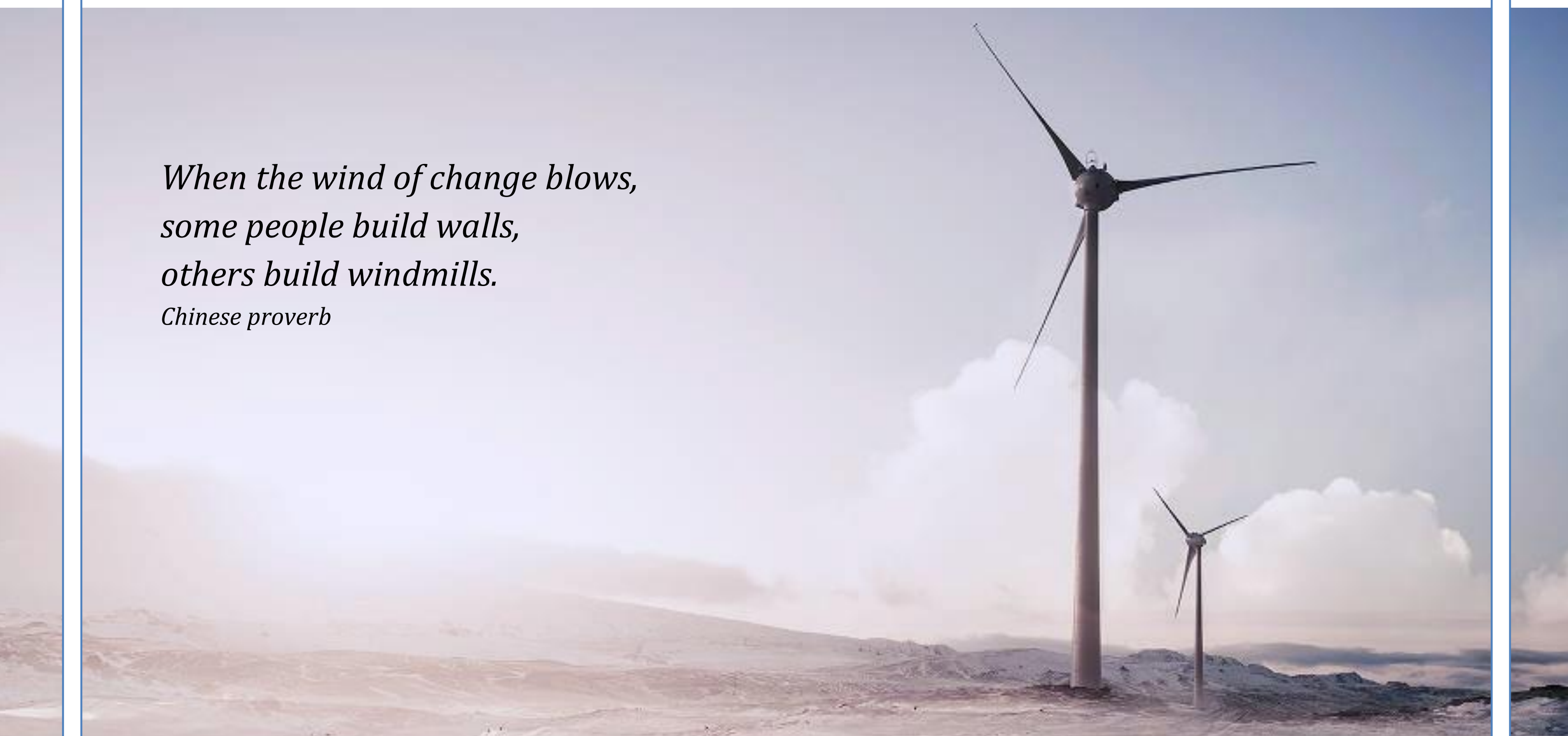
Social acceptance of wind projects in Iceland



When the wind of change blows,
some people build walls,
others build windmills.
Chinese proverb

Master thesis (M.Sc.) in Sustainable Energy Planning and Management

Department of Development and Planning

Aalborg University

Birkir Rútsson, June 2013
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Social acceptance of wind projects in Iceland

A 30 ECTS unit, Master´s thesis in Sustainable Energy Planning and Management

Department of Development and Planning

Aalborg University

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Abstract

The research presented in this thesis investigates people's perception towards wind power projects in Iceland and which means and methods could be used in order to increase contentment of such projects.

The research is carried out by designing two hypothetical wind farms where one is located in the vicinity of a tourist attraction and the other in the vicinity of a town with 6500 inhabitants. Results and data drawn from the wind farm design, and results from a literature study on the subject of social accept of wind projects and from interviews conducted with experts on that field, are used in surveys and interviews. The surveys and interviews are conducted focusing on local Icelandic people in addition to foreign people with interest in Iceland. In addition to municipal authorities and stakeholders within tourism in Iceland. An economic feasibility study of wind turbine cooperatives is also conducted.

The study reveals that people are generally positive towards wind power and harnessing it with wind turbines if certain conditions are fulfilled. That is not to place wind turbines in an unspoiled area or in an area that has natural, historical or cultural value, and preferably where they don't cause much visual interference.

Methods and means that might increase contentment are: Involve people affected by such a project in the planning process and keep them informed about the project. In some cases could establishing a cooperative be a method that increases contentment, the study shows that such a cooperative might be economically feasible. Enlighten people about wind energy and wind turbine pros and cons so myths and prejudices will not flourish. Choose location wisely in terms of visual interference and past and present use of the area where they are placed and don't overexploit it.

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Preface

The report, *Social acceptance of wind projects in Iceland*, is a final thesis of the master program Sustainable Energy Planning and Management at Aalborg University, Aalborg, Denmark. The thesis was carried out during the period 1st of February 2013 until 3rd of June 2013.

The Applied Energy output style was used to reference sources. Citations in the report are numbered with number in square bracket in accordance with appearance in the paper. A reference presented as [27] in the text is then the 27th reference. RefWorks is used for managing the references, generate citations and to create a bibliography which is at the end of the report. A reference that applies to a whole paragraph is presented after a dot, while a reference that only applies to a sentence is presented before a dot.

I wish to express my sincere thanks to the supervisors, Poul Alberg Østergaard for his patient, valuable comments and suggestions during the study and Thomas Sørensen for information and suggestions regarding wind energy planning and WindPRO.

I am deeply grateful to Margrét Arnardóttir at Landsvirkjun for all the information and time she gave me, and for cooperating with me on this thesis.

Appreciations to all the interviewees that were interviewed for the research, for their time and efforts.

Thanks to my wife for her patient and my parents in law for staying with us and take care of the home, child and dog during the last phase of the project work.

Birkir Rútsson

Table of content

List of abbreviations

AEP	Annual Energy Production
dB	The intensity of sound in decibel
DWA	Danish wind turbine owner's association
EWEA	European Wind Energy Association
IMR	Iceland Meteorological Research
IMO	Icelandic Meteorological Office
ITB	Icelandic Tourist Board
MERRA	Modern Era Retrospective-analysis for Research and Applications
MCP	Measure Correlate Predict
NPV	Net Present Value
NEA	Iceland National Energy Authority
O&M	Operation and maintenance
RE	Renewable Energy
Rk	Roughness class
SAF	Icelandic travel industry association
TSO	Transmission System Operator
ZVI	Zones of visual influences
c€	Euro cent
M€	Million Euros
øre DKK	0.01 Danish krone
Misk	Million Icelandic krone
kWh	1,000 Watt hours
MWh	1,000,000 Watt hours
GWh	1,000,000,000 Watt hours
TWh	1,000,000,000,000 Watt hours

Currency as of 25th of March 2013 [1] is used for conversions where:

- 1 EUR = 160 ISK
- 1 EUR = 1.29 USD
- 1 EUR = 7.45 DKK

1 Introduction

The introduction chapter contains description of general facts about Iceland, its location in the Atlantic Ocean and energy resources found there and a brief description of the country energy resource utilization history. The energy consumption and production is described and possible future options and limitations. The thesis purpose is described and the research question is put forward. Finally the report disposition is introduced.

