Thesis

Comparing local external costs of wind turbines and power plants through the effects on local residential values

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Abstract

Recent Dutch energy policies require an increase of wind energy capacity of nearly 200%. Many of these new wind turbines are likely to meet strong opposition. Not renewing the energy supply is not an option, therefore a comparison needs to be made. What are the total costs of different methods of electricity production? These total costs consist of construction costs, marginal costs and external costs. In previous research these external costs have been the costs to the environment. This study aims at adding the lost local residential value to these total costs. The datasets used include all wind turbines, all power plants and 2.5 million housing transactions in the Netherlands. The data allows for an historical analysis over 29 years of 70% of the housing transactions in the Netherlands. The richness of the data and the scope of including both wind turbines as conventional power plants in this research, sets this study apart. The dataset of the Dutch realtors association allows to control the transaction data with nearly fifty variables describing characteristics and surroundings.

The results of this study are summarised below:

- Between 1985 and 2013 all house sold within 2 kilometres of a wind turbine were actually 3.7% more expensive than the average house sold in the Netherlands.
- For houses sold within 2 kilometres of a power plant the average transaction price was 10,6% lower than the average transaction price in the Netherlands from 1985 to 2013.
- When the results are controlled for housing characteristics and year of transaction, houses sold within 2 kilometres of wind turbines and power plants are negatively affected 4.2% and 5.1% compared to all other transactions in the Netherlands
- A 3 kilometre range provides estimates of 2.6% and 4.2% lower transaction prices for properties due to the vicinity of wind turbines and power plants respectively.

Controlling for location within the Netherlands provides the following results:

- A wind turbine at up to 2 kilometres has a negative effect of 3% compared to wind turbine at 2 to 3 kilometres.
- A wind turbine within 3 kilometres has a negative effect of 2.6% compared to wind turbines at 3 to 4 kilometres.
- Power plants within 2 kilometres have a negative effect of 3.2% compared to power plants at 2 to 3 kilometres.

- Power plants within 3 kilometres have a negative effect of 6.5% compared to power plants located at 3 to 4 kilometres.
- The effect of wind turbines decreases with distance and is no longer significantly negative at just over 2 kilometres.
- The effect of power plants decreases with distance and is no longer significantly negative at just over 3 kilometres.
- Of the different power plant categories, coal plants have the largest negative effect, 8.1% for properties located within 3 kilometres.
- For gas fuelled plants and biomass plants these effects are 4% and 0.6% respectively.

The estimated total residential value lost due to the proximity of wind turbines and power plants:

- At the height of the Dutch housing market in 2007 nearly € 250 million lost due to power plants and over € 80 million due to wind turbines in that same year.
- The lost value due to wind turbines per kilowatt has decreased from € 150 per kilowatt in 1995 to € 27 per kilowatt of capacity in 2012.
- The lost value due to power plants per kilowatt has been decreasing since 2006 and is at € 6 per kilowatt of capacity in 2012.

1. Introduction

In 2015 Germany will celebrate the 15th anniversary of passing the law that made its *Energiewende* possible. Since the year 2000 the German renewable energy production has steadily risen to almost 25% of its total energy production (Blazejczak, Braun, Edler, & Schill, 2014). Due to thorough redevelopment of the German energy production, the country has become a forerunner in renewable energy production. Similarities between the geographic, economical and meteorological conditions of Germany and the Netherlands, and the considerable leap forward the Germans have made in the past decade, allows the Netherlands to look at its larger neighbour for best practices and possible problems in the near future.

Although the *Energiewende* has always been praised as a leap forward that left other developed nations behind, there is more than meets the eye. Troubles are only right beneath the surface. Germany saw negative wholesale prices for its electricity for the first time in 2007. Since 2007 negative prices have reoccurred, not only in Germany but in other western European countries as well. A sunny and windy Sunday 11th of May 2014 created conditions in which almost three quarters of Germany´s electricity production came from renewable energy sources (Economist, 2013). This creates a direct link between renewable energy sources and the negative wholesale prices. Since conventional power plants cannot be switched on and off in seconds, and since this process is costly, conventional power plants create excess electricity when weather conditions are favourable for renewable energy sources. Hence, the question arises how investing in electricity production, whether conventional or from renewable sources, can be profitable.

The German investments in renewable energy sources are made possible through subsidies, and in 2013 they totalled €16 billion (Mahalingam, Reiner, & Newbery, 2014). These subsidies encompass mainly tariffs that are borne by the ultimate user of the electricity. German end user electricity bills are therefore considerably higher than those in neighbouring countries.

Finally the reduction of greenhouse gasses emitted by electricity producing facilities has been disappointing. In 2013 the greenhouse gas emissions were higher than in 2012 (Economist, 2013). Although this is mainly due to the declining coal prices, it does show that the expensive German policies have not yet brought forward the results hoped for.

The *Energiewende* has left much material for thought for countries that are lagging in reaching their renewable energy goals, such as the Netherlands. The question if wind turbines and photo-voltaic panels are truly the best solution when it comes to making our electricity production cleaner has to be answered in many dimensions. The success of new energy policies is measured in the price of electricity, the percentage of electricity that comes from renewable resources, the reduction of greenhouse gasses, the impact on the economy, the independence of foreign resources, the stability of the grid, and the costs to the environment. The performance of policies will therefore always be reliant on the circumstances.

Most of these factors have been researched in recent years. The costs of producing renewable energy have moved closer to the costs of conventional energy, however a breakeven point between the two sources is predicted to be almost a decade away. Multiple studies into the subject have found offshore wind energy production to be more costly than onshore production. This leads to policymakers favouring onshore wind energy production for as long as offshore wind production remains economically unviable without subsidies.

In recent years there have been many studies aimed at identifying the true costs of energy and herewith aiding policymakers in their decision making process. The body of research includes studies from all fields of science. However the economic research has been focussed on the price and future price of conventional resources, comparing costs of renewable and conventional energy production, future costs due to greenhouse gas emission, costs of infrastructure, and the local external costs of wind turbines. The largest body of literature on local externalities of conventional power plants dates from the 1980's.

The local externalities of power plants and wind turbines have been mainly focussed on specific geographical locations and on either wind turbines or conventional power plants. A comparison of locally endured external costs of electricity production is difficult to make since the literature at this point appears to be incomplete. The aim of this paper is therefore to make a comparison of the local external costs of energy production between wind turbines and conventional power plants, in a similar geographical location. The location chosen for the purpose of this research is the Netherlands.

The Netherlands is on the verge of a rapid expansion of its renewable energy sources. In order to identify a most suitable course of action, academic research has been developing a more complete picture of the total costs of energy production per source. Loss of local residential value due to electricity producing facilities has been researched in multiple occasions.

However, the body of literature created does lack a countrywide thorough comparison of the effects of different energy sources on local residential value. This study will start filling this gap by comparing the effects of wind turbines to those of more conventional power plants using one of the most extensive datasets on housing transactions in the world.

2. Research framework

This paper will contain qualitative research as well as quantitative research, where the qualitative part of the research will set the goals of the paper as well as setting the outline for the quantitative analysis.

The qualitative research will outline the energy market's conditions in the chosen geographic location, the Netherlands. The local energy policies and specific goals will be outlined in order to give this research a time frame. Identifying factors that possibly affect the local external costs of electricity production will aid in the selection of variables in the quantitative analysis. This qualitative research will combine the literature on these factors for wind turbines and conventional power plants.

The quantitative section of this research paper will describe the data from the three datasets used for this research. The empirical methodology will use the qualitative research in order to construct models that will finally allow the main conclusion to be drawn. The result section of this research discusses the most important results from analysing the models previously constructed. The final part of the quantitative analysis will generalize the results and make a true comparison of total residential value lost due to different kinds of electricity producing facilities.

The main goal of this research is to identify which form of electricity production leads to the highest loss in local residential value due to negative externalities per kilowatt of electricity production capacity. This research would accordingly allow for future research to incorporate these results in the estimation of the true costs of electricity production.

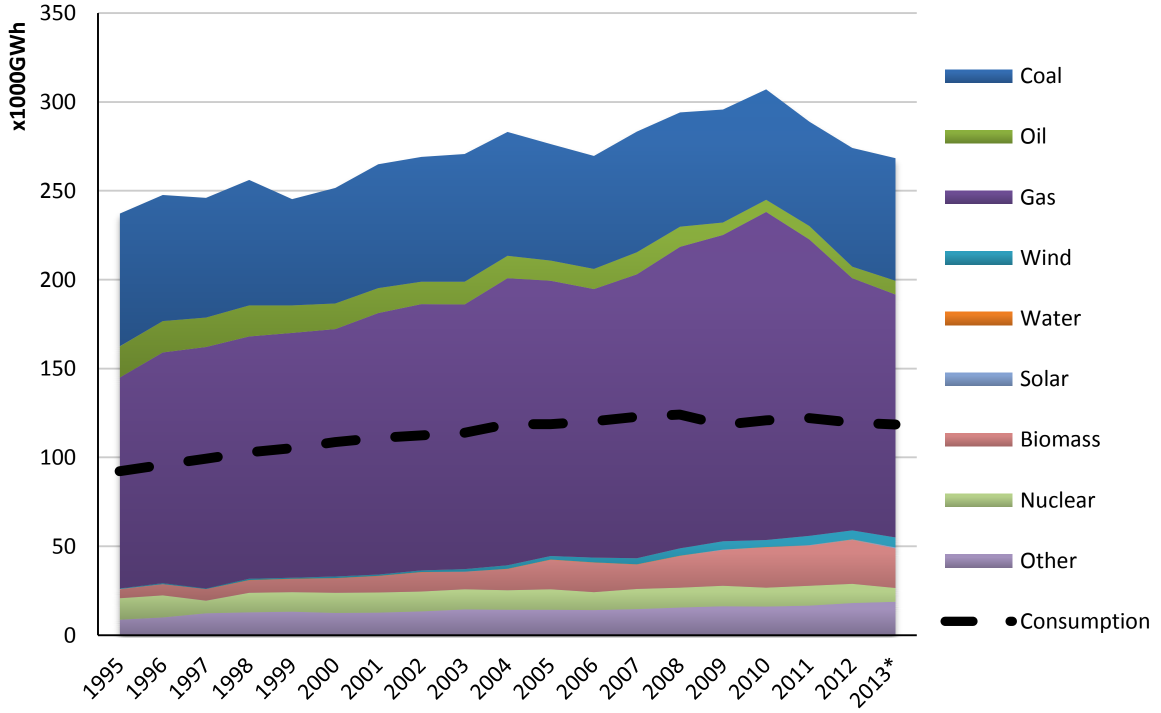
3. Qualitative analysis

A clear framework set through qualitative research will not only aid the empirical research, it will also provide future research guidance for the applicability of the results of this research. This analysis consists of the description of the Dutch electricity market in 2014, comparing the cost of different electricity generating techniques, government policies regarding electricity production, arguments opposing installing new wind turbines, and arguments that oppose the construction of new power plants.

3.1. The Dutch electricity market

The volume of the Dutch electricity market is slightly larger than 100 terawatt hours. In recent years the market has seen a decline in volume, which is mainly due to the financial crisis. However, Dutch governmental energy policy is also a factor in this decline. Figure 1 suggests a sharp decline in energy production since 2010. This decline can be mainly attributed to the financial crisis. The respective decline of gas as a carrier can be attributed to the start of the shale gas revolution in the United States and the continuing Energiewende in neighbouring Germany. The United States were a major importer of European coal until the shale gas revolution. The decrease in demand for coal has led to a price drop which has made coal an attractive alternative for gas for European utility companies.

Figure 1: Energy consumed and electricity production by carrier in GWh (the Netherlands).



Source: CBS (*preliminary)

The considerable shifts in the global energy markets have caused prices for importing electricity to decline. The total value of the electricity market in the Netherlands is roughly €12 billion. Figure 1 and the MarketLine Industry profile *Electricity in the Netherlands (2014)*, do not yet incorporate the recent decline in fuel prices. Since the summer of 2014 the price of a barrel of Brent oil has declined over 60%. This decline in oil prices puts pressure on the prices of other fossil fuels. Therefore the costs of producing electricity in conventional power plants is declining in late 2014. Costs of producing electricity through wind power are therefore likely to decline even further than predicted by most recent studies in order to be an economically viable alternative to fossil fuels without subsidies. The comparison of these costs is more thoroughly analysed later on.

MarketLine (2014) forecasts the volume of the electricity market in the Netherlands to grow to 112 terawatt hours in 2017, or a 6% increase compared to 2013. According to MarketLine (2014) the market value of the electricity market will be €14.5 billion in 2017. This forecast is without considering the recent decline in fuel prices. Tennet is increasingly integrating the electricity grid of the Netherlands with the west-German grid, so the wholesale energy prices in the Netherlands are becoming increasingly dependent on weather conditions (Mulder & Scholtens, 2013). The integration of grids and dependence on weather conditions are likely to increase the volatility of revenues of utility companies in the future.

Energie-Nederland (2013) research suggests that, when all planned capacity is installed, the total installed capacity in the Netherlands is forecasted to be 55 Gigawatts 2020. A predicted peak demand of just 20 Gigawatts in 2020, suggests retiring dated power plants with relatively high marginal costs. Peak capacity is becoming increasingly irrelevant with the increase in wind turbine and photovoltaic capacity. Since the capacity of these sources is not continuous, their output cannot be relied on for matching peak demand. In 2013 fossil fuels account for 83% of electricity production, wind and solar power account for just over 5% of total electricity production in 2013.

Electricity production in the Netherlands is still heavily reliant on fossil fuels, and the total market volume has been decreasing over the past 6 years. Combined with the current overcapacity, instalment of new capacity appears to be unnecessary. More importantly, wind turbines that are to be installed do not compete with power plants that are to be constructed, they compete with the marginal costs of the already installed capacity. This and the decreasing energy prices, suggests that the breakeven point for wind power and conventional power has moved further into the future than the earlier predicted ten years. For offshore wind turbines this effect is even greater than onshore wind turbines. Government intervention is therefore inevitable, if electricity production from renewables is to be increased.

