines and solar farms on house prices in the Netherlands. The dataset included over 1.5 million residential property transactions for the solar farm analysis.	The authors found statistically significant negative impacts of solar farms on nearby property values. Overall, the development of a solar farm was found to reduce local housing prices by -2.6%. Impacts were not found for properties located more than 1 km from a solar farm.	41

Authors (Journal)	Location	Impact Found	Summary	Findings	Citation Count[a]
Maddison et al. 2023 (Land Economics)	Europe (England and Wales)	Negative	The authors employed a hedonic model to estimate the impact of a solar farm on nearby residential property values in England and Wales. Over 204,000 property transactions within 1 km of 898 operational solar farms were included in the dataset. Over 96,000 of the property transactions in the dataset were in very close proximity to a solar farm (within 750 m).	The authors found that solar farms result in a statistically significant decrease in prices of -5.4% for properties within 750 m of a solar farm greater than 5 MW in capacity. Impacts were found to increase for larger solar farms (i.e., greater than 10 MW). No price impacts were found for properties within 750 m of a solar farm with less than 5 MW in capacity.	5

Notes:
[a] Citation counts are reported from Google Scholar at the time of this writing.

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