Iceland's location at the confluence of the Mid-Atlantic ridge where the North American plate and Eurasian plate meets makes the country volcanic and geologically active. The country interior is uninhabitable and consists mainly of black sand deserts and lava fields, mountains and glaciers, while the inhabited coastline mostly consists of cultivated land, towns and villages except large part of the south coastline from Reykjavik to the south-east part of the country which consists largely of uninhabited deserts and lava fields in addition to farms and occasional small villages.

Iceland, which was the last country in Europe to be settled, is the second largest island in Europe and the eighteenth largest in the world; with an area of 103,000 km^2 and a population of about 321,000 of which about 202,000 lives in the Reykjavík area, [2] this makes it Europa's most sparsely populated country with about three persons for every km^2. The interior of the country is classified as highland area where the elevation reaches over 400 meters above sea level; this classification applies to roughly ¾ of the country total area. In the highlands are sand-, ash- and snow storms frequent making it uninhabitable and buildings and constructions must be especially designed and reinforced to withstand the extreme weather conditions.

Figure 1.1: Iceland (103,000 km^2) is about two and half times bigger than Denmark (43,000 km^2) and nearly the same size of England (130,000 km^2). A large share of the country is though uninhabitable due to geological- and weather conditions. (Source: Hótel Óðinsvé edited by the thesis author)

Glaciers, who are the main source of water to hydro power plants, cover 11,922 km^2 or 11.5 % of the island surface, with Vatnajökull (8300 km^2) being the largest followed by Langjökull (953 km^2) and Hofsjökull (925 km^2) in a addition to large number of smaller ones. A vast number of rivers is found in Iceland; glacier rivers are biggest in volume with the biggest one having flow of 423 m^3/sec [3]. All the biggest hydro power plants are feed with water from glacier rivers. Due to global warming and melting of the glaciers in the summertime it can be expected that most glaciers will have disappeared in two centuries [4].

The country is geologically young, in fact it has the youngest landmass in Europe and its position at the juncture between the North American and Eurasian continent means that it is highly active geologically with numbers of active volcanos and vast amount of high- and low temperature geothermal areas. Figure 1.2 shows where the rift crosses the country where the bedrock is youngest and positions of high temperature geothermic areas as red dots and low temperature as black dots. The south-west part of the country where many high temperature areas are located, have 226,881 inhabitants [2] making it the most densely populated area in Iceland with the capital Reykjavik and surrounding communities and number of villages on the Reykjanes peninsula.

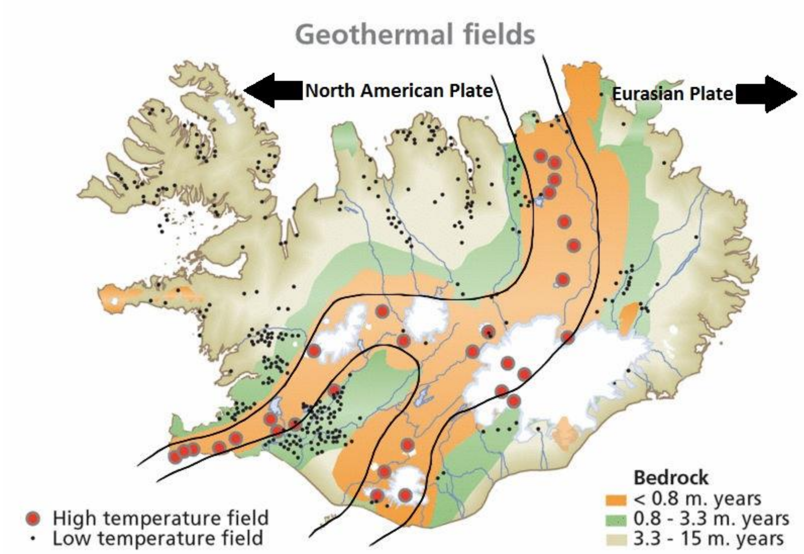

Figure 1.2: The most active geothermic areas are located where the rift crosses the country and the bedrock is youngest. [3].*The south-west part of the country is most densely populated.*

The separation of the North American and Eurasian plates causes both earthquakes and eruptions and Icelanders have learned to live with the drawbacks and enjoy the advantages of the country location and its resources caused to by the separation of the two tectonic plates. Geothermal heat has been used for decades for space heating and lately also for production of electricity in addition to vast hydro power utilization. Iceland is at the forefront in use of renewable energy which makes it one of the greenest countries in the world [5].

1.1 Outline of Iceland energy utilization history

The first utilization of natural energy resources in Iceland started around 1900 when farmers and land-owner's started harnessing small streams on their properties. The first attempts were mainly to produce electricity for lighting since other electric devices did not exist at that time. In 1921 was the first commercial hydro power plant, Elliðaárvirkjun, established in the vicinity of Reykjavik; in the beginning the installed capacity was 1032 kW but it was increased few years later to 3160 kW [6].

Figure 1.3: Iceland first commercial hydro power plant Elliðaárvirkjun in Reykjavík (picture source: Orkuveita Reykjavíkur)

Until 1969 few smaller hydro power plants were erected with the biggest one being 16 MW. The year 1969 marks a turning point in Iceland energy utilization history when Búrfellstöð, a 270 MW hydro power plant and Bjarnarflag, a 3 MW geothermal power plant which was first of it its kind in Iceland, were finished. Until then the geothermal heat had only been used for space heating but now also electricity was produced with it. Detailed data of utilization of geothermal heat doesn't exists prior to 1970 but the utilization of it increased from approximately 5000 TJ in 1970 to 18800 TJ in 2008 [7]. Biggest share of geothermal energy is used for residential heating or 45 % (year 2010) followed by electricity production with a share of 39 % (year 2010), other mentionable shares are heating of swimming pools 4 %, snow removal (melting) system 4 % and fish farming 4% [7].

The largest increase has happened in recent years with three 30 MW turbines in Nesjavellir approximately 30 km from Reykjavík, Reykjanesvirkjun 100 MW in Reykjanes peninsula and Hellisheiðarvirkjun 303 MW approximately 20 km from Reykjavík and the world's largest geothermal power plant [8,9]. Considerable critique has been on Hellisheiðarvirkjun due to earthquakes caused when waste water is reinjected into the ground and high share of hydrogen sulphide pollution in Reykjavik originated from the plant [10,11] causing damages to electric devices, [12,13] in addition there are indications that an increase in respiratory problems amongst inhabitants in the great Reykjavík area is due to the pollution from the plant [12,14]. Furthermore has the sustainability of geothermal power been seriously questioned, that the resource is finite and will eventually run out [15-17].

Figure 1.4: Hellisheiðarvirkjun is the world largest geothermal power plant with production capacity of 303 MW electricity and 133 MW thermal energy (picture source: Iceland science web)

The hydro power plant at Búrfell which was finished in 1969 was built to provide electricity to the Alcoa aluminium smelter, since then has two other aluminium smelters been established in addition to other heavy industries and in 2011, 74 % of the electric production was to the heavy industry in contrast to 42 % in 1994. This sharp increase for electricity was met with the building of three large scale hydro power plants located in south-central Iceland driven by glacier water from Þjórsá and smaller surrounding rivers.

In 2007 the construction of a controversial 690 MW hydro power plant, located in then unspoiled highland area in the north-east highlands, finished when Fljótsdalsstöð started to provide electricity to the Alcoa Fjarðarál aluminium smelter in the east fjords of Iceland. The building of the plant, which is Iceland largest, was protested heavily from the start where vast numbers of articles against the plant were written in both local and foreign newspapers. Numerous protests were organised, where some of them became violent [18] and various events held by those who want to draw attention to the fact that other industrial policy that does not cause harm to the natural environment can be profitable [19][20].

The newest addition to the Iceland power plant flora are two 900 kW wind turbines in the vicinity of Búrfell hydro power plant erected in January 2013 and Búðarhálsvirkjun, a 95 MW hydro power plant in Þjórsá river which is estimated to be operational in late 2013. These plants have not received any protests since they are located within an area where already are number of hydro power plants, in fact were environmentalists glad that the Búðarhálsvirkjun plant was constructed instead of others possibly in an unspoiled area [21].