3.2. Costs of electricity production compared

Electricity production costs are for the purpose of this research divided in three different categories. The first category being the direct costs of electricity production, which includes the construction costs as well as the marginal costs. The second category being the external costs bared by residents in the immediate surroundings of the facility, which is the main focus of this paper. The final category would be the costs bared by the environment, a number of studies have quantified these costs. This section of the research will focus on finding a general indication for the costs in the first and second category.

Roth and Ambs (2004) categorize the costs of power plants into four categories. The first being the construction costs, the second the maintenance costs, third the costs of the fuels and finally the costs of the externalities. Combined the costs per kw/h in cents for a plants lifetime can be summarised as follows:

Table 1: Combined costs of electricity production $cents

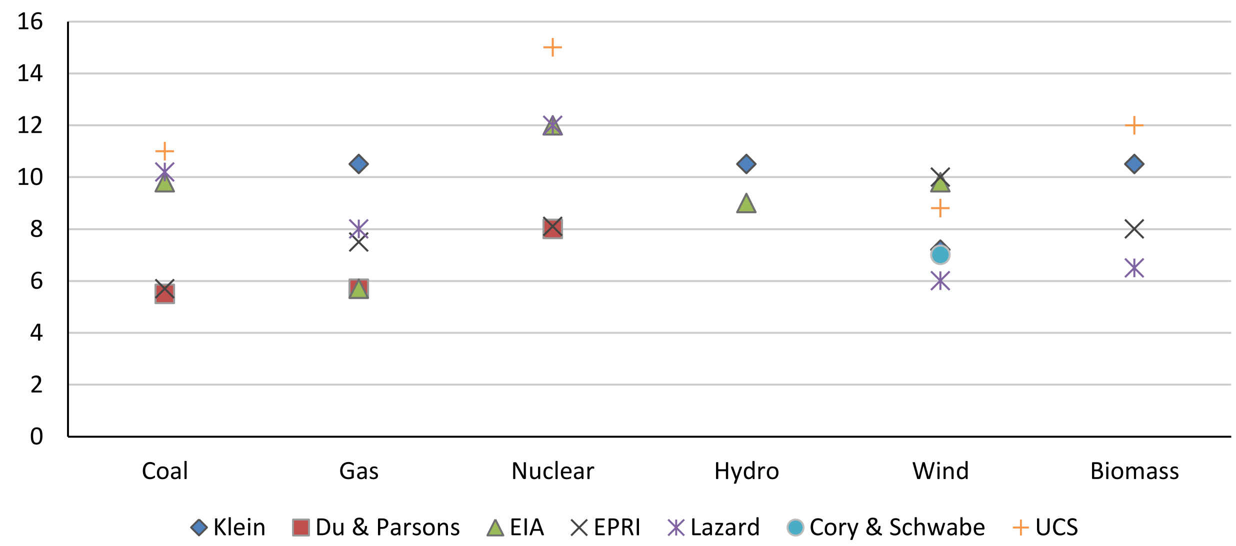
	Coal	Gas	Combined	Wind turbine	Biomass
Construction	2.81	0.82	0.91	5.74	3.54
Maintenance	1.00	0.42	0.31	1.66	2.59
Fuel	1.06	3.29	2.11	0.00	2.75
Externalities	12.07	9.15	7.31	2.13	1.30
Total	**16.94**	**13.68**	**10.65**	**9.54**	**10.17**

Source: (Roth & Ambs, 2004)

These combined costs are levelised costs, Roth & Ambs (2004) estimate these costs in order to compare the economic feasibility of different power sources over their life cycles. These levelised costs are supposed to incorporate all costs, from construction to externalities, made for producing a kilowatt hour of electricity. A thorough analysis of previous literature provides Roth & Ambs (2004) with estimates for all different factors that accumulate to the levelised lifecycle costs. However, externalities of wind turbines are based on a book from 1990 by Ottinger et. al, which is not based on empirical analysis but an estimation of the costs of the visual impact, noise and land use. The externalities in Roth & Ambs (2004) are environmental (pollution and damage due to extraction of energy carriers) and non-environmental (military and diplomatic costs for securing fuels). Combining results from different articles in order to make an comparison of the costs in difficult, especially since location and time are key drivers of residential value (DiPasquale & Wheaton, 1992). Therefore studies such as the study by Roth & Ambs (2004) would be aided by a comprehensive investigation of the local external costs.

Borenstein (2011) combined the levelised costs of different methods of electricity production from different researches. This provides an insight into the range of estimated total costs of electricity production. Levelised costs are dependent on many factors, including the costs of construction and the costs of fuel. For none of the researches included by Borenstein (2011) these costs are likely to be the same. Fuel costs are volatile and construction costs, especially for wind turbines, are subject to innovations. Figure 2 presents the ranges of estimated levelised costs by the different researches.

Figure 2: Range of levelised costs of electricity found in different research, $ cents per KWh



Source: Borenstein (2011)

Exact levelised costs are difficult to estimate from this research. However, it does give a clear picture on the ranges of the multiple power plants compared to each other. It is clear that on levelised costs different methods cannot be differentiated from each other. This makes the local externalities being researched in this paper, the costs that could set the different methods of electricity production apart.

3.3. Government Policies

The exploitation of our planet's exhaustible assets has been a concern for a long time. In 1931 Hotelling acknowledged the failure of the market with respect to the preservation of natural resources. Hotelling therefore suggested government intervention trough taxation (Hotelling, 1931). Since then and especially since the club of Rome emphasized the strain economic and demographic growth (Meadows, Meadows, Randers, & Behrens, 1972), governments are intervening in order to produce electricity in a more responsible way.

As noticed in the introduction not all effects of government policies are foreseeable. Since the Dutch government has committed itself to the "energieakkoord", pressure is likely to rise on the allocation of wind turbine construction sites (Londo & Boot, 2014). The "energieakkoord" can be summarized in two main goals: yearly 1.5% energy consumption reduction from 2013 to 2020, and a 14% of energy production has to come from renewable sources in 2020. The first goal is less relevant for this research, although meeting the first goal on a yearly basis would make achieving the second goal substantially easier.

The second goal stated in the "energieakkoord", increasing the share of renewables in the energy production mix, is likely to have a substantial influence on the allocation and numbers of new wind turbines on land. The treaty specifically states the sub goal of having 6,000 megawatt of wind capacity installed on land by 2020. In this period about 500 megawatt of old turbines needs to be replaced, which means an additional 4,000 megawatt needs to be installed onshore in the next 6 years, or a 133% increase in capacity (Londo & Boot, 2014).

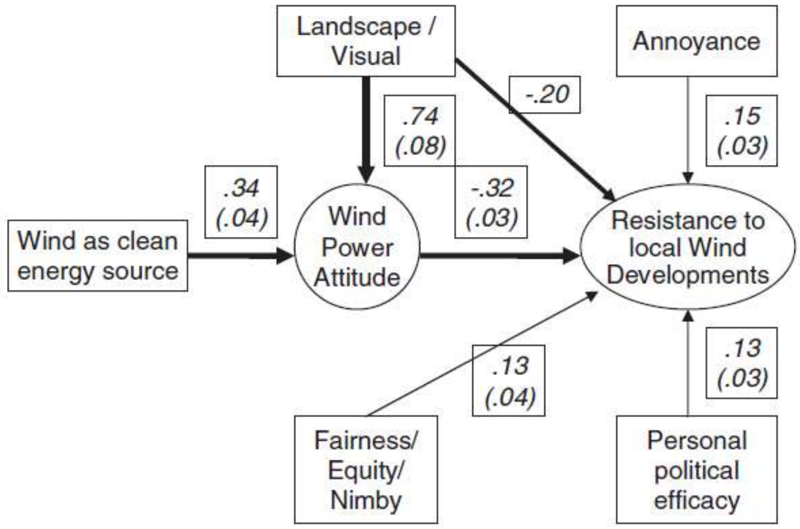
The goals of the "energieakkoord" underline the relevance of this research. The Dutch government is willing to invest in order to increase the share of energy production from renewables. Offshore is favoured, but expensive, therefore the real question is: Should the focus be on biomass or on onshore wind energy? The answer to this question has to come from economical as well as environmental benefits. For the economic part this research will contribute through estimating the residential value lost through either power plants or wind energy.

3.4. Arguments opposing instalment of new wind turbines

The main reasoning behind this research is that increasing the share of renewables in the Dutch energy mix is limited in the number of new onshore wind turbines that can be built. There are enough windy locations in the Netherlands on which to construct new wind turbines for the "energieakkoord" goals to be met (Gibescu, Brand, & Kling, 2009). However the construction of new wind turbines is met with opposition. Neither the majority or the Dutch population, nor most of the residents of potential wind turbine sites are opposed to renewable energy and specifically wind energy (Wolsink, 2000). Their opposition therefore is not opposition of wind turbines in general, but to wind turbines located near their homes. Is this due to nimbyism (Not In My BackYard)? And if so, where does this nimbyism stem from? The here following section will try to identify as many factors as possible, which aids the variable selection process in the quantitative analysis section of this research.

Nimbyism has been a classical explanation for the opposition of new wind turbines, according to Wolsink (2007). However, social science has proven this approach to opposition inadequate. Nimbyism assumes residents maximizing utility, which would mean that as long as all residents would agree on the benefits of wind turbines, they would be in favour of the maximum number of wind turbines built outside the area that affects their homes. Wolsink (2007) finds opposition towards wind turbines in other locations than peoples vicinity, suggesting the incompleteness of nimbyism as an explanation for this opposition. Wolsink (2007) summarizes the factors that drive opposition in the following diagram:

Figure 3: Direct and indirect impact of arguments and motives on resistance to wind turbine projects.



Source: Wolsink (2007)

In this model the “annoyance” is the actual physical effects on the local residents, “fairness” and “personal political efficacy” together describe the nimby effect, “landscape” is a measure for the perceived negative impact of wind turbines on the landscape. In the study by Wolsink (2007) the landscape effect is the most important driver of resistance.

We will therefore not only consider distance as an explanatory variable for peoples opposition. Other possible variables used to explain the opposition are categorised in noise pollution and general annoyance, spoiled scenery, and interference with natural areas.

3.4.1. Noise pollution and visual effects causing annoyance

The literature on the health effects of nearby wind turbines focuses on two factors, annoyance due to sound and annoyance due to visual effects.

Reported health effects such as sleep disturbance, headache, visceral, vibratory and/or vestibular dysfunction, dizziness, vertigo, unsteadiness, tinnitus, ear pressure or pain, external auditory canal sensation, memory & concentration deficits, irritability, anger fatigue, loss of motivation are acknowledged by literature as factors that can be caused by the noise from wind turbines (Farboud, Crunkhorn, & Trinidade, 2013). These effects are especially prevalent when found at sound pressure levels greater than 40 db(A). However, visual effects do appear to have a stronger impact on the annoyance than noise (Bakker et al., 2012). The conclusion of multiple researches into the health effects of people living near wind turbines is that the people living nearby wind turbines have more self-reported health effects and that these health effects are more likely to be caused by the annoyance due to presence of a wind turbine rather than the actual noise (Pedersen & Persson Waye, 2007). The change in the residents’ environment due to the construction of a wind turbine has an actual effect on the general health state in the vicinity, which is no direct link to the noise wind turbines create is found (Van Renterghem, Bockstael, De Weirt, & Botteldooren, 2013).

For visual effects the results are similar. People nearby wind turbines have reported health effects, claiming those effects were due to photo-induced seizures (Harding, Harding, & Wilkins, 2008), also known as photosensitive epilepsy, and wind turbine blade flicker. These effects are infrequent, construction of wind turbines typically takes these effects into account and construction is only allowed when the effect is prevalent for less than 30 hours a year. The effects are most likely to occur at dusk and dawn time when wind turbines are casting long shadows due to the low position of the sun on the horizon. Harding et al. (2008) suggests that the turbine flicker causes a potential risk of photosensitive seizures in 1.7 of 100,000 photosensitive people. This is only true when the frequency of interruptions of sunlight is greater than 3 Herz. This translates in a maximum rotation speed of 60 rpm for wind turbine with three blades. Normally the rotation speed of wind turbines is below this threshold.

Concluding, health effects are observed with people living near wind turbines. However, the effects do not seem to be relational to the sound of wind turbines, nor is the effect due to flickering large and prevalent enough do draw conclusions. This indicates that the health effects are mainly due to the general annoyance local residents perceive due to new wind turbines.

3.4.2. Spoiled scenery, interference with natural areas.

The visual intrusiveness of a wind turbine is not only related to the height of the wind turbine or the diameter of the rotor blades. The surrounding landscape is a mitigating factor when it comes to visual intrusiveness of wind turbines (Devine-Wright, 2005). Two studies have researched these effects, other landscape effects are the impact on fauna, which will not be discussed in this paper.

The first study to investigate the mitigating effect of the surrounding landscape on the visual intrusiveness of wind turbines is set in Australia. Lothian (2008) surveyed a population by asking to rate landscapes without wind turbines and the same landscapes with wind turbines. This study finds a relationship between the perceived beauty of the landscape and the height of the negative effect wind turbines cause. The higher the landscape is rated the higher the negative impact of wind turbines. For example, landscapes rated 10 received an average rating of just 7.3 after treatment, instalment of wind turbines, a reduction of 2.7 points on average. Landscapes that were rated a rounded 5, received an average rating of 4.6 after treatment, a reduction of just 0.4 points on average. The researchers also indicate that for even less rated sceneries, the treatment effect appeared to be positive. This effect was not significant.