1.2 Energy consumption and production in Iceland

Until just recently with implementation of wind power to the Iceland energy mix, the primary energy usage in Iceland has been from geothermal- and hydro power as well as imported fossil fuel such as coal and other fossil fuels. The share of domestic primary energy resources has increased significantly since 1970 from roughly 35 % to 85 % in 2011 as figure 1.5 shows.

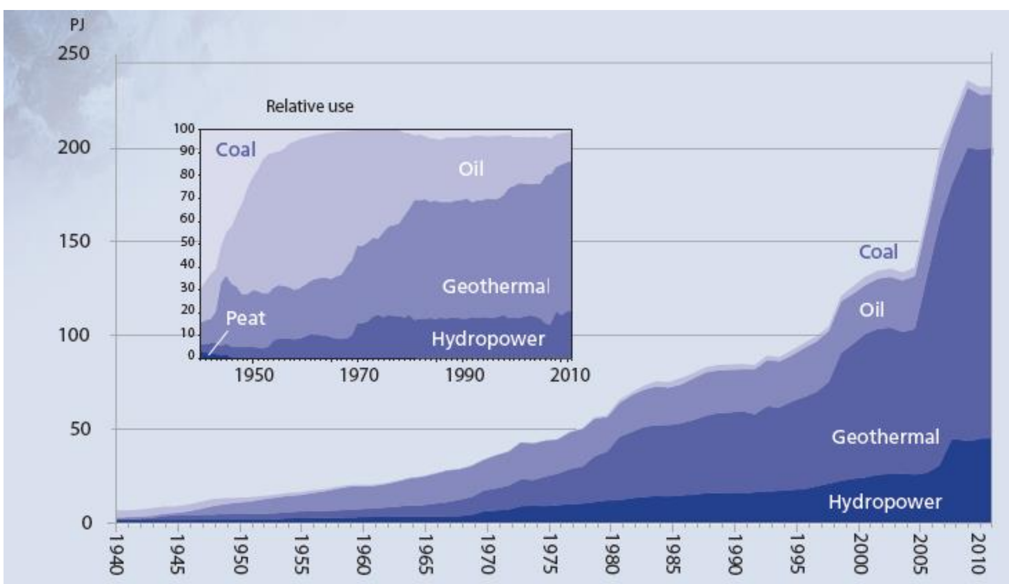

Figure 1.5. Primary energy use in Iceland from 1940 to 2010, the integrated image shows the relative use from 1940 to 2010 in per cent.[22]

In 2010 about 66 % of the primary energy usage was from geothermal resources, primarily for space heating; hydro power share was 19 %, oil 13 % and coal 2 %. The share of oil is mainly fuel for transportation and for fishing vessels but a small share of it used for electricity generators in remote islands and for emergency backup [23]. 90 % of the imported coal is used in the production of ferrosilicon and the rest for production of cement [24]. Peat was mainly used in hearth in primitive turf houses until the early 20th century when the use of it faded out as more houses got connected to the electricity grid.

From 1970 the usage of coal and other fossil fuels has steadily faded out with the increased share of geothermal- and hydro power. After the oil crises in the 1970´s there was increased pressure on the government to increase the share of domestic resources i.e. water- and geothermal resources, which led to more research and development. Iceland national energy authority, NEA, was established in 1967, its role is to advise the government on energy issues, promote energy research and administrate development and utilization of the energy resources making the institution an important actor for development and research of hydro- and geothermal resources and utilization of them [5,25].

Figure 1.6 shows the change of share of energy resources that provides electricity to the Icelandic electricity market from 1945 to 2011, the main source of electricity in 2011 comes from hydro power with a share of roughly 73 %, geothermal energy provides the rest in addition to very small share of electricity from other resources as 0.01 %. Under the 0.01 % falls diesel generators used in scarcely populated islands and as backup source in remote areas if the transmissions system fails, one 400 kW waste incinerator and a 840 kW generator that produces electricity from waste biogas [3,22].

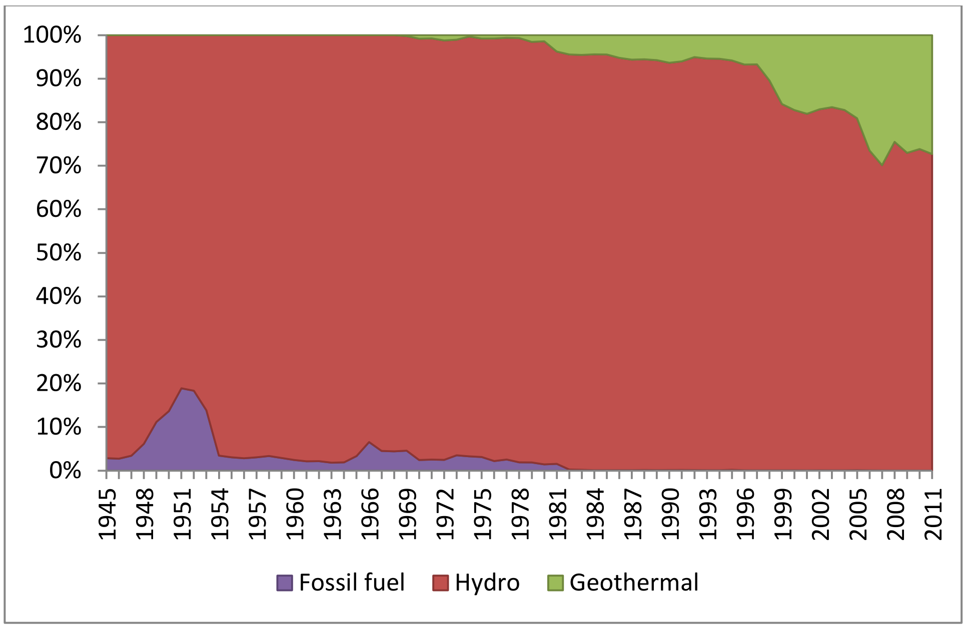

Figure 1.6: Share of harnessed energy resources for electricity production from 1945 to 2011. [23]

From figure 1.6 it can be seen that hydro power has been the chosen method for decades while the use of fossil fuel has steadily declined. Geothermal power has increased considerably in recent years by establishing number of geothermal plants, especially from 1997.

Figure 1.7 represents the production and consumption of electricity over time. It is noticeable the increase in electricity need and consumption from the heavy industry from 1997 to 2007 while other users have nearly steady consumption until 2009 when it started to decline.

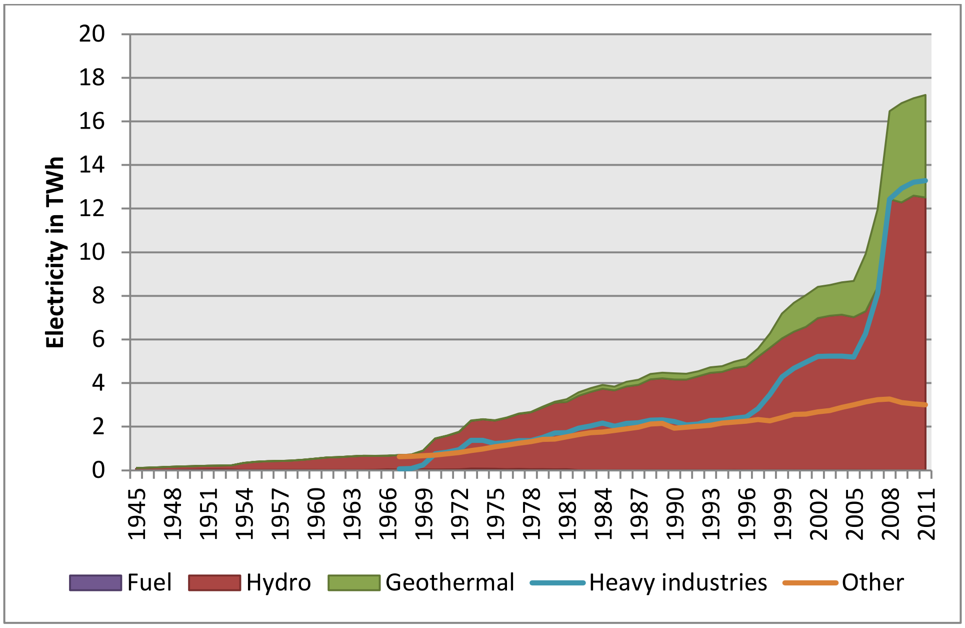

Figure 1.7: The division of energy production between fuel, hydro- and geothermal power from 1945-2011 and consumption from the heavy industry and the rest [26]. *The graph shows yearly production and consumption values, the share of fossil fuel is not visible since the production values are so low (reached highest in 1973 with 80,2 GWh produced while the total production was 2285 GWh).The total consumption is equal to total production.*

In October 2008, Iceland three largest banks went bankrupt causing total collapse in the country's economy. This caused number of other companies to also go bankrupt or to close down. The economic crisis also contributed to slight increase in electricity prices that might have contributed to more awareness in people's electricity consumption.

The production of electricity has increased by about 124 % from the year 2000, as seen on previous graph is the increase caused by growth in the heavy industry while public consumption has declined. The high share of electricity usage by the heavy industry, together with relatively few inhabitants, causes that electricity consumption per capita is with the highest in the world in Iceland or 59.3 MWh/per capita in 2011 [5].

In the year 2011 the total electricity production was 17.2 TWh where 99.99 % were from renewable resources. Iceland ranks as number thirteen amongst the European nations when it comes to amount of electricity from renewable resources where Norway is number one with 120 TWh, Spain at second with 100 TWh and France third with 82 TWh [5]. Worldwide Iceland ranks as number two in the world when it comes to share of electricity produced with renewables with only Paraguay above with 100 % usage of renewable resources.

1.3 The future, more energy intensive plants on the drawing board while there is increased emphasis on nature conservation

Iceland's national energy authority, NEA, has issued a prediction on how much the need for electricity will grow in upcoming years. Latest prediction issued in 2011 describes how the need will increase until 2050 only taking into account that no more energy intensive plants will be erected, causing the mean consumption to increase by 1.7 % per year for the next 39 years; the growth is shown in figure 1.8 on next page.

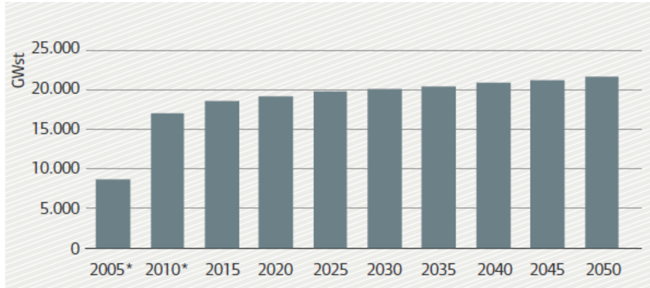

Figure 1.8: Electricity requirement prediction from Iceland national energy authority issued in 2011 to 2050 [5]

However the Iceland national parliament Althingi approved on the 28th of March 2013 the building of a Silicon-sheet metal factory in the north-east corner of Iceland, which when finished requires 104 MW of power or 915 GWh of electricity pr. year. To provide the electricity a new geothermal power plant or plants are planned to be established in the vicinity of the factory [27,28], plants that according to recent survey a majority of the Icelandic people are against [29]. In addition a new aluminium smelter is on the construction stage at Reykjanes peninsula even though all licenses haven't been acquired and agreements for providing energy haven't been signed and issues regarding supplying the smelter with electricity haven't been solved [30]. It is therefore likely that the need for electricity will be higher than NEA estimated in 2011 causing that more power plants need to be constructed.

In 1999, work began on a master plan for conservation and exploitation of natural resources with emphasis on hydro and geothermal resources, the main objective of the framework is that decisions on energy utilization will be taken on the basis of professional comparison and research on usefulness of the areas where energy is available on, with respect to nature preservation, recreation and tourism. The resources were categorized according to energy efficiency, economic feasibility and possible environmental impacts. Final results were published in July 2011 and the hearing process was finished in November same year with about 200 comments and opinions registered. [31]

The master plan sort's possible harnessed resources into three categories, utilization class, pending class and preservation class, lately in the political turbulence undergoing in Iceland it has been pointed out that the categorization of resources has nothing to do with professional evaluation but more of political issues with no regard to environmental impacts [5]. The master plan has limited considerably, possible hydro and geothermal resources that otherwise might be feasible for harnessing. Figure 1.9 on next page shows which resource areas are in which category.

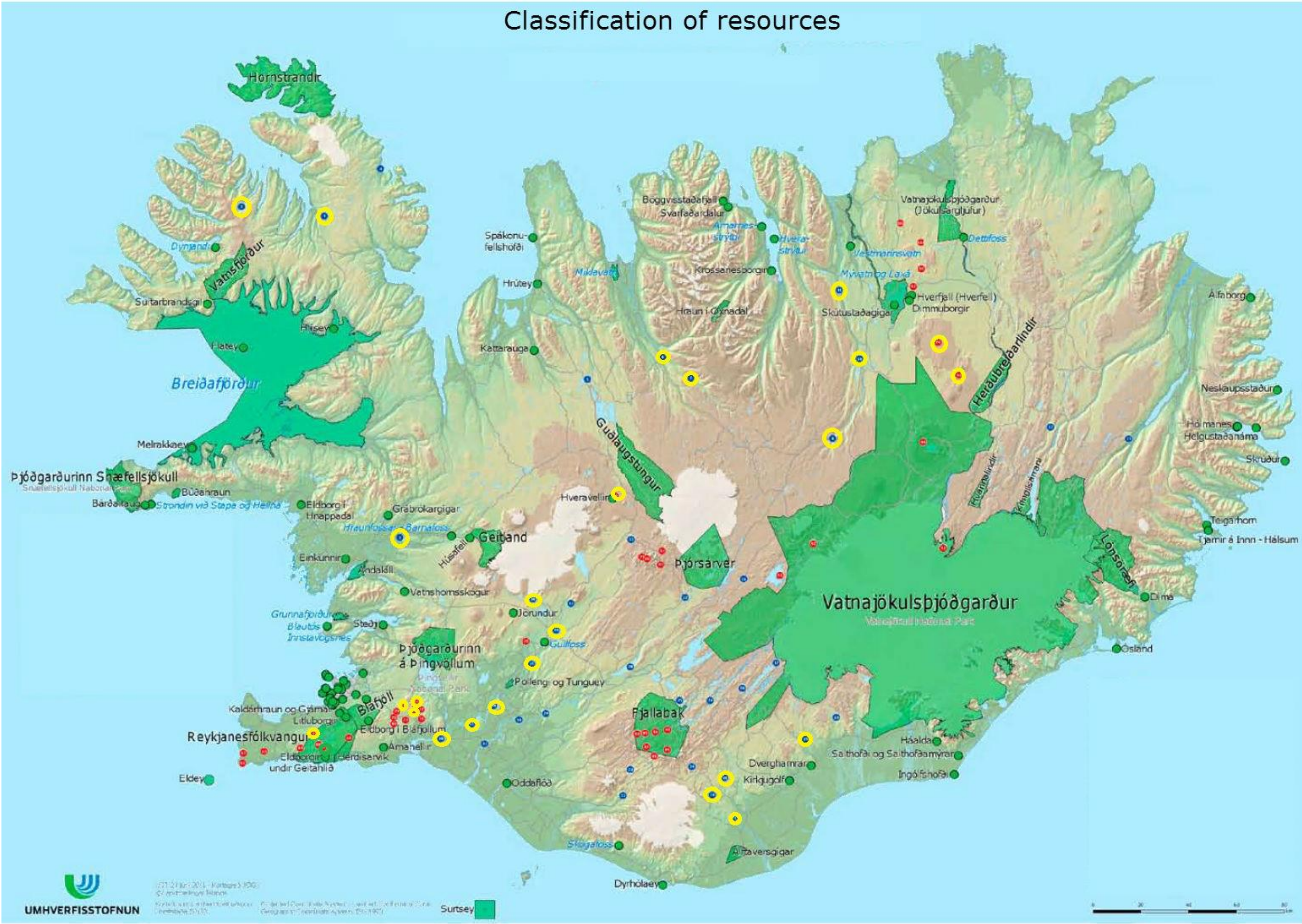

Figure 1.9: Green areas and dots indicate preserved areas; yellow circles indicate areas that are on hold, blue dots possible hydro utilization areas and red possible geothermal utilization areas. (Source: rammaaaetlun.is)

Only areas marked with blue (hydro) or red (geothermal) dots are in the utilization category meaning that they can be harnessed subsequent to habitual work progress, involving environmental assessment, acquiring licenses and so on. The areas marked with yellow are in pending mode, meaning that it is not decided to allow harnessing them or not and when the decision is taken they will move to either utilization or preservation class. How many of the pending resources will move to utilization or preservation is decided by the sitting government at that time. The green areas and dots are preserved areas where harnessing is and will not be allowed.