The second study is part of the research by Wolsink (2007). In this study a survey is conducted investigating the location preference for instalment of wind turbines within the Wadden sea area in the Netherlands. Wolsink (2007) has the sample population indicating the acceptability of instalment of wind turbines in 19 categories of landscapes. The three landscapes that are most acceptable to the population are: “Industry, harbour areas”, “Military areas”, and “Afsluitdijk”, where the “Afsluitdijk” is a major dike cutting of the IJsselmeer from the Wadden sea. The three least acceptable landscapes are: “Wadden sea”, “Nature areas”, and “Dunes on islands”. All three of these landscapes are considered to be contributing to the specific beauty of the Unesco Wadden sea world heritage site. The results of this study are biased however, since the reviewed population are all members of the Wadden sea conservation society.

Both these studies indicate that the negative landscape effect of wind turbines increases when the perceived beauty of the landscape increases. Industrial sites are on the other hand likely to benefit from instalment of wind turbines (Devine-Wright, 2005).

3.4.3. Political motivation

The political motivation effect explains the effect of people generally not opposing wind turbines but do oppose wind turbines located in their vicinity. As mentioned before, the traditional explanation for this effect was nimbyism. However, studies (Devine-Wright, 2005) have shown that the effects are beyond this relatively simple explanation, and imply a democratic deficit and a fairness factor.

The fairness factor is most thoroughly investigated by Wolsink (2005). His research states that the “crucial factor is not that residents have strong intentions to shift the burden to others, but that they consider it unfair that others, or the decision makers, shift the burden to them” (p. 1203). Indicating that local residents are willing to except wind turbines in their vicinity as long as they perceive the distribution of wind turbines as being fair.

This leads us to an implication of democratic deficit. Although the local residents are able to elect their representatives on municipal, provincial and nation level in the Netherlands, local residents do not have the perception that they can influence the distribution of new wind turbine sites (Wüstenhagen, Wolsink, & Bürer, 2007). Similar results are found in the United Kingdom (Bell, Gray, & Haggett, 2005), United States (Pasqualetti, 2011a), and Mexico (Pasqualetti, 2011b). Denmark has long been a forerunner on wind energy implementation and has applied methods for local inclusiveness in some projects. An example of the inclusiveness in these Danish projects is the financial ownership of local residents. Some projects that were located near residential areas allowed residents to participate financially in the wind park. This led to a better perception of the project among the local population, even for those that chose not to participate (Loring, 2007).

Creating a more inclusive environment is likely to lead to higher acceptance of the project. Especially since fairness, not nimbyism is found to be a major factor of acceptance. The question is if higher acceptance will lead to a lower effect on residential values.

3.5. Arguments opposing construction of new power plants

The construction of new power plants has often been faced with local opposition. This paper investigates the literature on two possible factors that cause opposition: air pollution and the disaster hazard. Intuitively, the opposition of biomass power plants is more likely to be driven by air pollution whilst nuclear power plant opposition is more driven by the disaster hazard effect.

Every power plant that uses combustion for electricity generation emits pollution into the air. The type of power plant and technological innovations influence the amount of pollution emitted. Multiple studies have found a negative relation between local residential value and the amount of pollution (Ridker and Henning (1967); Myrick Freeman Iii (1974); Davis (2011)). Roth and Ambs (2004) investigate the external costs of different types of power plants. They find coal power plants to have the highest external costs due to pollution and other environmental factors, followed by gas and combined cycle power plants. Biomass appears to have only little external costs in spite of its combustion driven method of electricity production. These external costs include healthcare costs due to pollution, the height of the external costs is resembled by the rate of worry found in the Burger (2012),research.

It is likely that residential prices resemble the fear of a disaster in a nearby power plant. Research into this factor has been primarily focussed on nuclear power plants. A much studied area is the three mile island in the United States. In 1979 the worst nuclear accident to date in the United states took place on three mile island, studies have investigated residential values before and after the accident. Gamble and Downing (1982) show no significant relationship between the accident and the residential values of properties near the TMI plants or other nuclear plants in the region. A later research that tried to resemble the Gamble & Downing (1982) research after the Fukushima disaster, did find a negative effect on the properties near the TMI nuclear plant (Boes, Nüesch, & Wüthrich, 2014). This indicates that the severity of nuclear power plant accident, wherever it takes place, has the largest effect on residential values near nuclear power plants. The effect is thus influenced by the visualization of the disaster and the salience of the accident.

The negative local effects of power plants are mainly due to pollution according to available research, therefore coal plants should have the highest negative effect. Disaster potential is a factor, but only research for nuclear power plants is available and this indicates a time relation with salient disasters.

3.6. Earlier research of local externalities

The opposition to wind turbines has created a perception of decreased residential value in areas close to wind turbines. The recent activism due to construction of wind turbines has brought forward a body of literature has been created that investigates the lost residential value in these areas. Up until recently these researches were highly geographically focussed, Davis (2011) Droës & Koster (2014) and Gibbons (2014) were among the first to provide a country-wide analysis. The size of the transaction dataset might prove to be just as important as the number of variables it describes. Factors that influence residential values are numerous, geographic characteristics, to housing characteristics, demographics and temporal covariates. A regression analysis on such a large body of dependent variables is unlikely to provide stable results unless the number of observations is large enough.

Similar reasoning holds for the local externalities of power plants. Research into the local effects of power plants originated in the 1970's, even so the research has focussed on single or multiple power plants, not on country-wide effects. A conclusion on the effects of power plants or wind turbines that can be generalised for the entire country is therefore impossible. The lack of geographic diversity within these researches is a probable explanation for the differences observed in the measured effects in the researches that were analysed.

Table 2: Measured effects by previous researches.

Research	Geographic location	Observed effect	Specifics
Gibbons (2014)	England & Wales	5% - 6% <2 kilometres	Wind turbines, no housing characteristics, homes with a wind farm view.
Davis (2011)	USA	5% - 7% <2 miles	Power plants, housing characteristics and demographics.
Gamble and Downing (1982)	North-eastern USA	Not-sig. 0 – 5 miles	4 nuclear plants, housing characteristics
Clark, Michelbrink, Allison, and Metz (1997)	California, USA	Positive < 23 miles	2 nuclear plants, housing characteristics, demographics
Heintzelman and Tuttle (2012)	Northern New York State, USA	2% - 16% <3 miles	Wind farms, housing characteristics demographics
Hoen (2014)	9 states, USA	2.4%, not-sig. < 1mile	Wind turbines, housing characteristics
Lang and Opaluch (2013)	Rhode Island, USA	5% <0.5 miles	Wind turbines, housing characteristics, neighbourhood effect
Carter (2011)	Lee county, Illinois, USA	Not-sig. <3 miles	Wind farm, housing characteristics
Sims, Dent, and Oskrochi (2008)	Cornwall, UK	Not-sig. <0.5 miles	Wind turbines, view effects, housing characteristics
Dröes and Koster (2014)	Netherlands	1.4% – 2.4% <2 kilometres	Wind turbines, view effects, housing characteristics
Blomquist (1974)	Winnetka, Illinois, USA	Value decreases by 0.9% per 500 feet <2 miles	Combi power plant, housing characteristics

Table 2 provides a basic understanding of the body of research accumulated. The number of variables included and the number of observations included in these researches differs greatly. The most remarkable result is the positive effect of two Californian nuclear plants on residential values within 23 miles. The difference in these results is an indication of the importance of the chosen explanatory variables. A clear relation between type of electricity generating facility and the effect on local residential value cannot be established from these studies.

3.7 Conclusion of the qualitative research

The analysis of the Dutch energy market as well as the policies indicate an approaching change in the energy landscape in the Netherlands. This changing landscape provides urgency for a research that quantifies the impact of previous policy decision, in order to make more optimal decisions for future policy. Furthermore, the qualitative analysis of the Dutch electricity market and policies provides a framework in which the quantitative analysis is set. This allows future research to compare the results of the quantitative research with the results prevailing in their time and location. Without this background would not be as usable for future research.

The need for context is exemplified by Roth & Ambs (2004). Without context such research would not be able to construct a model that estimates the levelised costs of electricity production. This brings forth the academic motivation of this quantitative analysis, to contribute to the existing literature in order to make a more comprehensive estimation of the total costs per energy source.

Previous research has indicated the resistance to wind turbines to originate from perceived unfairness, decrease in landscape beauty, and actual health complaints. In order to make the results as representative as possible for the actual effects, the three prevailing factors need to be controlled for. The number of wind turbines in the vicinity will provide an indication for the unfairness. Decrease in landscape beauty will be captured by the surroundings variables in the dataset. The health complaints are a result of proximity and are thus captured by the distance to the nearest wind turbine.

For power plants research has found pollution to be the main driver, the quantitative research will make a distinction between the different types of power plants. This investigation of the heterogeneity of the power plant sample could provide additional insights into the factors that drive the local external costs.

4. Quantitative analysis

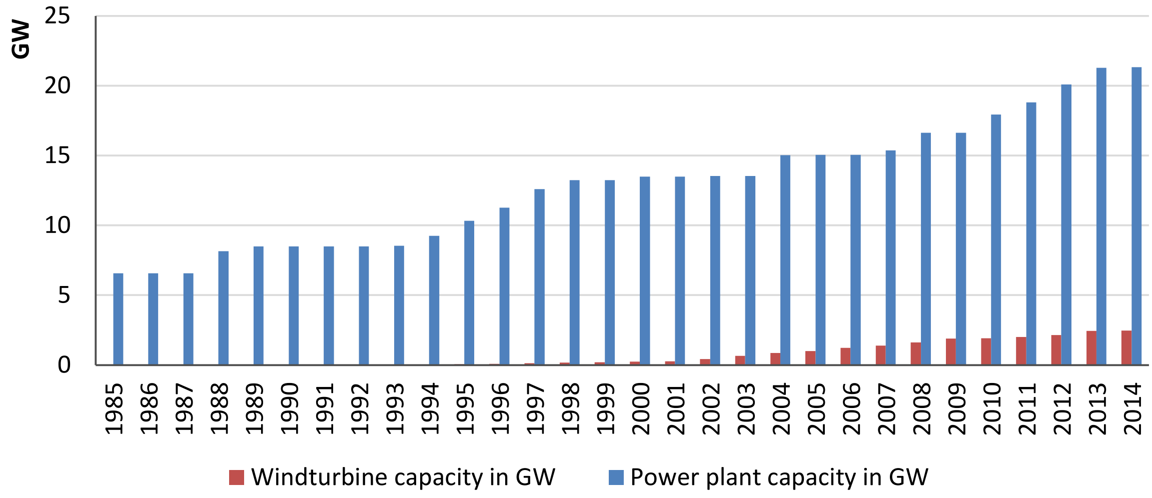
The aim of this paper is to find the average value reduction in local residential value for each type of electricity generating source, per megawatt of electricity in capacity. The actual megawatt hours of electricity produced by these facilities is dependent on multiple factors such as weather conditions, power demand from a particular facility, type of fuel used by the plant. Accordingly, the actual yearly production of a wind turbine will too be dependent on its location to generalize the results for the entire country.

4.1. Data

The data for this research is extracted from three data sets. For the location and production capacity of wind turbines the data was accumulated per wind turbine from Windstats Bosch & van Rijn. The location and production parameters for conventional power plants were in large part provided by the Energieonderzoek Centrum Nederland (ECN). Finally, for the actual residential values the data on house transactions accumulated by the Nederlandse Vereniging van Makelaars (NVM) was used.

The combined dataset has information on wind turbines and power plants operational in 2013. Older power plants that were operational during the investigated period of 1985 to 2013, but have been retired before 2013, are not included. Unfortunately no data could be found on these retired power plants and wind turbines. The effect of retired wind turbines is likely to be minimal. Wind turbines have a life cycle of at least 20 years (Keith, 2012). Since construction only started on a larger scale in 1995, almost all wind turbines have yet to come to the end of their life cycle. The relative number of power plants missing due to retirement is likely to be larger than for wind turbines. Retired power plants are unlikely to corrupt the results on the overall effect power plants have on local house prices. Unless the retired power plants are very much different, in their nearby pollution or the imminent threat of disaster in the vicinity, from the still active power plants, the results are unlikely to effected much. However missing the retired plants does make the analysis less rich, and a complete dataset would be an improvement. Figure 4, visualizes the increase in wind capacity and the continuous addition of new power plants to the total production capacity.

Figure 4: Capacity in gigawatt for wind turbines & power plants.



Source: Windstats (2014) and ECN (2014)

4.1.1. Wind turbines

The first dataset contains the wind turbines build onshore between 1982 and 2014 and is obtained from Windstats Bosch & van Rijn. Offshore wind turbines are not included in this research since their costs differentiates them from onshore wind turbines. Since the datasets of offshore wind turbines contains less than 100 wind turbines in 2014, most of those are well outside a five kilometre zone of any residential property (Dröes & Koster, 2014), including offshore wind turbines as a new category is not worthwhile. The dataset of onshore wind turbines gives us the exact location of the wind turbine in geographic coordinates as decimal degrees. Furthermore the dataset contains information on the axis height in meters, diameter of the rotor blades in meters, the production capacity in kilowatt, the manufacturer, year of construction and the current operator of the wind turbine. For the purpose of this research the exact location, capacity, axis height and diameter of the rotor blades are essential. The information on manufacturer and current operator is not used for this analysis.

The dataset as constructed contains information on 1,836 wind turbines constructed between 1982 and 2014. Table 3 contains the descriptive statistics on all the wind turbines in the dataset. The least powerful wind turbine has a capacity of 15 kilowatt whilst the most powerful wind turbine in the Netherlands, the "Ambtenaar" has a capacity of 7500 kilowatt. The average capacity is just over 1.3 megawatt, combined all the onshore wind turbines in the dataset have a capacity of nearly 2.5 gigawatt. The average wind turbine in the dataset is 11 years of age, which is roughly halfway through a typical lifetime for a wind turbine (Joskow, 2011). One wind turbine in the dataset has no given axis height, for three wind turbines the diameter of the rotor blades is missing. On average the height and diameter of rotor blades are 61 and 58 meters respectively.

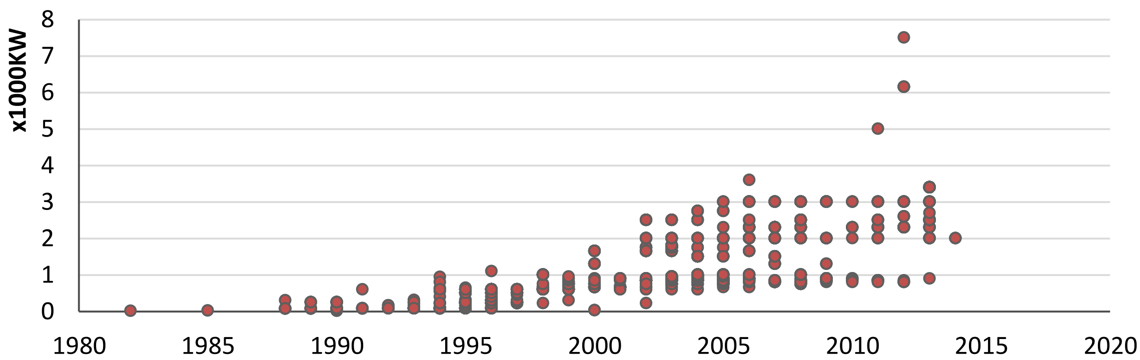
Table 3: Descriptive statistics wind turbines

	Minimum	**Maximum**	**Mean**	**Std. Dev.**
Capacity in kilowatt	15	7500	1337	980
Year of construction	1982	2014	2003	6
Axis height in meters	0	135	61	21
Diameter rotor blades in meters	0	127	58	23

Source: Windstats (2014)

Wind turbines constructed today differ from the wind turbines constructed in 1982. The most noticeable trend is the trend towards larger, high capacity wind turbines. Figure 5 captures this relation, 1996 was the first year that saw a wind turbine with a capacity over 1 megawatt constructed. In perspective, 2013 saw the construction of 1 turbine with a 0.9 megawatt capacity, all of the other 105 turbines built this year had a capacity of at least 2 megawatt.

Figure 5: Distribution of wind turbine power output by year of construction.



Source: Windstats (2014)

The geographical location of the wind turbines within the Netherlands is dependent on average wind speeds as well as factors identified in the qualitative section of this paper, such as policies and nimbyism. For the interaction with the dataset of housing transaction the geographical location is essential. Not all provinces in the Netherlands have an identical population density, therefore it is likely that the number of transactions observed differs greatly between provinces. Table A.1, appears to show a negative relationship between the number of wind turbines installed in a province and the population of a province. Although the table does not contain any data on population, the least populated provinces in the Netherlands are Zeeland, Flevoland, Drenthe, Groningen, Friesland, from least populated to most populated. These five provinces account for two thirds of all wind turbines installed in the Netherlands. The exact geographical location is visualized in figure 6, combined with the geographical locations of the power plants of the second dataset.

Figure 6: Distribution of wind turbines and power plants in dataset.

4.1.2. *Power plants*

The second dataset used consist of all major power plants operational in the Netherlands January 1st 2014. The core of this dataset is formed by the major power plants identified in the report by the ECN & SEO (Sijm et al. 2014). This report only contained data on power plants fuelled by fossil fuels and wind parks. Therefore further desk research was done in order to identify sites of biomass plants and hydro-electric plants. Furthermore for the conventional power plants in the ECN & SEO report, exact locations and year of construction were still needed to construct a spatial relation between the transaction prices dataset and this dataset.

The desk research has also led to an identification of the visual intrusiveness of these power plants. The power plants received a ranking from 1 to 5 on both the visibility of the main structure as well as the stack(s). Images of the specific power plants were used by the author in order to construct these ratings, the quality of these ratings is therefore questionable.

The dataset consists of 50 power plants spread throughout the Netherlands. The descriptive statistics can be found in table 4. The smallest in capacity has a maximum capacity of 0.1 megawatt, the most powerful plant has a capacity of 2,445 megawatt. The mean capacity of the power plants is 427 megawatt.

Table 4: Descriptive statistics of power plants

	N	Minimum	Maximum	Mean	Std. Dev.
KW	50	100	2,445,000	426,518	481,806
Year	50	1906	2014	1991	18

Source: ECN (2014)

For this research I have identified 6 different types of power plants, Davis (2011) found different effects for different types of power plants. It is important to state that many more categories could be identified and that most modern power plants are able to run on more than one type of fuel. All of the 5 plants identified as “Combi”, are able to run on coal (Sijm et al. 2014). Four of these “Combi” facilities are able to run on biomass as a fuel. For the purpose of investigating the heterogeneity of the power plant sample we have categorised the “combi” plants as coal plants. One power plant was categorized as waste facility, due to the nature of the processes the characteristics of the plant, it has been re-categorised as a biomass facility. One facility had been categorised as Hoogovengas, which indicates that this plant is fuelled on a gas by-product produced by the steel mills of IJmuiden. This plant has been re-categorised as gas. Furthermore there are multiple locations in the dataset where the current plant has expanded. Although these extensions might be able to operate as stand-alone plants, their output was added to the output of the original plant and the extensions were eliminated from the database. The logic behind this decision will be further explained in the section 4.3.4 on the spatial relation.

Table 5: Descriptive statistics power plants per type

Type	Number	Percentage	Capacity kw	Percentage of capacity
Biomass	7	14%	1,046,800	5%
Coal	1	2%	1,065,000	5%
Combi	5	10%	3,313,000	16%
Gas	30	60%	15,123,000	72%
Nuclear	1	2%	485,000	2%
Hydro	6	12%	37,100	0%
Total	**50**		**21,069,900**	

Source: ECN (2014)

Gas is clearly the most important fuel for producing electricity in the Netherlands. Figure 1 already identified gas as the most used fuel, table 5 confirms this since 60% of power plants run on gas and those account for 72% of power plant capacity installed in the dataset. Hydro power is, with 12% of the number of power plants, an important category. However, it contributes only 37 megawatt, less than 0.5% of total capacity. Table 5 is misleading towards the importance of coal in the Dutch energy market. As mentioned earlier, modern coal plants can run on both coal and biomass, these plants are therefore categorised as “Combi”, but mostly run on coal. The descriptive statics in table 5 do indicate that producing results which can be generalised might be difficult for the categories coal and nuclear, due to the single observations in both categories.

Since the production output of power plants is not influenced by weather, but there is cost of transportation per kilometre, it is to be expected that power plants are located closer to the most populated areas in the Netherlands than wind turbines. Table 5 confirms this expectation. Although more evenly distributed over the country than wind turbines, almost half of all power plants is located in the three Randstad provinces; Noord-Holland, Zuid-Holland and Utrecht. Drenthe is the only province in the Netherlands for which the dataset does not contain a power plant. The figure 6 map, indicates that a number of power plants is located near or in populous areas such as Utrecht, Den Haag and Leiden. This complicates the analysis since in urban areas intangible characteristics of neighbourhoods are likely to significantly influence house prices. This will be further discussed in the section 4.1.3 on the transactions dataset.

4.1.3. Transaction database

The third dataset contains housing transactions in the Netherlands between 1985 and 2013, accumulated by the "Nederlandse Vereniging voor Makelaars" (NVM). This dataset does not only contain transaction prices for all regions of the Netherlands for 28 years, it is also very detailed. All the nearly 3 million transactions in the dataset have over 40 characteristics, which makes the dataset rich and very usable for a hedonic price analysis. The dataset categorises 27 different types of houses. The NVM has accumulated housing attributes on each of these transactions, such as size of plot, maintenance level, parking space etcetera. Furthermore, the dataset provides the time horizon from first listing to actual transaction, as well as original asking prices and final transaction prices.

4.1.3.1. Selection of variables

In order to prepare the dataset for analysis, some variables were excluded. Table A.2 contains an overview of the data selection process. Before selection the database contained roughly 2.9 million transactions, after the selection process it contained roughly 2.5 million transactions. The first group of cases to be excluded were those without a province or city, which excluded 3,531 cases from the dataset. The second selection criterion was integer house numbers larger than zero. Without a number the exact location of the house could not have been determined. This second criterion excluded almost 45,000 transactions from the dataset. The third of these criteria was the size of the actual houses in square meters, which excluded the highest number of cases. Since only houses, not building plots were to be included, all houses needed to be at least 25 meters squared. This requirement mostly excluded houses with a square meter value of 0, in total 356,168 transactions were excluded due to this requirement. The fourth requirement exclude outliers with a transaction price outside a range of €10,000 to €2,500,000. This requirement excluded 3,586 cases form the dataset or less than 0.2% of the total number of cases in the database. For the final requirement cases needed to obtain a valid geographical decimal degree coordinate for longitude and latitude. Without a geographical decimal degree coordinate, no spatial relation could be made between the power generating facilities and the transaction location. This final requirement excluded 19,120 cases from the dataset. In total roughly 425,000 cases were excluded, resulting in a database of nearly 2.5 million transactions.

Although there is a considerable amount of transactions for each of the 12 provinces, the transactions are not evenly distributed. The three Randstad provinces of Noord-Holland, Zuid-Holland and Utrecht account for 50% of all transactions in the database. Zeeland has the least amount of transactions, only 36,654 transactions were registered in this province between 1985 and 2013. When comparing these frequencies with the five provinces with the highest number of wind turbines, Flevoland, Friesland, Groningen, Noord-Holland and Zeeland, these are, with the exception of Noord-Holland, also among the 6 provinces with the least amount of transactions. Interestingly Limburg has only 68,500 valid transactions in this database, although it has a population similar to Overijssel and Utrecht.

4.1.3.2. Geocoding

Spatial analysis requires a distance to be measured between the locations of transactions and the nearest treatment factor. Every transaction therefore needed a geographic decimal degree coordinate for its longitude and its latitude. A Visual Basic Application, developed by , was extended and adapted for geocoding addresses per province. The application used Bing Maps through an Application Programming Interface in order to search for the coordinates per address. Per province was checked if all found coordinates lay within the boundaries of the province. As a security check the transactions with coordinates outside the province boundaries were excluded from the dataset, as were addresses that could not be found.

There is a wide array of geographic coordinates systems to choose from, for this research the decimal degrees system was chosen. The decimal degree system is used by most applications and GPS devices for its decimal system allows for easier calculations compared to the degrees minutes and seconds system.

4.1.3.3. Distance calculation

For calculating distances between two geographic decimal degree coordinates the system of great circle distance calculation was used. The formula gives the shortest distance between two coordinates over the spherical surface of the earth. This formula does not take elevation differences into account, however in the Netherlands these effects are marginal. The formula for distance calculation is as follows (Admiralty, 1967):

$$\Delta\sigma = 2\arcsin(\sqrt{sin^2(\frac{\Delta\emptyset}{2}) + cos\emptyset_1 cos\emptyset_2 sin^2(\frac{\Delta\lambda}{2})})$$

Where the radius of the earth is calculated by:

$$R_{1=\frac{1}{3}(2a+b)}$$

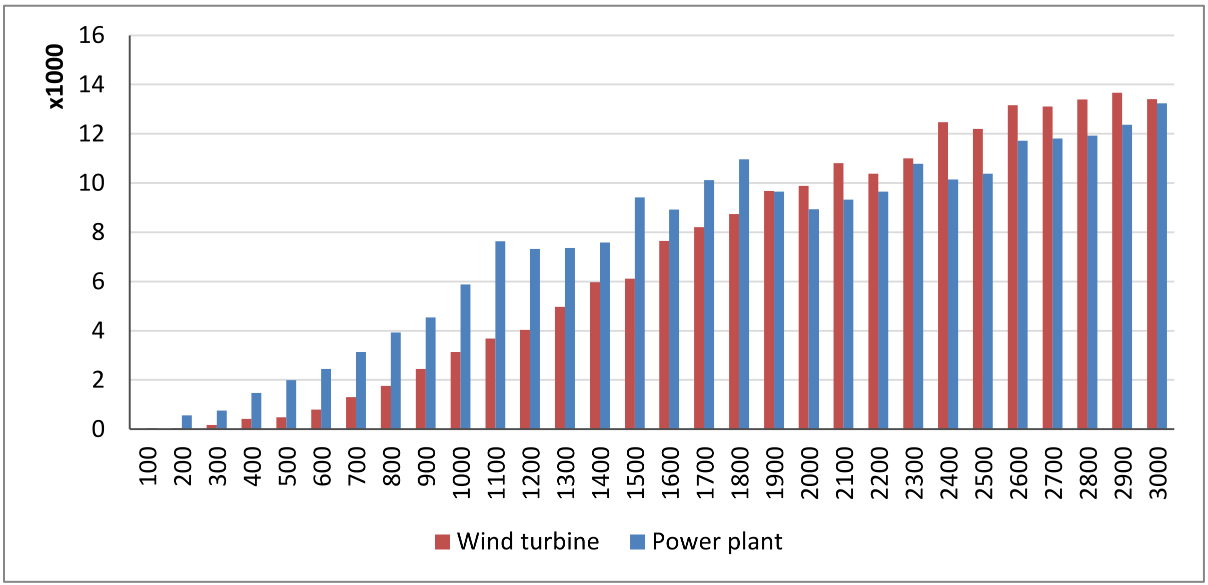
Where a is the earths radius at the equator; 6378,137 and b is the distance from the centre of the earth to each pole. This calculation gives a mean radius of 6371 kilometre for the earth, which is more exact than using the equatorial radius, since the earth flattens at the poles.

The distance to the nearest electricity producing facility for each of the transactions in the NVM dataset was found by creating a vector for distances to all power plants and wind turbines for each transaction. The smallest distance in the vector would be the nearest facility, conditionally that it would be constructed before the transaction or no later than two years after the transaction. When this condition was not met, the second nearest facility was selected if it met the condition, if not the next nearest would be selected. Power plants or turbines had to be constructed before or no later than two years after the year of transaction since Droes & Koster (2014) have found these two years to be the time span in which the planning and construction for wind turbine takes place and the knowledge of the future wind turbine starts to have an effect on the residential value.