Resources in utilization class are not necessarily feasible in terms of economy or to other reasons and probably only few of them will be harnessed. This fact in addition to increased public awareness on the environment and nature preservation has led to that power companies are now starting to look at other means to produce electricity than hydro and geothermal, even though that those methods are potentially costlier.

In table 1.1 is the construction cost of hydro- and geothermal power plants listed compared to wind power plants where the latter is more inexpensive than harnessing hydro- and geothermal power. Numbers originating from Landsvirkjun, the Iceland national energy company fully owned by the Government and produces 73 % of all the country's electricity making it the biggest actor in Iceland energy market [5], tells that the construction cost for wind harnessing is approximately two times lower than for harnessing hydro- and geothermal power but in contrast is the maintenance and production cost relatively higher for wind energy than it is for the other two resources [32], however a wind farm is a reversible implementation while hydro- and geothermal plants are not, making it possibly a more feasible option for sensitive areas.

	Hydro Power	**Geothermal Power**	**Wind Power**
Construction cost [M€/MW]	2.17	2.23	1.16
Accumulated production cost [€/MWh]	26.4	29.5	34.9
Yearly maintenance cost [% of construction cost]	1.5	3.0	4.0
Lifetime [years]	50	35	25
Utilization time [% of time]	79	94	45

Table 1.1: Comparison on costs, lifetime and utilization time for harnessing of hydro power, geothermal power and wind power [33].

While the production cost of MWh of electricity is at the moment higher than for wind energy [33-36] than for hydro and geothermal, as table 1.1 shows (cost of harnessing wind energy is more thoroughly discussed in chapter 5). The cost is though expected to decrease in upcoming years with further development of wind turbines and the technology used. The price at the moment according to numerous sources [37-39] is around one million euro for each installed MW and is estimated to be approximately 0,8 M€ in 2020 according to World Wind Energy Association making wind energy utilization in Iceland perhaps more feasible option than before [32]. In case of Iceland, the unstable production of electricity could harmonize well with hydro power plants since they can control the production of electricity easily while geothermal power plants have rather steady production [39]. In addition is Iceland a windy country with wind resources within the highest class as defined in European Wind Atlas and according to a research done by the Icelandic Met Office, that even modest winds farms in Iceland would be capable of producing as much energy as a small hydro- and geothermal power plant in Iceland [40].

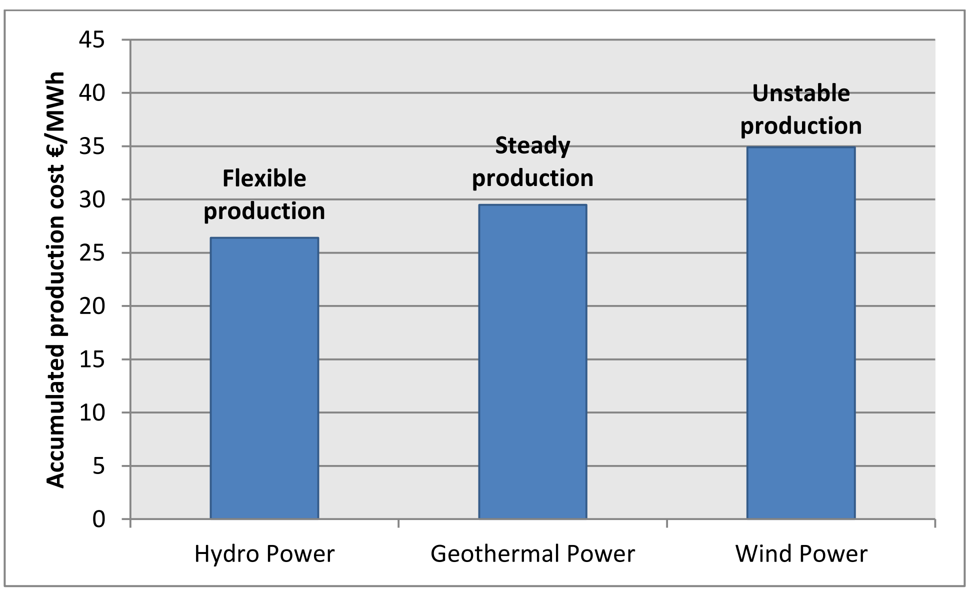

Figure 1.10: Production cost of MWh of electricity divided between hydro and geothermal, and estimated production cost of MWh of electricity produced with wind turbines in Iceland [39].

Iceland national energy company Landsvirkjun, where one of its goal is to harness energy resources which general contentment is about in the society [41], has now just started a research and development project where two 900 kW wind turbines from Enercon are set up in remote area of south central Iceland in the vicinity of a number of hydro power plants. The experience with wind power and wind turbines is at time very limited in Iceland, and the purpose of the project is to build up knowledge of the field in addition to analyse and define cost on installed MW, estimate possible capacity factors and analyse environmental- and social effects [39]. If the results are promising wind power will possibly be added as the third post to the country energy mix which consists 99.99 % of hydro- and geothermal power.

1.4 Thesis objectives

From what is mentioned previously it is clear that:

- Hydro- and geothermal power has dominated the energy scene in Iceland in decades.
- The heavy industry constantly craves more energy with enlargements of current factories and with building of new ones.
- The exploitation of hydro- and geothermal resources has been limited considerably with the master plan which allows preservation of resources located on areas that are considered to have more value if not utilised for energy production.
- That Iceland has good wind resources.
- That the building of large-scale (on Icelandic standards) hydro- and geothermal power plants has been controversial and received significant criticism for disturbance of land and pollution.
- And that Landsvirkjun is concerned that a general contentment is prevalent in the society about its projects.

Wind power is considered to be able to supplement to some extent for the limitations to the hydro and geothermal resources, both in term of production and price and harmonise well with flexible electricity production from hydro power plants. However experience from other countries tells that wind power projects are controversial and it is expected that it will also be the case in Iceland.

The purpose of the thesis is therefore to investigate the views and conception of the Icelandic people, tourists visiting the country and authorities, towards wind energy and harnessing of it with wind turbines, and what means, methods and approaches would be successful to change their perception from negative to positive so general satisfaction is established in the society about harnessing wind energy. This thesis aims to answer following research question:

What is the social opinion towards wind power projects in Iceland, and which approaches and methods might be used to increase public contentment of these projects?

In order to answer the research question a literature study and interviews with experts in the field of social acceptance were made and key issues regarding social acceptance on wind power projects were pinpointed. Furthermore, two hypothetical wind farms were designed in areas where it was considered that they might have considerable influences on the people living there, or visiting the vicinity.

Based on information collected from literature and interviews in addition to results and data from the wind farm design, are two surveys and interviews conducted focusing on local people’s as well as tourists views on wind power projects in Iceland. Their opinions on means and methods for increased contentment on wind power projects are collected and assessed. The results and data from the wind farm design are used to emphasis on certain issues regarding annoyances that a wind farm might, or might not generate.

Municipal authorities and stakeholders in tourism are interviewed to get their views on the subject. Those interviews are considered to describe general opinion and views of a those groups towards the subject.

An economic feasible study of cooperative is carried out in order to assess if it could be a realistic solution when the Icelandic economy situation is taken into consideration.