4.1.4. Combined dataset

The characteristics of the nearest wind turbine or power plant are added to the NVM dataset as additional housing characteristics per transaction. A transaction now includes all housing characteristics, information on the actual transaction and important characteristics of the wind turbine and power plant nearest to the location of the transaction. These wind turbine and power plant characteristics include the capacity, visual intrusiveness and year of construction. As can be observed in figure 7 only a few transactions are located within 500 meters of a wind turbine, in fact it is less than 0.05% of all transactions in the NVM dataset is located within 500 meters of a wind turbine, for power plants this is less than 0.2%. This increase in number of transactions given the increased distance is one that would be expected due to zoning regulations.

Figure 7: Number of transactions by distance to nearest wind turbine or power plant in meters.



For the testing of the models as will be described in the next section I have made two datasets: Two datasets with all transactions within 2 kilometre of a wind turbine or a power plant, a dataset for transactions that took place within 3 kilometres of a wind turbine or a power plant were created, and for both these datasets a control dataset in which the treated transactions were excluded.

The descriptive statistics can provide insights in how houses that are close to wind turbines and power plant are different than the average house in the rest of the Netherlands which is not treated by the construction of a wind turbine or power plant nearby. Furthermore, the data can provide insight in how to improve the models. In the regressions analyses performed in the results section of this paper, the models could gain explanatory strength by excluding highly correlated explanatory variables, or insignificant variables. Gaining insight in the values of these variables is likely to aid this process (Tse, 2002).

The transaction price is the dependent variable in later models. Table A.3 shows that the average transaction price for houses located near wind turbines is actually higher than the average in the not effected group, €203,899 versus €195,514. This effect is opposite of what theory would predict. A possible explanation lies in the characteristics of the houses in both groups. Consistent characteristics could be larger, thus more expensive houses in rural areas, such as near wind turbines. Such a consistent characteristic could explain such an effect. The mean distance to the nearest wind turbine in the treatment group of 1.48 kilometres confirms the data of figure 4, the distance of the treatment group are skewed towards the 2 kilometres rather than the 0 kilometres. A possible explanation could be that transactions near windmills have a later average year of sale than the other, 2005 versus 2002. Dröes and Koster (2014), found an effect by wind turbines two years before their first operational year. Transactions are therefore considered affected by a wind turbine when they take place no later than 2 years before construction.

For other characteristics the datasets appear to be quite similar, even the variable that indicates if a property is located in the centre of a town or city is almost identical. An expected difference can be observed in the variable that describes if a property is located near water. This variable is almost twice as high for the properties located near a wind turbine. This confirms the expectation that properties near wind turbines are situated in more rural open spaces.

Transactions that took place in the vicinity of power plants have average prices which are more in line with the expectations. Table A.4 summarizes the values for transactions near power plants and accordingly its control group. The average price for a transaction near a power plant is €179,898 versus €197,855 in the control group. Houses near power plants therefore do appear to have lower value than those not affected. This again might be explained by the attributes of the houses in the dataset. The main difference in these two datasets lies in the type of houses. The transactions that have taken place near power plants more often involve apartments or flats. For example, 14% of homes near a power plant are a deck access flat versus 6% for the control group and 9% of houses sold near a power plant is a ground floor apartment versus 3% for the control group. Since these types of homes are most common in more urbanised areas, it appears that this dataset confirms the map showing power plants located in urbanized areas such as Utrecht, Leiden, The Hague and Rotterdam.

The average values in the dataset indicate substantial differences in time, location and characteristics between the transactions that were affected by wind turbines and power plants and their control groups. It also indicates a need to control for year of sale and spatial distribution, the methodology section will deal with this need. Although finding the expected results of negative relations between the houses affected by power plants and their sales price. In case of the wind turbines this negative effect does not come forth from the descriptive statistics as analysed in this part.

4.2. Methodology

The aim of this paper is to find an estimate for the total residential value lost due to the construction of wind turbines and an estimate for the total value lost due to the construction of power plants. Ultimately, the aim is to link these lost values to the capacity of electricity production that was created by the construction of these wind turbines and power plants. The size of the total lost value effect is determined by two factors: how strong is the effect and what is the size of the area in which a significant effect is observed?

As already observed, the average price of residential property in the vicinity of a wind turbine is lower than the average price of residential property in the Netherlands. The same holds for residential property in the vicinity of power plants. However, the wind turbines and power plants might not be the only variables that can explain such an effect. Wind turbines are placed in less populated areas and might therefore be priced lower in general. Furthermore, rural property might have different housing attributes. This could also be an explanation for the lower prices. Finally, the year of transaction should be controlled for, since house prices in urban areas have risen much faster than prices in rural areas in the defined period, a dataset where relatively more urban properties are sold in more recent years could also create the observed effect.

The analysis will be a 5 step approach. First, the weights of different housing attributes for the entire NVM dataset are identified. Since the marginal effect the housing attributes have on the price is of interest, the regression model is to estimate $logp_{it}$ where p is the price of property i in year t (Dröes & Koster, 2014). The housing attributes are represented by h_{it} which specifications can be found in table 9. The $\in_{it}$ captivates what cannot be explained by the model, in other words the error term. The first model which will weight all the housing attributes included have in the NVM dataset is,

(1) $logp_{it} = \delta_0 + \beta h_{it} + \in_{it}$

The second step is the inclusion of year-effects. Inclusion of these factors will reduce the bias towards larger price effects in later years that originates from the increasing house prices between 1985 and 2010. The year effect is denominated as y_t. The second model to be tested is therefore,

(2) $logp_{it} = \delta_0 + \beta h_{it} + y_t + \in_{it}$

The third step is the inclusion of the actual dummy variables for transactions that do find a wind turbine in the vicinity, w_{it}. Or in case of a power plant a dummy variable that indicates a power plant in the vicinity c_{it}. This effect will first be regressed with all transactions in the Netherlands serving as control. Where model I is the model for wind turbines and model II the model for power plants.

(3I) $logp_{it} = \alpha w_{it} + \beta h_{it} + y_t + \in_{it}$

(3II) $logp_{it} = \alpha c_{it} + \beta h_{it} + y_t + \in_{it}$

The fourth step is to address to possible location bias (Kuminoff, Parmeter, & Pope, 2010). Facilities that have a negative effect on local residential value are likely to be constructed in areas of low initial residential value (Farber, 1998). In order to address this issue the control group will no longer consist of all other transactions in the Netherlands, but the control group will consist of properties that are located in a 1 kilometre radius outside the radius w_{it}. Thus is vicinity is described as <2 kilometer to the nearest wind turbine, the control group properties will have a distance between 2 and 3 kilometers to the nearest wind turbine. For power plants the control group distance is also 1 kilometre.

(4I) $logp_{it} = \alpha w_{it} + \beta h_{it} + y_t + \in_{it}$

(4II) $logp_{it} = \alpha c_{it} + \beta h_{it} + y_t + \in_{it}$

The final step is to observe the distance effect. Since it stands to reason that the effect of a nearby wind turbine or power plant diminishes when the distance increases. This effect is captivated. Ranges of 100 meters are created from 0 meters to 3000 meters for wind turbines and form 0 to 5000 meters for power plants. This creates 30 new dummy variables z for the wind turbine dataset and 50 new dummy variables z for the power plant dataset. For each of the dummy variables the weight of the effect will be given.

(5I) $logp_{it} = \sum_d \alpha_d z w_{itd} + \beta h_{it} + y_t + \in_{it}$

(5II) $logp_{it} = \sum_d \alpha_d z c_{itd} + \beta h_{it} + y_t + \in_{it}$

The treatment group radius and the control group radius will be established by the results of model 5I & 5II. Therefore I will first go through steps 1 till 5 after which I will recalculate models 1 till 4 with the new input.

4.3. Results

The results section will follow the models and their order as put forth in the methodology section. After model 1 to 6 is analysed, the heterogeneity of the treatment effect will be further investigated. This could indicate characteristics of wind turbines and power plants that cause the effect to be under- or overweighed. Finally the results section will conclude with an effort to make the treatment effects more generalizable and implacable. An estimation is made for the total residential value lost per kilowatt of electricity in capacity.

4.3.1 Housing characteristics (model 1 & 2)

Model one is a hedonic pricing model for all transactions in the NVM dataset. A linear regression was used to estimate the coefficients. This model can aid us is finding possible improvements for future models through indicating the general importance and correlations for all variables. The models that investigate the treatment effects could gain explanatory power by excluding insignificant and highly correlated variables. Table A.5 summarizes the coefficients for all the variables and their respective significance. The regression on nearly 2.5 million transactions yields some interesting results. In order to create more usable results, the natural logarithms of the square meter of house and plot size are taken (Hoen, 2010). The most striking result is the importance of the house size. Although it is to be expected that size is important, a coefficient of 0.579 indicates that the height transaction price is highly dependent on the size of the house.

Two variables in this model do not contribute to a significant change in the transaction price when using a 5% confidence interval. An unknown year of construction of the house with a coefficient of just 0.003 with a p-value of 0.388, and the air-conditioning variable with a coefficient of -0.02 and a p-value of 0.254. Before variables are excluded in order to improve the explanatory power of the model, which currently has an R-squared of 0.654, year effects will be controlled for in order to improve the model.

Model two (table A.5) includes dummy variables for each of 29 years for which the dataset contains transactions. By including the year effects into the hedonic pricing model the predictive value rises from an R-squared of 0.654 to an R-squared of 0.843. When the year of sale is controlled for, the coefficient of the unknown construction period variable is significant. The only coefficient that does not contribute significantly to the change in the transaction price, is the coefficient for the air-conditioning. The regression has been rerun with the exclusion of this variable as well as with exclusion of variables with high correlation. However, none of these tests had an increased R-squared value and therefore exclusion of these variables does not lead to a model with higher explanatory power. It is therefore decided to include all variables in future models. The before mentioned location effect will be addressed in model 4.

4.3.2 Effect in treatment groups controlled by entire NVM dataset (model 3)

Model 3I includes a dummy variable which is activated when a transaction was located within two kilometres of a wind turbine (for model 3III, this is 3 kilometres). The linear regression provides a coefficient for this dummy variable that indicates the effect on the logPrice when a wind turbine is located within 2 kilometres in table 6. The dummy variable is not activated for every transaction in the dataset that did not have a wind turbine located within 2 kilometres. The coefficient has a value of –0,041, indicating that the transaction prices, controlled for year effects and all housing attributes, within 2 kilometres of a wind turbine are on average 4.1% lower than all other transactions observed in the Netherlands in this dataset. The coefficient of 4.1% is significantly different from zero at a 1% level.

Table 6: Coefficients model 3(I&II), dependent variable is logPrice

	3I (wind turbine <2KM)	**3II (power plant <2KM)**	**3III (wind turbine <3KM)**	**3IV (power plant <3KM)**
Wind turbine \ Power plant	-,042**	-,051**	-0,026**	-,042**
Log Plot size	,027**	,024**	0,028**	,025**
Log House size m2	,650**	,649**	0,655**	,651**
New Built	,060**	,061**	0,061**	,062**
Investment	-,032**	-,049**	-0,026*	-,051*
Listed	,176**	,175**	0,173**	,174**
Quality Garden	,020**	,020**	0,020**	,016**
Maintenance level inside	,020**	,021**	0,020**	,023**
Maintenance level outside	,026**	,026**	0,026**	,039**
Quality of isolation	,001**	,001**	0,001**	,001**
Hereditary tenure	,078**	,076**	0,085**	,077**
Period of construction (9)	Yes	Yes	Yes	Yes
Type of house (18)	Yes	Yes	Yes	Yes
Layout characteristics (14)	Yes	Yes	Yes	Yes
Heating characteristics (3)	Yes	Yes	Yes	Yes
Surroundings characteristics (9)	Yes	Yes	Yes	Yes
Year of transaction (29)	Yes	Yes	Yes	Yes
Adjusted R Square	,807	0,808	0,808	0,811
Excluded	1971-1980 Single family y2006	1971-1980 Single Family y2006	1971-1980 Single Family y2006	1971-1980 Single Family y2006
N	2.259.142	2.291.597	2.174.808	2.176.724

*** Significant at a 1% level, * Significant at a 5% level*

According to the descriptive statistics of table A.3, the average transaction price for properties located near a wind turbine where actually higher than the average transaction prices outside the 2 kilometre zone throughout the Netherlands. This result was contradictory to the expectations, due to the possible negative effect of wind turbines and the fact that wind turbines are located in rural areas where ground prices tend to be cheaper. However, it is now observed that the wind turbines do bring negative externalities when the transaction prices are controlled for all the house characteristics. Apparently the houses located near wind turbines have more positive attributes than the average non-affected house in the Netherlands. The location could still be a factor though, if wind turbines are indeed all located in less expensive rural areas, their location could explain the 0.041 negative coefficient.

The effect of power plants on transaction prices is measured in a 2 or 3 kilometre radius. Model 3II (3IV) includes a dummy variable that is activated when a transaction was within 2 (3) kilometres from one of the 50 power plants in the dataset. The established coefficient in table 9 for this variable is 0.034, indicating that a transaction that took place within 2 kilometres of a power plant had on average, when controlled for all characteristics except location, a 3.4% lower price than the transactions outside the 2 kilometre radius. This result is significantly different from zero at a 1% level. The absolute averages observed in the descriptive statistics in table A.3&A.4 already indicated lower values for properties located near power plants. When controlled for their characteristics this still holds.

Although residential prices have a negative relation with both nearby wind turbines as well as nearby power plants, power plants were expected to have a greater effect. This might be due to two factors. First, the results are not yet controlled for location, as seen in figure 6 power plants are also located in more urban areas, which might contribute to higher average nearby residential values. Wind turbines on the other hand are more located in rural areas and therefore the negative coefficient might be due to the location.

Both power plants and wind turbines show a decreasing effect when the radius increases. For both the wind turbines and the power plants the distance factor appears to have a positive relation with the measured effect.

4.3.3 Effect in treatment groups controlled for location (model 4)

The location is known to be an important factor in real estate values (DiPasquale & Wheaton, 1992). Especially since figure 6 indicates wind turbines to be located in more rural areas whilst a number of power plants is located in urban areas such as Utrecht, Leiden and The Hague. For the purpose of controlling location effects in the transaction prices, model 4I (4III) and 4II (4IV) constructed. In these two models the characteristics and the years are controlled for similar as in model 3I (3III) and 3II (3IV). However the control groups in model 4I (4III) and 4II (4IV) are not all transactions outside the set radii, but rather a 1 kilometre control radius outside the bound set as affected area. The transactions that are used as control are therefore only those located close to the affected observations.

Model 4I (4III) includes a dummy variable which is activated when a transaction was located within 2 (3) kilometres of a wind turbine and which is not activated when the transaction was located 2 to 3 (3 to 4) kilometres from a wind turbine. The coefficient in table 7 is -0.03, indicating that a transaction located within 2 kilometres from a wind turbine was on average 3% lower, controlled for housing characteristics and years, than transactions that took place in a 2 to 3 kilometre radius. This result is significant at a 1% level.

Table 7: Coefficients model 4(I&II), dependent variable is logPrice

	4I (wind turbine <2km)	**4II (power plant <2km)**	**4I (wind turbine <3km)**	**4II (power plant <3km)**
Wind turbine \ Power plant	-0,030**	-,032**	-0,031**	-,065**
Log Plot size	0,020**	,002**	0,019**	,001**
Log House size m2	0,602**	,582**	0,585**	,607**
New Built	0,055**	,074**	0,061**	,074**
Investment	-0,062*	-,164*	-0,028*	-,133*
Listed	0,126**	,156**	0,144**	,173**
Quality Garden	0,022**	,018**	0,020**	,016**
Maintenance level inside	0,023**	,032**	0,025**	,032**
Maintenance level outside	0,026**	,034**	0,030**	,034**
Quality of isolation	0,006**	-,003**	0,004**	-,001**
Hereditary tenure	0,066**	,022**	0,084**	,012**
Period of construction (9)	Yes	Yes	Yes	Yes
Type of house (18)	Yes	Yes	Yes	Yes
Layout characteristics (14)	Yes	Yes	Yes	Yes
Heating characteristics (3)	Yes	Yes	Yes	Yes
Surroundings characteristics (9)	Yes	Yes	Yes	Yes
Year of transaction (29)	Yes	Yes	Yes	Yes
Adjusted R Square	0,737	0,818	0,739	0,797
Excluded	Single family y2007	Single family y2006	Single family y2007	Single family y2006
N	203.104	205.020	331.884	334.892

*** Significant at a 1% level, * Significant at a 5% level*

The dummy variable in model 4II (4IV) is activated when the transaction was located within 2 (3) kilometres of a power plant, it is not activated when the transaction took place within 2 to 3 (3 to 4) kilometres from a power plant. The coefficient in table 7 is -0.065, a property located within 3 kilometres of a power plant therefore has on average, controlled for all housing characteristics and years, a 6.5% lower transaction price than transactions located 3 to 4 kilometres from a power plant. This result is significantly different from 0 at a 1% level.

Model 4 does not show a decreasing effect with an increasing radius for power plants. This is likely due to the fact that the control group of model 4II is a part of the treatment group of model 4IV. When this part (2 to 3 kilometres) of the treatment group has no relation to the effect on transaction price, the effect would be the real effect. In this occasion the treatment group is controlled by a group that is still affected.

The expectations raised at model 3 appear to hold. When the location is controlled for, the negative effect of power plants increases, indicating that those power plants are located in areas with an above average value, when controlled for the housing attributes. This increase in effect is strong, from 3.4% in model 3 to 6.5% in model 4. Wind turbines are located in areas with a below average value, when the housing attributes are controlled for. Since the effect of a nearby wind turbine is less strong when the location is controlled for, 4.1% in model 3 and 3% in model 4. The negative effect of a nearby power plant is thus more than twice as high as the effect of a wind turbine nearby.

A further investigation into the heterogeneity of the power plants sample is done on three subsamples; gas plants, coal plants and biomass plants. Unfortunately nuclear and hydro plants are not suitable for this analysis. However these three categories are considered conventional power plants and will therefore give an indication of the differences found within the conventional power plant sample. All three categories are regressed using a 3 kilometre radius as treatment group and a 3 to 4 kilometre radius as a control group (table 8). Confirming the study of Roth & Ambs (2004), the most polluting of the conventional power plants lead to the highest loss in value. Even though the coal plant sample consists for a large part of “combi” plants that are supposed to be less polluting than coal (Keith, 2012). Biomass has an only 0.6% effect compared to transactions in the 3 – 4 kilometre radius. This could be due to either a smaller radius affected by biomass, or a smaller effect altogether. Investigating this renewable energy source in comparison to wind turbines is an interesting line of future research.

Table 8: Coefficients model 4, specified for gas plants, coal plants, and biomass plants

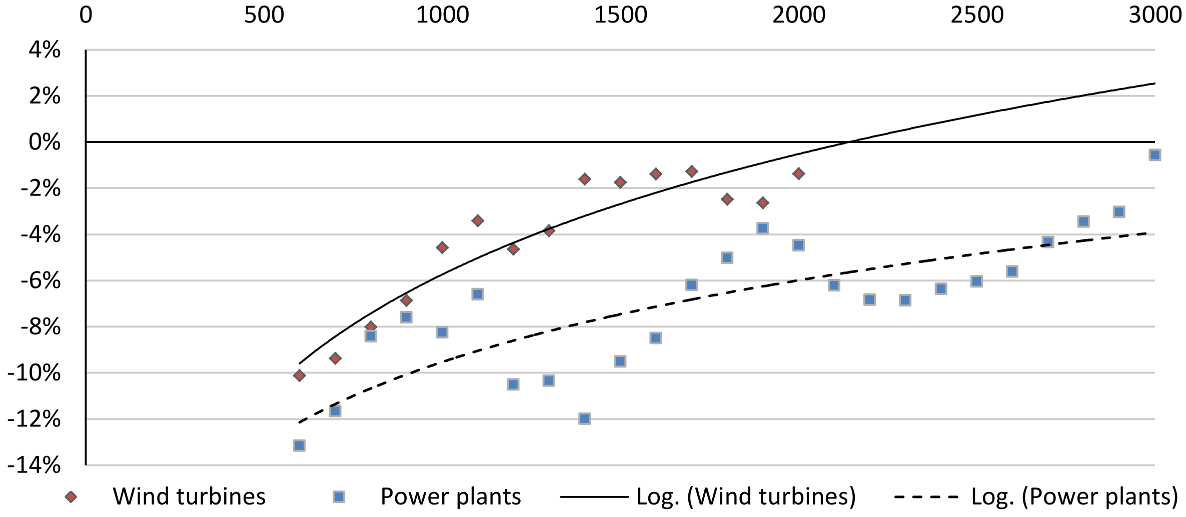
	Gas (<3km)	Coal (<3km)	Biomass (<3km)
Power plant	-,040**	-,081**	-0,006**
Log Plot size	,003**	,006**	0,057**
Log House size m2	,632**	,597**	0,690**
New Built	,080**	,026**	-
Investment	-,205*	,153*	-0,209*
Listed	,156**	,195**	0,173**
Quality Garden	,016**	,018**	0,022**
Maintenance level inside	,033**	,032**	0,018**
Maintenance level outside	,032**	,029**	0,015**
Quality of isolation	-,004**	,001**	0,012**
Hereditary tenure	,001**	,034**	0,048**
Period of construction (9)	Yes	Yes	Yes
Type of house (18)	Yes	Yes	Yes
Layout characteristics (14)	Yes	Yes	Yes
Heating characteristics (3)	Yes	Yes	Yes
Surroundings characteristics (9)	Yes	Yes	Yes
Year of transaction (29)	Yes	Yes	Yes
Adjusted R Square	,815	0,868	0,863
Excluded	1971-1980 Single family y2006	1971-1980 Single Family y2006	1971-1980 Single Family y2006
N	265.251	47.654	10.916

*** Significant at a 1% level, * Significant at a 5% level*

4.3.4. Distance effect (model 5)

It is unlikely that properties located two kilometres from a wind turbine or power plant are affected just as much as properties which are only 500 metres from such constructions. For the purpose of understanding the value that is lost due to these facilities the relation between distance and the negative effect of these facilities need to be visualised. Models 5I and 5II include dummy variables for all 100 metre steps, between 0 and 3 kilometres for wind turbines and 0 to 4 kilometres for power plants. These dummy variables are active when a transaction took place within the 100 meter radius the dummy describes. For wind turbines the 0 to 2 kilometre range is controlled by transactions between 2 and 3 kilometres of a wind turbine. For model 5II the 0 to 3 kilometre range is controlled by transactions between 3 and 4 kilometres of a power plant. Table A.6 contains the coefficients of dummy variables, the coefficients are visualised in figure 8.

Figure 8: Value effect, by distance in meters from wind turbine or power plant



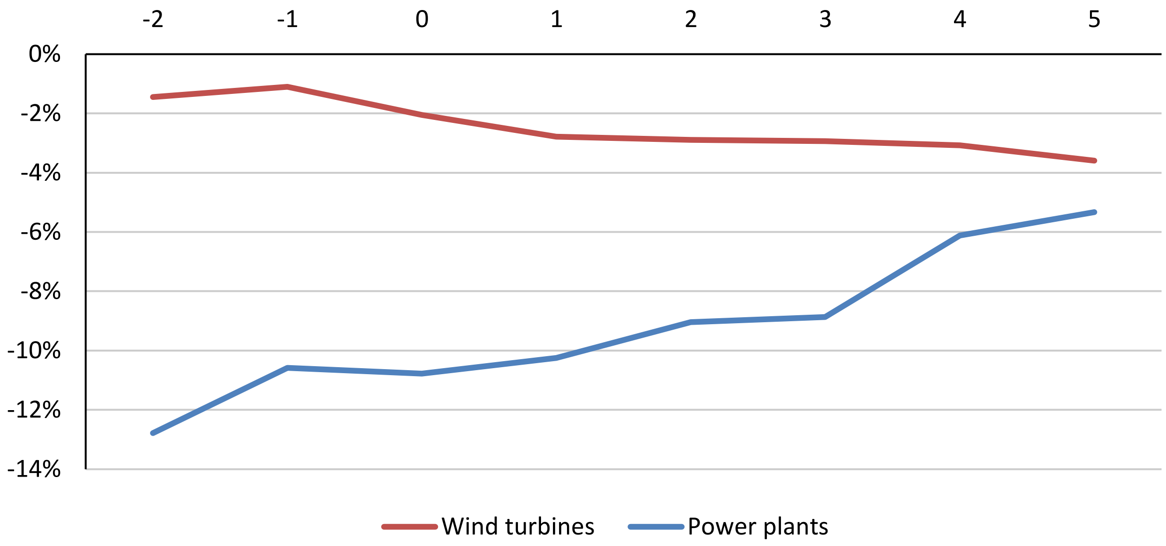
From both the figure 8 and the table A.7 is becomes apparent that the results do not follow a logarithmic line perfectly. The trend however is clear, the effect of both wind turbines as power plants becomes exponentially stronger as distance decreases. The effects below 500 meter are less reliable because of the small number of observations and high standard deviation and are therefore left out. The effect of wind turbines remains significantly different from zero at a 5% level until two kilometres. The effect of power plants on the adjacent residential values remains significantly different from zero at a 5% level until 3 kilometres.

These results were used to recalculate model 1 to 5, with the appropriate boundaries. The above mentioned results are, as mentioned, the recalculated values with the correct radii set. The results of model 5I and 5II also provides us with the opportunity to approximate the total value lost due to the construction of electricity generating facilities in our sample.

4.3.5. The effect over time

Models similar to models 5I and 5II can also be used to approximate the effect wind turbines and power plants have on the residential real estate in the vicinity over time (Dröes & Koster, 2014). The dataset allows measuring this effect from 2 years before the first operational year. Due to planning application processes and construction time of wind turbines and power plants it makes sense to assume that properties are already affected by these facilities before the first operational year. Figure 9 visualizes the effect from 2 years before first operation until 5 years after. For this analysis the treatment group of wind turbines is again set to 2 kilometres, with a control group of 2 – 3 kilometres, for power plants these radii are below 3 kilometres and 3 – 4 kilometres.

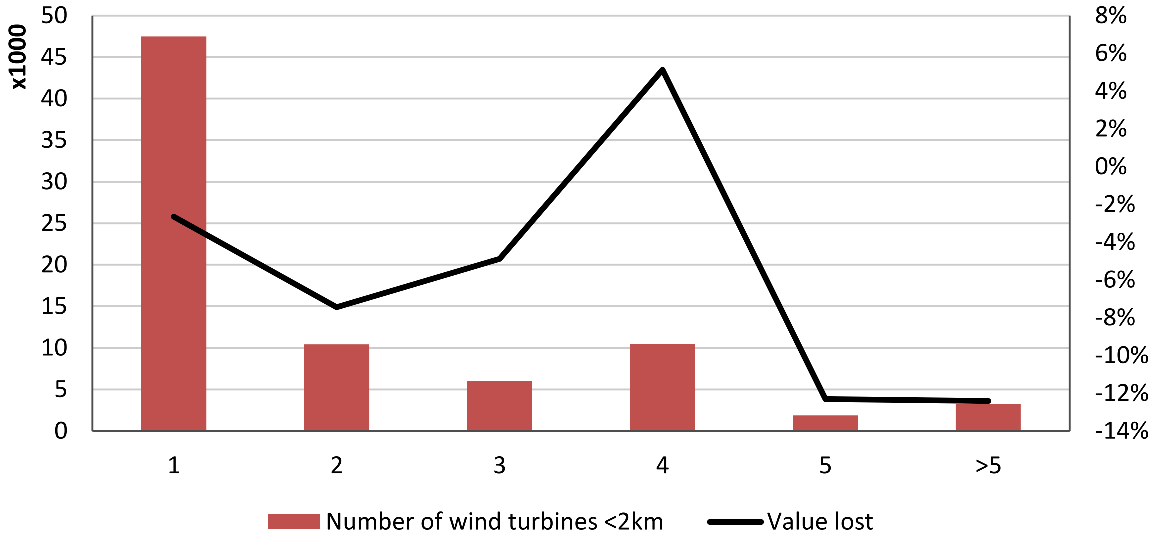
Figure 9: Value effected, by year since the wind turbine or power plant was first operational.