Finally, are all results, views and ideas summarised and final conclusion regarding the subject is made and a answer to the research question is given. The answer tells what current views there are on wind power in Iceland, and of harnessing it with wind turbines. And which means, methods and approaches to increase public contentment toward wind power projects can be useful.

The project is done in cooperation with the Iceland national energy company Landsvirkjun where one of its goals is to increase the positive impact of the company’s projects, and minimize the negative impact on the environment and society which harmonize well to the subject of this project.

1.5 The thesis disposition

Chapter 2 – Methodology, describes the methodology used in the thesis. What surveys and interviews are, and different types and their function. Wind farm design and elements included in the design and description of literature review and data analysis methodology.

Chapter 3 - Design of hypothetical case study wind farms, is divided to seven subchapters and contains a brief description of wind farm planning and basis of wind energy. It furthermore describes conditions regarding choosing the locations for the hypothetical wind farms that is used as case studies in this thesis, short description regarding projection on wind speed to higher altitudes and general conditions regarding connection of wind farms to the Icelandic transmission grid. Number, type and size of wind turbines introduced and arguments why they were chosen. Finally is the modelling of the case studies with wind farm planning software and results from the software introduced.

Chapter 4 - Reviewing social acceptance of wind power, reviews the literature and interviews regarding social acceptance of wind power in Denmark and worldwide in addition to views on utilization of Icelandic highland areas for hydro power plant.

Chapter 5 - Wind energy cooperative, contains economic feasibility study of cooperatives, assumption regarding future development of electricity prices and energy production at the case study locations. It furthermore contains assumptions regarding operation and management costs of wind turbines and sensitivity analysis of economic feasibility of wind farm cooperative.

Chapter 6 - Views on wind energy projects in Iceland, presents the surveys and interviews conducted and results made by the study. Chapter 6 is written in a way that a reader can leave out preceding chapters if he wants solely read about views and opinions of wind power projects in Iceland. Due to this some repetition of previous chapter may occur when reading chapter 6.

Chapter 7 – Outcome of the study, summarises the results from chapter 3, 4, 5 and 6, final conclusion and an answer to the research question is given.

Chapter 8 – Bibliography.

Chapter 9 – Appendixes.

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2 Methodology

The methodology chapter reviews the theoretical framework and methods used in order to carry out the research. The chapter is divided to five subchapters where the methodology of surveys, interview, wind farm planning, literature-reviewing and data-analysis are described. Each subchapter starts by defining the subjects and listing steps, types and/or different views, lastly are methods and means used in this thesis listed.

In order to answer the research question presented previously, surveys and interviews were conducted. The building block of the surveys and the interviews were a literature study and interviews with experts, in addition to an analysis of two hypothetical wind farm projects designed for the thesis. The method provides both quantitative and qualitative data that is used both for the design and execution of the surveys and the interviews and is followed by analysis of collected data.

2.1 Surveys

As described in a report by Sæþórsdóttir and Ólafsson a survey is a non-experimental, descriptive research method of collecting information from a sample of a target population [42]. A survey is a standard tool for empirical research and may refer to many different types or techniques of observations where a questionnaire is commonly used. With an application of a questionnaire it is possible to measure the characteristics and/or attitudes of people towards a certain subject or topic [43].

Surveys can use **open-ended questions**, where the respondent has possibility to write an answer of his or her own delight, or **force-choice questions** where the answers are listed and the respondent choses which apply to his or her opinion and/or views [44].

There are two basic types of surveys, cross-sectional and longitudinal. **Cross-sectional surveys** are used to gather information about views about a certain subject at a single point in time, for instance what political party a respondent would vote if there was an election today. Longitudinal surveys, however gather data over some certain time period. They are divided to three subgroups: Trend studies, cohort studies and panel studies. Surveys based on trend studies focus on particular target group, such as employees of a company or students at a university, which is sampled and analysed repetitively. Trend studies may be conducted over long period of time and sometimes by many researchers who may combine data from several studies of same target group in order to show a distinctive trend. [44]

Cohort studies also study trends, but just using the same target group over and over again. A cohort study samples the same group and analyse how the attitudes changes, or not, over time. Finally there are panel studies that allow the researcher to find out why some specific trend is occurring. Panel studies do not just find out that some trend or tendency is occurring but also why it is occurring. [44]

There are several ways of collecting data through surveys. Recently mobile data collection has become more popular, where the strengths from mobile communication and their function are used in order to collect data from users of them regardless of time and location of the respondents. The advantages of using this method are quick response time and the possibility to reach target groups that otherwise would be hard to reach. Mobile data collection is abundant now due to high concentration of smart phones and tablets. [45]

Another way is using **online surveys,** as was the preferred method for this thesis. Online surveys allows respondents of a target group to answer questions whenever they like and where ever, just as long that they are connected to internet. The advantages of this method are that it is normally faster, simpler and cheaper than surveys conducted by paper. Complex skip patterns can be implemented so the respondent don't need to answer questions that are not relevant to him, limiting the number of questions and reducing the danger of that the respondent drop from the survey without completing it. Online surveys are normally created as web forms where the answers are transferred to a database where they are stored. Statistical software provides the analytical tool where the surveyor can download or export graphs and tables for use in his or hers report and to conduct various analyses. By using online surveys there is a possibility to reach a certain target group by only sending out invitations to the survey to predefined group, such as within a company or a school for example. [46]

Using online surveys has many advantages such as: Very low financial costs, short response time which can even be cut lower with more frequent use of the internet amongst all social groups. Data is directly loaded to the analysis software and extracted in forms of graphs or tables, furthermore allows online survey easy control of the sample. However can online surveys distort the results since not all internet users represent a entire population of preferred sample, in some countries would a mixture of online and mail survey be a better option [46].

Telephone surveys are good for large national or international sample. There an interviewee calls the target group directly that the customer has already defined, for example customers of a company or similar, encouraging the respondent to answer which leads to higher response rate [47]. Telephone survey is often more cost effective than a mail survey since there is no waste of paper and the cost of postage is minimal.

Using mail surveys the researcher hands out a questionnaire or mails it to its respondents, which the respondents than returns or mails back when it is answered. An advantage is that the respondent often can answer at their own convenience and allows them to break up long surveys. A disadvantage is that the response time is often long, several months even. [47]

Face-to face surveys are often suitable where telephone or mail is not accessible or as a short survey conducted on a street or in a busy area with lot of people. In a face-to-face survey the target group is determined by the location that the survey is conducted at. Face-to-face survey is comparable to telephone survey where the interviewee accesses a target group directly.

An empirical research carried out by Janet Ilieva [46]in 2002 shows that email surveys generated better results than web-based in terms of response rate and that they provided greater research control over the sample of respondents, avoiding multiple entries by the same person. But web-based surveys on the other hand are better displayed in a browser window than in an email letter and are more user-friendly.

An issue regarding online surveys is that the anonymity can be important and assuring respondents anonymity on the web can be difficult since people can be suspicious about how much information is being recorded [46,48].

The surveys conducted in the thesis were online based where the target group was invited with a link posted on relative online forums and social-media on the internet. The surveys were cross-sectional surveys with a mixture of force-choice questions and open-ended questions. The open-ended questions were used as a supplement to a number of force-chosen questions in instances where it was assumed that the respondent could answer the question in multiple ways and that predefined potential answers listed might not be satisfactory for that purpose.

2.2 Interviews

An interview is a conversation between two or more individuals where questions are asked by the interviewer to gain facts, statements or opinions from the interviewee. Interviews are often used in a qualitative research in order to collect view and opinions of certain person or group and to understand the meaning of what the interviewee says [49].

Interviews are often considered as a method for qualitative research and used to understand the experience of others [50]. The qualitative research interviews are listed to four main types:

- Informal conversational interview where no predetermined questions are asked. The interviewer asks questions that he or her thinks are relevant and tries to remain as open and adaptable to the interviewee views, opinions and priorities.
- **General interview guide approach** where the same general areas of information are collected from each interviewee allowing a degree of freedom and adaptability in getting information from the interviewee.
- Standardized, open-ended interview where the same questions are asked to all interviewees allowing them to answer at will.
- Closed, fixed-response interview where all interviewees are asked the same questions and asked to choose answers from the same set of alternatives.
  [50]

The general interview guide approach, which is used when conducting the interviews for the thesis, is good to use since it gives relevant information and allows more freedom to explore views and opinions in more details than a closed interview for example. The approach is good to use on sensitive topics since it allows the interviewee to answer at his own will. It is vital to prepare for the interview as to not make the questions prescriptive or leading.

When conducting an interview for a qualitative research it is important to be tactful and sensitive in the approach to answers. Firstly, you need to listen to the interviewee. Listen to what he is actually saying, listen to the “inner voice” or “read between the lines” and listen to the process and flow of the interview in order to remain aware of how tired or bored the interviewee is. And to remain focus on how much time there has already passed and how many questions there still remains. The listening skills required in an interview require more focus and attention than in typical conversation. [50]

Secondly, ask questions to follow up and to clarify on subjects that are not clear to the interviewer. Not only use previously determined questions, but also follow-up with questions throughout the interview which might encourage the participant to elaborate on subjects that could give more comprehensive understanding of the matter. Additionally, it is important to ask clarifying questions if the interviewee or the interviewer gets confused. [50]

Thirdly, the interviewer should always be respectful of boundaries, explore not probe is the key on this matter. It is essential that the interviewee is treated in a manner that is both sensitive and respectful. They should not be “probed” is such a way that makes them feel uncomfortable or like a specimen in a lab which might lead to that the participant becomes defensive or unwilling to share. [50]

Number four, be wary of leading questions which might suggest or imply an answer. Ask open-ended questions instead. And number five, don’t interrupt. Participants should feel comfortable and respected throughout the entire interview and interruption might take the interviewee of the track. [50]

The general interview guide approach was the chosen approach for this thesis, where a list of questions and subjects that the interviewee wanted to get comments on was mailed beforehand to the interviewee so he had the possibility to get acquainted with the questions and subjects there might be asked about. And in order to give him a chance to collect further data and/or information about the subject if necessary.

The interviews conducted in Iceland were two folded on one hand focusing on stakeholders within the administrative body and tourism in addition to a person that owns and operates a wind turbine on his property and to the project manager of wind power at Landsvirkjun. And on the other hand to persons who have experience in social accept on wind power projects in Denmark. Their experience and advices were together with results drawn from the literature study the building block of the interviews carried out in Iceland and to the surveys questions design.

Interviews carried out in Denmark were through telephone and Skype and included:

- Søren Stensgaard, a technical chief of Samsø community, and former lead person of Samsø energy academy. A specialist with experience within the subject of social acceptance and public involvement in wind power projects.
- Inge-Dorthe Ellegård Larsen, a chairman of Paludans Flak wind turbine cooperative.

Interviews conducted in Iceland were with:

- Þorvaldur Vestmann, manager of environmental and construction division of Akranes community where one of the hypothetical case study wind farms is designed at.
- Margrét Arnardóttir, project manager for wind power at Landsvirkjun.
- Gunnar Guðjónsson, manager of Hveravellir tourist association and operator of boat tours on Hvítárvatn Glacier Lake.
- Guðrún Þórisdóttir, sales manager of Iceland Excursion which is a coach- and tour operator.
- Ólöf Ýrr Atladóttir, director of Iceland tourist board.
- Haraldur Magnússon, a farmer who has erected 30 kW wind turbine within his property.

In addition two persons were not able to meet for an interview so a question list was sent to them by email which they answered swiftly. They were:

- Sveinn Rúnar Traustason, environmental mangaer of Iceland tourist board.

- Gunnar Valur Sveinsson, project manager at the Icelandic travel industry association

2.3 Wind farm design

The development of a wind farm is a complicated and multi-structured task which involves a profound understanding on engineering-, scientific- and meteorological subjects. The design process proposes challenges to the designer as the farm both need to be energy effective and within financial and environmental constraints.

In this thesis the focus is set on generating reasonable data that normally could be used in an environmental impact assessment report including assessment of visual influence and annoyances such as sound and shadow flicker in addition to values used for an economic assessment. The preferred tool used was WindPRO which is modular based software suite for the design, development and planning of both single wind turbine and wind farms. It consists of number of modules where each of which has its purpose [51]. The environmental assessment of impacts that a wind farm might generate is a vital part in the planning process, few of those issues are listed here and taken into consideration for this thesis wind farm design, together with resource assessment and estimated energy yield used for the economic feasibility calculation.

Wind speed – The energy production is of course closely related to wind speed. The energy that lies in the wind is proportional to the third power of the wind speed, thus if the wind speed doubles the available power increases eightfold. Due to this fact is the resource planning extremely difficult since a small change in the wind speed can drastically change the power output, therefore it is essential to do a long-term assessment of the wind speed at the site. This can be done by making on-site wind speed measurement at a level close to the hub height over long time, or alternatively using reanalysis data if it is of proper quality. Reanalysis data is a collection of weather data collected through long period of time by different means and methods, it is assimilated and stored in data bases where specific elements such as wind speed, can be extracted for specific grid points, often with ½ degree interval covering the entire globe [52]. The variation in wind speed between short and long-term wind data can be minimised by using measure-correlate-predict method which involves the calculation of speed-up or down ratios, on a directional basis, between the short-term measuring device and long-term data collected by other means. [53]

Wind speed flow over the site – The geographical conditions of an area where a wind farm is situated has considerable effect on the wind speed, if a wind turbine is situated on a hill where the wind needs to "pressure" itself over, then the wind speed at that point is higher than in the surroundings that are placed lower. The calculation of the wind flow over a hill or hills is very complex and has sophisticated software tools been developed for that purpose, such as the WAsP technology developed by DTU Wind Energy. These tools take into account the effects of surface roughness and topography. [53]

Wake effect – A wind turbine removes kinetic energy from the wind and creates a wake effect. The effect reduces mean wind speed and creates turbulent energy, making the energy production on downwind turbines, which has its rotor on the back side of the turbine, less and increases dynamic loading. The wake effect is dependent on placement of wind turbines, wind speed and direction. [53]

Visual considerations – Topographical data used for calculation of wind flow over the site are also used to assess the visual interference of a wind farm. When the wind turbines have been placed, the zones of visual interference (ZVI) can be calculated. A ZVI is the area where the structure is theoretically visible from nearby surroundings. By using this method it is possible to move some elements of the wind farm to reduce the effects that it might have on the area and its residents. [53]

Sound – The sound produced by wind turbines is a sensitive issue. All manufactures lists the sound in relation to wind for that their wind turbines produces whereas the sound from a distance can be computed dependent on geographical conditions, ground cover, background sound levels and air quality, in addition to objects or structures that might block the sound to some extent. [53]

Shadow flicker – A relatively new problem associated with wind turbines is the effect when the blades periodically cast shadow on nearby surroundings and through constrained openings such as windows. It is caused by the position of the sun and cloud cover, wind speed and direction. Once relative data concerning cloud cover, wind data and position of the sun has been established, the flickering effect may be calculated in addition to geographical conditions, objects and structures in the neighbourhood that might block the effect. [53]

2.4 Literature review

Conducting a literature review is an important part of any research process; it founds the base for the research and creates greater understanding of the topics investigated. A literature study can help answering questions like where to start the research, how to select a subject, what have other experienced on the subject, which solutions there are etc.

A literature review is a neutral summary of relevant research literature of a topic similar to those that is currently being studied. Its goal is to bring the reader up-to-date on a topic previously studied and form a basis for a new a study on a similar matter. A literature review gathers information about a certain subject from many sources and contains few if any personal views and opinions. It should contain a clear search and selection strategy [54].

A **narrative literature review** summarizes and critiques relevant studies and knowledge that addresses the subject area of literature and draws conclusions about the topic in question. It is useful in gathering a large amount of literature on specific subject area and summarising and synthesising it. It provides the reader with a broad background for understanding the subject and highlighting the significance of new research and inspires new research ideas. [55]

Systematic literature review uses a well-defined approach to reviewing the literature on a specific subject area. Its purpose is to provide a complete list as possible, of all the published and unpublished studies regarding the subject area and identify, critically evaluate and synthesise all the literature on the topic. [55]

Meta-analysis review is seen as a form of systematic review which is largely a statistical technique. It involves taking the findings from several studies on the same subject and analysing those using standardised statistical actions. This helps to draw conclusions and detect patterns and relationships between findings [56].