The effect in each year is stronger for power plants than for wind turbines, which confirms earlier results. Striking in these results is that the effect of power plants decreases over time whilst the effect of wind turbines increases. Possible explanations for this are not found in the current literature on value effects of wind turbines and power plants. A possible explanation, which is an increase in the number of wind turbines, which was tested but did not provide logical results, a further elaboration on this will follow in the limitations. Figure 9 represents the effect before and after the first wind turbine is constructed, the results could be influenced by the construction of additional wind turbines in the vicinity. Power plants are less likely to showcase such an effect, since their limited number makes construction of an additional power plant in the vicinity unlikely.

The results of tests on multiple wind turbines in the vicinity are unfortunately inconclusive. Figure 10 gives the number of transactions treated by multiple wind turbines and the effect of the number of wind turbines within 2 kilometres has on the average value. Dummy variables were created for each number of wind turbines in the vicinity, ranging from 1 to the category “over 5”. The dataset appears to have an unexplainable effect for four wind turbines located within 2 kilometres. The results therefore do not give an explanation for the decreasing effect over time.

Figure 10: Number of transactions by number of wind turbines within 2 kilometres, and the logPrice effect by number wind turbines in the vicinity.



4.3.6. Absolute comparison wind turbines and conventional power plants in the Netherlands

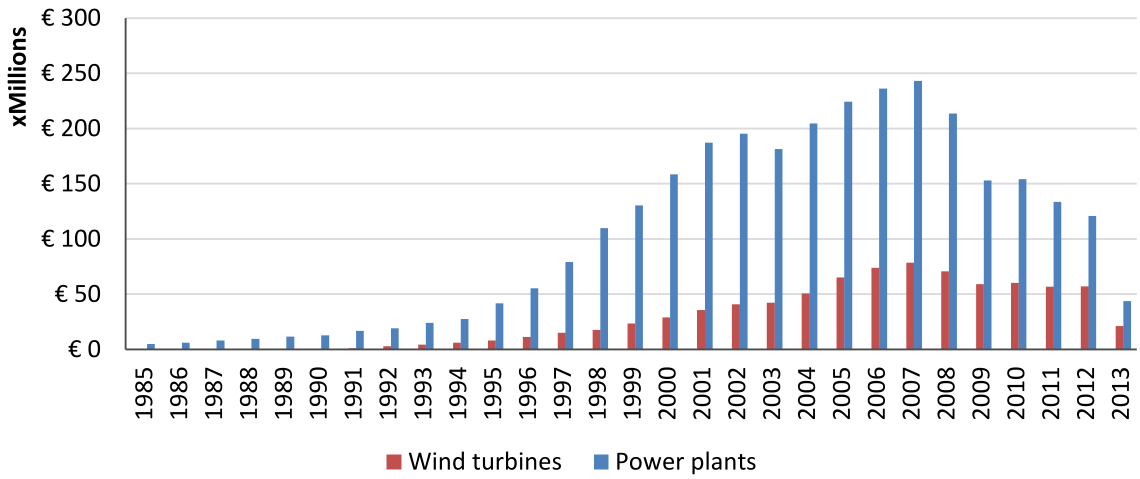
The final part in the quantitative analysis will approximate the transaction price value lost due to nearby wind turbines and power plants as well as approximate this effect per kilowatt of capacity installed. This final result should give insight in what the actual costs of producing electricity are and if the externalities of wind turbines are long overlooked costs which should be considered in the decision making process on installing new electricity generating capacity.

For the approximation of the total value lost due to the externalities, the outcomes of model 5I and 5II are used. The effect per distance radius is multiplied with the transaction price when the transaction lies within that radius category, which predicted value lost is then corrected for inflation since the year of transaction to January 1st 2014. Combined this gives the following calculation:

$$total\ value\ lost = \sum((logPrice_i * TransactionPrice_i) * inflationcorrection_t)$$

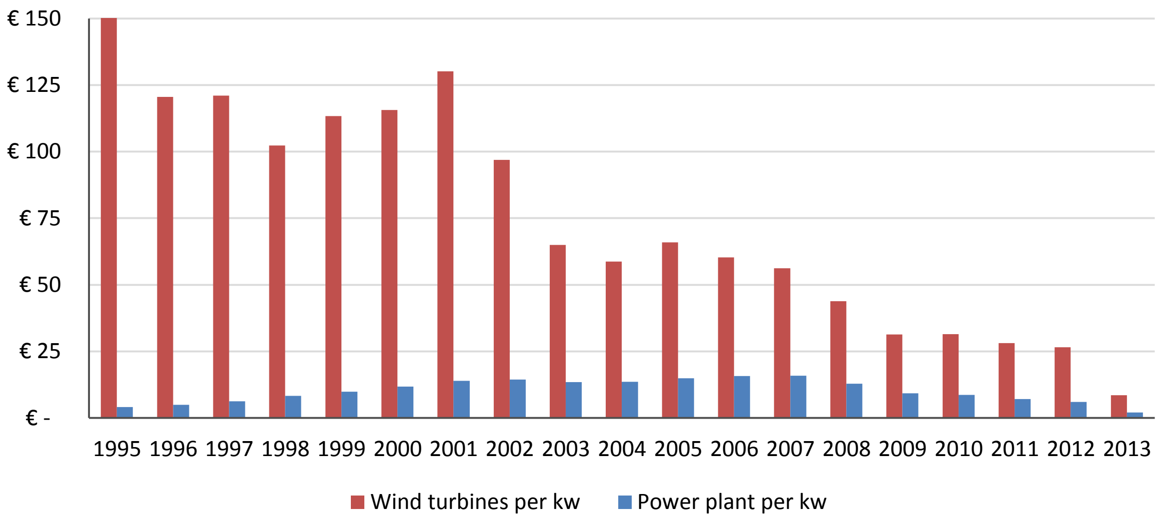
Figure 11 shows an increase in the total value lost for both power plants as wind turbines until 2007. Obviously the decline after 2007 coincides with the decline in the number of transactions due to the financial crisis. For 2013 the dataset is not complete. At its highest in 2007 the approximated value lost due to wind turbines in the vicinity was just over €78 million. For power plants the approximation comes to a maximum value in 2007 of €243 million.

Figure 11: Value lost in transactions per year due to wind turbine / power plant effect



As observed in figure 11, wind turbines only account for 5% of the installed capacity in the Netherlands. A comparison of total value lost is therefore unfair and irrelevant when guiding a decision on future electricity capacity instalment. Therefore, the total value lost from figure 10 is corrected for the total capacity in wind turbines or power plants operational in each year. Figure 12 visualizes the total effect per kilowatt produced over time. Striking is the decline in lost value per kilowatt of operational wind turbines, whilst the effect per kilowatt of power plant capacity is very stable over time. The observed time period starts in 1995 due to the limited number of wind turbines before 1995.

Figure 12: Value lost in transactions per year due to wind turbine / power plant effect, per kilowatt of capacity installed.



The decline in the relative externality costs is likely due to innovation; new wind turbines are much more powerful than earlier models. In the last fully included year, 2012, the local external costs per kilowatt of capacity had decreased to € 27 per kilowatt. Power plants at € 6 per kilowatt of capacity were still more efficient in terms of production versus local external costs. However, figure 11 does suggest a breakeven point between wind turbines and power plants is reached in the near future. Apparently their increased size does not increase the externality costs by as much as their increase in capacity. The heterogeneity of the wind turbine sample was tested in order to explain the declining relative externality costs. However no clear relation was found between height or diameter of rotor blades and externality costs, and as mentioned before also not in the number of wind turbines effecting one property. These results will be further discussed in the limitations section of this paper.

5. Limitations

Not every wind turbine in the dataset has similar characteristics. Although research has found an effect on residential value by some of these characteristics (Dröes & Koster, 2014), the results of this research provide no evidence for such conclusion. Regression analyses on both the number of wind turbines within 2 kilometres and the height and diameter of the nearest wind turbine were conducted, both were without a logical relation between the characteristics and the residential value.

Although the NVM dataset is extensive, it does not contain information on less tangible location characteristics such as the state of maintenance of the neighbourhood, the level of education in the neighbourhood and the vicinity of amenities. Inclusion of such characteristics in the model is likely to improve the model and make the explanation of the effect more robust.

Research of residential values using hedonic pricing models often find a part of the explained effect not in a direct relation with the treatment factor, but rather due to a spill over effect (Irwin, 2002). The decrease is in value of the of treated properties is in its turn effecting the value of its surrounding properties. So the effect is not direct, but in a second degree. This research does not investigate the possible spill over effects, since the ultimate goal was to find total residential value lost due to nearby electricity producing facilities. However, for an investigation into the absolute treatment effect on just one property the spill over effect should be considered.

The treatment effect is likely to be driven for a large part by visibility of the wind turbine or the power plant from the premises. Developments in geographic information systems could help to identify this factor and estimate its effect on the results of this research. On the final conclusion of this research the effect of direct view is likely to be none.

6. Conclusion

The Dutch electricity market has stagnated with regards to volume. However, due to recent policies the production side of the market will be changing rapidly. The Netherlands is one of Europe's laggards in renewable energy production, especially when compared to western European countries such as Denmark, Germany, Norway and Sweden. The "energieakkoord" has set goals that will have to be met by rigorous change. Although the focus of this Dutch energy treaty has been on increasing offshore wind energy production, due to high construction costs and the short time horizon a large part of renewables will have to be placed on land. According to recent calculations this will lead to the construction of at least an additional 4,000 megawatt of wind turbine capacity on land, almost tripling the current amount. The study into the viability of these goals takes into account the construction costs, operational costs and costs of externalities. These externalities are calculated on macro level, and therefore forgo the costs bared by local residents due to value reduction of their property. This paper therefore sets out to compare those local external costs of wind turbines with those of conventional power plants, in order for future research to include these costs into the total costs.

The first indication that electricity generating facilities have a negative effect on local residential values is the opposition that meets construction of new power plants and wind turbines. For wind turbines these negative effects are driven by health effects such as sleep deprivation, spoiled scenery, and political injustice. This indicates that this research should find the significance of the wind turbine – residential value relation with distance and the significance of the wind turbine – residential value relation with visual intrusiveness. For power plants previous research has suggested the negative residential value relation is driven by both the local pollution a power plant creates and the possibility of disaster. The power plant – residential value by distance is therefore essential to investigate, for the disaster it is essential to differentiate between different types of power plants. Previous research indicated the disaster factor to be mainly present with nuclear power plants.

The results give a clear picture of the development of local costs in the Netherlands. Over the entire dataset (1985-2013), transactions located within 2 kilometres from a wind turbine had a 3% lower value, controlled for years and housing characteristics, than the transactions located 2-3 kilometres from a wind turbine. The results also indicate a decreasing negative relation with distance. Transactions located 500 – 600 meters from a wind turbine had a 11.8% lower value, controlled for year and housing characteristics, than their 2 – 3 kilometre control group, for the 1900 – 2000 metre transactions the measured effect is 3%. For power plants similar results apply, 6.5% value reduction for a 3 kilometre treatment group with a 3 – 4 kilometre control group and a negative effect that decreases over distance. For power plants a larger radius is significant than for wind turbines. Thus an average single power plant has a higher negative effect on local residential value than a single wind turbine. However an average single wind turbine has not nearly the production capacity an average single power plant has. Per installed kilowatt of capacity the local external costs of power plants are lower than those of wind turbines, although the difference has decreased over time. The first and foremost conclusion therefore is that previous calculations of total costs of electricity production have benefitted the wind turbines. For local residential value it is better to install one large power plant than multiple wind turbines that combined have the same capacity.

Further distinction within the wind turbine and power plant datasets would provide more insights in the factors that cause the effects. Analysis of the wind turbine dataset according to height does not provide any further insights. The analysis of different types of power plants does provide significant results. Coal has the highest negative effect (-8.1%), biomass has an negative effect of only 0.6%. Biomass therefore appears to have less a negative effect on local residential values than even wind turbines.

Future increase in the number of onshore wind turbines will likely lead to difficulties distributing those over the Netherlands. Not only does this research show that the fairness argument used by wind turbine opposition is justified, it also indicates that total economic costs for wind turbines are higher than previously estimated, and also relatively higher compared to conventional power plants. Future policy regarding the distribution of wind turbines in the Netherlands should take these additional costs into account.

Appendix

Table A.1: Frequency of wind turbines and power plants per province.

	Wind turbines		Power plants	
	Frequency	Percent	Frequency	Percent
Drenthe	5	0%	0	0%
Flevoland	559	30%	2	4%
Friesland	260	14%	1	2%
Gelderland	23	1%	2	4%
Groningen	197	11%	3	6%
Limburg	7	0%	6	12%
Noord-Brabant	85	5%	5	10%
Noord-Holland	331	18%	5	10%
Overijssel	11	1%	4	8%
Utrecht	8	0%	4	8%
Zeeland	204	11%	4	8%
Zuid-Holland	146	8%	14	28%
Total	**1836**		**50**	

Source: Windstats (2014)

Table A.2: excluded cases NVM dataset

Variable	Start	House number	M2	Transaction price	Geocode	Total excluded	Total remaining
Requirement		>0	>0	>10000 <2500000	>0		
Groningen	119.697	1.586	13.073	157	1.304	16.120	103.577
Friesland	107.874	1.328	17.378	124	1.960	20.790	87.084
Drenthe	103.006	1.221	10.241	92	1.710	13.264	89.742
Overijssel	177.891	2.496	10.417	169	464	13.546	164.345
Flevoland	73.685	960	13.721	67	144	14.892	58.793
Gelderland	378.441	8.526	41.502	392	2.264	52.684	325.757
Utrecht	279.649	5.582	36.452	297	878	43.209	236.440
Noord-Holland	547.567	7.420	73.646	1.145	1.337	83.548	464.019
Zuid-Holland	641.370	8.112	109.058	645	7.035	124.850	516.520
Zeeland	38.856	319	1.710	71	102	2.202	36.654
Brabant	364.100	6.204	20.016	334	1.591	28.145	335.955
Limburg	79.054	1.176	8.954	93	331	10.554	68.500
No province	3.531				1240	3.531	
Total	**2.914.721**	**44.930**	**356.168**	**3.586**	**20.360**	**428.575**	**2.486.146**

Table A.3: Descriptives of transactions <2km of wind turbine , <2km power plant, control group >2km

	Wind turbine <2KM		**Power plant <2KM**		**Control >2KM**	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Transaction price	203.811	117.637	175.244	122.339	196.506	144.676
Distance nearest wind turbine / power plant km	1,48	0,38	1,35	0,44	18,57 / 16,21	18,24 / 11,30
Year of transaction	2005	5	2003	6	2002	7
Plot size	66.773	2.540.071	32.918	1.768.826	43.344	2.081.047
House size m2	116	41	107	43	122	45
#Rooms	,02	,14	,01	,10	,01	,11
#Kitchens	2,38	,80	2,07	,94	2,38	,84
#Floors	4,33	1,31	4,13	1,59	4,41	1,44
#Balconies	,24	,43	,15	,36	,26	,44
#Dormers	,22	,43	,38	,52	,25	,45
#Roof terraces	,00	,02	,00	,03	,00	,02
#Sculleries	,01	,09	,01	,11	,01	,08
#Toilets	,15	,37	,10	,31	,13	,34
#Bathrooms	,06	,25	,08	,29	,05	,22
Quality Garden	,66	,48	,78	,47	,78	,43
Maintenance level inside	,22	,41	,07	,26	,21	,41
Maintenance level outside	3,46	1,82	3,14	1,92	3,19	1,95
Quality of isolation	,93	,39	,88	,45	,94	,41
New built	3,36	,83	3,22	,65	3,35	,76
Attic	6,98	1,16	6,93	1,27	7,06	1,18
Investment	7,00	1,06	6,98	1,08	7,08	1,08
Listed	2,06	1,74	1,48	1,59	1,94	1,66
1500-1905	,05	,22	,09	,28	,05	,21
1906-1930	,16	,36	,25	,43	,11	,31
1931-1944	,09	,28	,15	,35	,08	,27
1945-1959	,08	,28	,07	,26	,07	,26
1960-1970	,15	,35	,07	,25	,17	,38
1971-1980	,16	,36	,11	,32	,20	,40
1981-1990	,12	,33	,13	,33	,15	,36
1991-2000	,12	,32	,09	,28	,13	,33
2001>	,08	,27	,03	,18	,04	,20
<1500 or unknown	,00	,05	,02	,13	,01	,08
Type unknown	,00	,00	,00	,00	,00	,00
Mobile home	,00	,01	,00	,00	,00	,01
Type basic	,05	,21	,05	,21	,04	,20
Houseboat	,00	,03	,00	,03	,00	,02
Holiday home	,01	,07	,00	,02	,00	,07
One family	,61	,49	,34	,47	,51	,50
Canal house	,00	,06	,00	,07	,00	,04
Manor	,06	,24	,08	,27	,10	,30
Farm house	,01	,11	,00	,05	,01	,12
Bungalow	,03	,16	,01	,09	,04	,19
Villa	,02	,16	,01	,10	,03	,18
Country house	,01	,09	,00	,04	,01	,10
Estate	,00	,01	,00	,01	,00	,01
Unknown apartment	,00	,00	,00	,00	,00	,00
Ground floor apartment	,02	,16	,11	,31	,03	,17
Upper floor apartment	,05	,21	,14	,35	,06	,23
Maisonnette	,02	,14	,03	,18	,02	,14
Flat combined entrance	,07	,25	,14	,34	,08	,27
Deck access	,05	,21	,08	,27	,06	,25
Service flat	,00	,02	,00	,01	,00	,05
Combined ground and upper floor apartment	,00	,03	,01	,11	,00	,05
Basement	,02	,15	,03	,16	,06	,24
Medical practice	,02	,15	,01	,11	,03	,16
Parking space	,05	,22	,05	,21	,05	,22
Carport/Garage	,28	,45	,13	,33	,36	,48
Gas heater	,09	,28	,13	,34	,07	,25
Central heating	,88	,33	,82	,39	,90	,30
AC/ZC	,00	,01	,00	,01	,00	,01
Countryside	,02	,14	,00	,04	,01	,12
Residential area	,59	,49	,55	,50	,47	,50
In center	,08	,28	,08	,28	,07	,26
Adjacent forest	,01	,09	,00	,07	,02	,14
Adjacent water	,10	,30	,06	,23	,05	,22
Near park	,03	,18	,03	,16	,03	,17
Views	,15	,36	,13	,34	,12	,33
Quiet road	,35	,48	,33	,47	,31	,46
Busy road	,03	,18	,05	,23	,03	,17
Hereditary tenure	,06	,24	,15	,36	,06	,23
Number of observations	79.201		112.335		2.294.292	

Table A.4: Descriptives of transactions <3km of wind turbine , <3km power plant, control group >3km

	Wind turbine <3KM		Power plant <3KM		Control >3KM	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Transaction price	209.598	125.543	178.752	124.383	196.211	146.327
Distance nearest wind turbine / power plant km	2,11	0,61	1,91	0,70	19,68 / 16,98	18,56 / 11,18
Year of transaction	2005	5	2003	6	2001	7
Plot size	53.201	2.265.249	47.911	2.206.882	41.834	2.042.784
House size m2	117	41	110	43	123	45
#Rooms	,02	,14	,01	,10	,01	,10
#Kitchens	2,38	,82	2,10	,93	2,40	,84
#Floors	4,33	1,34	4,17	1,51	4,43	1,44
#Balconies	,24	,43	,16	,37	,26	,44
#Dormers	,23	,43	,38	,52	,24	,45
#Roof terraces	,00	,02	,00	,03	,00	,02
#Sculleries	,01	,08	,01	,09	,01	,08
#Toilets	,15	,36	,11	,32	,13	,34
#Bathrooms	,07	,26	,08	,28	,05	,22
Quality Garden	,67	,48	,78	,46	,79	,43
Maintenance level inside	,20	,40	,08	,28	,22	,41
Maintenance level outside	3,49	1,83	3,18	1,91	3,17	1,96
Quality of isolation	,94	,38	,89	,44	,94	,41
New built	3,37	,82	3,24	,67	3,36	,76
Attic	7,02	1,14	6,96	1,25	7,06	1,18
Investment	7,04	1,04	7,02	1,06	7,09	1,08
Listed	2,15	1,77	1,60	1,65	1,93	1,65
1500-1905	,05	,22	,07	,26	,05	,21
1906-1930	,13	,34	,20	,40	,11	,31
1931-1944	,07	,26	,14	,35	,08	,27
1945-1959	,06	,25	,08	,27	,08	,26
1960-1970	,15	,35	,11	,31	,17	,38
1971-1980	,17	,38	,11	,31	,20	,40
1981-1990	,14	,34	,13	,34	,15	,36
1991-2000	,14	,35	,11	,31	,12	,33
2001>	,08	,27	,04	,19	,04	,20
<1500 or unknown	,00	,06	,02	,13	,01	,08
Type unknown	,00	,00	,00	,00	,00	,00
Mobile home	,00	,01	,00	,00	,00	,01
Type basic	,04	,20	,04	,19	,04	,20
Houseboat	,00	,03	,00	,03	,00	,02
Holiday home	,00	,06	,00	,02	,00	,07
One family	,58	,49	,36	,48	,51	,50
Canal house	,00	,05	,00	,06	,00	,03
Manor	,07	,25	,09	,28	,10	,30
Farm house	,01	,10	,00	,05	,02	,13
Bungalow	,03	,16	,01	,10	,04	,19
Villa	,03	,17	,01	,12	,03	,18
Country house	,01	,09	,00	,05	,01	,11
Estate	,00	,01	,00	,01	,00	,01
Unknown apartment	,00	,00	,00	,00	,00	,00
Ground floor apartment	,03	,17	,09	,29	,03	,16
Upper floor apartment	,06	,24	,12	,33	,05	,22
Maisonnette	,02	,14	,03	,18	,02	,14
Flat combined entrance	,06	,25	,14	,35	,07	,26
Deck access	,05	,22	,09	,28	,06	,24
Service flat	,00	,04	,00	,02	,00	,05
Combined ground and upper floor apartment	,00	,04	,01	,10	,00	,05
Basement	,02	,15	,03	,18	,06	,25
Medical practice	,02	,15	,01	,12	,03	,16
Parking space	,05	,22	,05	,21	,05	,22
Carport/Garage	,30	,46	,16	,36	,37	,48
Gas heater	,07	,26	,11	,31	,07	,25
Central heating	,89	,31	,85	,36	,90	,30
AC/ZC	,00	,02	,00	,01	,00	,01
Countryside	,01	,12	,00	,04	,01	,12
Residential area	,59	,49	,55	,50	,46	,50
In center	,09	,28	,08	,27	,07	,26
Adjacent forest	,01	,11	,01	,08	,02	,15
Adjacent water	,09	,29	,06	,23	,05	,21
Near park	,03	,18	,03	,17	,03	,17
Views	,14	,35	,14	,34	,12	,33
Quiet road	,36	,48	,33	,47	,30	,46
Busy road	,03	,16	,05	,21	,03	,17
Hereditary tenure	,06	,24	,16	,37	,05	,22
Number of observations	193.316		195.232		2.068.849	

Table A.5: Coefficients model 1 & 2, hedonic pricing model

N 2,486,146	(1) NL without year	(2) NL With Year
Log Plot size	,032**	,024**
Log House size m2	,576**	,647**
New Built	,164**	,061**
#Floors	-,050**	-,014**
#Rooms	,012**	,008**
Attic	,001*	-,020**
#Balconies	,057**	,048**
Investment	,062**	-,051**
Listed	,170**	,177**
#Dormers	,089**	,085**
#Roof terraces	,107**	,065**
#Kitchen	-,217**	-,011**
#Sculleries	-,013**	-,030**
#Toilets	,060**	,012**
#Bathrooms	,075**	,059**
Quality Garden	,042**	,020**
Maintenance level inside	,004**	,021**
Maintenance level outside	,012**	,027**
Quality of isolation	,001**	,001**
1500-1905	,367**	,241**
1906-1930	,252**	,154**
1931-1944	,200**	,117**
1945-1959	,188**	,094**
1960-1970	,072**	,021**
1981-1990	,119**	,069**
1991-2000	,228**	,121**
2001>	,305**	,142**
<1500 or unknown	,003	,132**
Mobile home	-,664**	-,834**
Type basic	-,159**	-,070**
Houseboat	,363**	,224**
Holiday home	-,204**	-,375**
Canal house	,193**	,240**
Manor	,078**	,149**
Farm house	,165**	,151**
Bungalow	,245**	,290**
Villa	,440**	,459**
Country house	,329**	,369**
Estate	,461**	,507**
Ground floor apartment	,250**	,181**
Upper floor apartment	,252**	,164**
Maisonnette	,143**	,063**
Flat combined entrance	,158**	,096**
Deck access	,114**	,079**
Service flat	-,269**	-,361**
Combined ground and upper floor apartment	,024**	,082**
Basement	-,115**	-,016**
Medical practice	,073**	,009**
Parking space	,064**	,051**
Carport/Garage	,085**	,098**
Gas heater	-,251**	-,115**
Central heating	-,049**	,009**
AC/ZC	-,020	-,003
Countryside	,347**	,121**
Residential area	,292**	-,040**
In centre	,352**	,018**
Adjacent forest	,264**	,078**
Adjacent water	,235**	,099**
Near park	,141**	,013**
Views	,141**	,017**
Quiet road	,162**	,015**
Busy road	,180**	-,034**
Hereditary tenure	,077**	,073**
Year of transaction (29)	No	Yes
Adjusted R square	,654	0,843
Excluded	1971-1980 Single family	y2006 1971-1980 Single family

*** Significant at a 1% level, * Significant at a 5% level*

Table A.6: Effect of wind turbines and power plants per dependent distance dummy variable

Distance in metres	Wind turbines	Power plants
100	-,020	-,245**
200	-,123**	-,085**
300	-,090**	-,096**
400	-,145**	-,023**
500	-,149**	-,068**
600	-,118**	-,132**
700	-,110**	-,117**
800	-,096**	-,084**
900	-,085**	-,076**
1000	-,062**	-,083**
1100	-,050**	-,066**
1200	-,062**	-,105**
1300	-,054**	-,103**
1400	-,032**	-,120**
1500	-,033**	-,095**
1600	-,030**	-,085**
1700	-,029**	-,062**
1800	-,041**	-,050**
1900	-,042**	-,037**
2000	-,030**	-,045**
2100	-,031**	-,062**
2200	-,040**	-,068**
2300	-,032**	-,069**
2400	-,018*	-,064**
2500	-,022**	-,060**
2600	-,011*	-,056**
2700	-,003	-,043**
2800	,002	-,035**
2900	-,004	-,030**
3000		-,006
3100		-,005
3200		,007*
3300		-,005
3400		-,000
3500		,015**
3600		-,001
3700		,000
3800		,007*
3900		,007*
4000		,006

*** Significant at a 1% level, * Significant at a 5% level*

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