Meta-synthesis review is a non-statistical method and is used to evaluate and interpret the finding of multiple qualitative researches. Unlike meta-analysis review, meta-synthesis review involves analysing and synthesising key elements in each study, with the aim of converting individual findings into new conceptualisations and understandings [56].

Of course the first steps when doing a literature review is to pinpoint the review topic and search for relevant literature. Important is to refine the search so that the amount of information collected is manageable [55]. Literature review in an academic paper should have some limitations in length so topics that are too broad will result in a review that is too long or too superficial. As a rule of thumb start with narrow and focused topic and then broaden the scope of the review as you progress, if necessary [55].

Once the topic is chosen and relevant literature is found the next step is to read and analyse the literature. Advisably is to undertake a first read to get a sense of what they are about, reading abstracts or summary part of the article might assists to get a general view of what it is about and weather it is worthy to read further. Once the initial overview of the articles has been done a more systematic and critical review of the content is performed. It is recommended that it is done in a structured manner so it demonstrates the knowledge gathered in a clear and consistent way [55].

That can be done by dividing the literature into themes and/or categories and present the literature chronologically if the topic appears over period of time, followed by exploring the theoretical and methodological literature. Lastly examine theoretical and empirical literature in two sections [57].

The key to a good literature review is the ability to introduce the findings in such a way that it demonstrates your knowledge in a clear and consistent way [55]. The organisation of material and the structure of the review are crucial to its comprehensiveness. Sentences should be kept as short as possible and avoid using long and confusing words. The length of it should be kept within reasonable limit and conclude with a concise summary of the findings [55].

In this thesis numerous articles regarding social accept of wind power have been studied, articles based on research with social acceptance in Germany, France, Greece, Denmark and UK and on views towards exploitation on highland areas in Iceland. The results from these studies bases the building block for the questions in surveys and interviews, and suggestions to possible methods and means that could be used to increase public contentment of wind power projects in Iceland. A narrative literature review was the chosen approach for this study where a summary of the key findings from reviewed literature is included in the end of the chapter.

2.5 The analysis of collected data

The process of data analysis includes the step of inspecting, cleaning, transforming and modelling data with the aim to pinpoint useful information and suggesting conclusions based on the information gathered [58]. The data analysed for this thesis can be divided to qualitative and quantitative data. Where the wind resource data and some part of the survey data are qualitative numerical data and the interview data is textual quantitative data.

The analysis can furthermore be divided to three pillars, a technical analysis dealing with the actual wind farm design and issues associated with nuisances from the wind farm. Fundamental analysis or analysis of previously gathered knowledge and experience regarding social accept on wind energy projects and sentiment analysis that deals with the task of inspecting and assessing the viewpoints and opinions collected through surveys and interviews. An analysis of something is to ask what that something means. A good analysis is done in a way that the researcher becomes more aware of his own thinking process, building on skills he already holds and reject habits that might interfere [58]. Five simple steps to keep in mind when an analysis is done are listed below.

Suspend your own judgement and opinions – Your taste, your interest, and your views can distort the results of an analysis. As a general rule, you should seek to understand the subject you are analysing before moving to a judgement about it. Figure out what the subject means before deciding on what you feel about it [58].

Define significant parts and how they are related – Always divide the subject into its defining parts, its main elements or ingredients. Consider how these parts are related, both to each other and to the subject as a whole [58] and pay close attention to details especially if they appear repeatedly. Don’t generalise, but move from larger subjects to the key issues.

Make the implicit explicit – Converting suggestions into direct statements is an essential part of an analysis, but it is also what inexperienced analysts fear or oversee. They fear that, like the emperor´s new clothes, implications aren’t really there but are mirages of overactive imagination. [58] Be bold, be brave, but avoid making something up which isn’t presented in the text or the dataset you are working with.

Look for patterns – Search for certain pattern of repetition or similarity, basically a repetition is a sign of emphasis. Look for organizing contrasts, sometimes patterns of repetitions can be significant because they are a part of a contrast or an opposition which the subject matter is organise around. Look for anomalies, unusual pattern or things that seem not to fit, since anomalies helps to revise stereotypical assumptions [58].

Keep reformulating questions and explanations – When conducting an analysis you don’t necessarily know exactly where you are going, at least not in the beginning, how the subject parts fit together and to what end. The key is to be patient and know that are questions and answers and explanations to them, which is possible to rely on to take you from uncertainty to understanding. The questions listed below are typical of what goes on in an analytic head when trying to understand a subject [58]:

- Which details seem significant? Why?
- What is the significance of a particular detail? What does it mean?
- What else might it mean?
- How do details fit together? What do they have in common?
- What does this pattern of details mean?
- What else might this pattern of details mean? How else could it be explained?
- What details don’t seem to fit? How might they be connected with other details to form a different pattern?
- What does this new pattern mean? How might it cause me to read the meaning of individual details differently?

3 Design of hypothetical case study wind farms

This chapter contains brief description of issues that was considered when the wind farms for the case study were designed. The description is not comprehensive in that way that it does not touches upon all aspects that need to be considered when a wind farm is planned, but only series of criteria for contemplation for the two hypothetical wind farms designed for the thesis.

The technical part of this thesis, designing a wind farm is largely dependent on collection of data and resources that were analysed in WindPRO, which is wind farm design and planning software (the software is more thoroughly described in section 3.7). The data consists of measured weather data through ten years by Iceland Meteorological institute, topographical maps from Iceland National Land Survey Institute and online height contour lines downloaded through WindPRO and modified according to height contour lines on previously collected maps.

The wind turbines were on one hand placed in the vicinity of town with approximately 6500 inhabitants, and on the other hand in the neighbourhood of popular tourist destination, both wind farms are identical in terms of size and number of wind turbines and alignment. Visualization are generated in order to help interviewees and surveys participants to visualise the changes that a wind farm might have on their living area or the destination they are visiting The output data is presented in order to validate how people perception towards wind energy projects might change when presented to values different to them they had imagined e.g. in terms of noise or shadow flicker and annoyances caused by them.

The locations of the wind farms were chosen in order to get various and multifaceted answers from the interviews and surveys conducted and fulfil the criteria introduced in section 3.3.

3.1 Basis of wind energy

Wind energy originates from the sun where temperature differences drive air circulation where the areas closer to the equator are heated more by the sun then the rest of the globe. The air that is heated by the sun rises to the skies where it spreads out towards the north and the south poles causing low pressure zones close to the ground attracting air from the north and the south which causes winds. These winds are called geostrophic winds and are not much affected by the earth surface, however when dealing with wind energy are the surface winds, i.e. winds with altitude up to 100 meters, that are interesting. Those winds are highly depended on the earth surface, roughness and obstacles. [59]

A wind turbine works by converting the force of the wind to turning force. The amount of the turning force depends on the density of the air, the rotor diameter and the wind speed. The denser the air is the more energy is received by the turbine. Wind turbine deflect the wind before it reaches the rotor blades, due to the air behind it is at sub-atmospheric pressure while the air in front is under higher pressure than the atmospheric pressure [59,60].

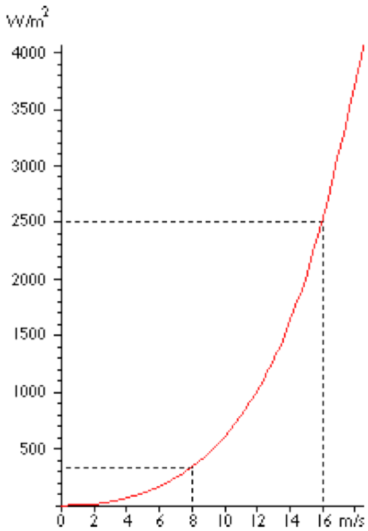


Figure 3.1: The energy that the wind contains in relation to wind speed. [59]

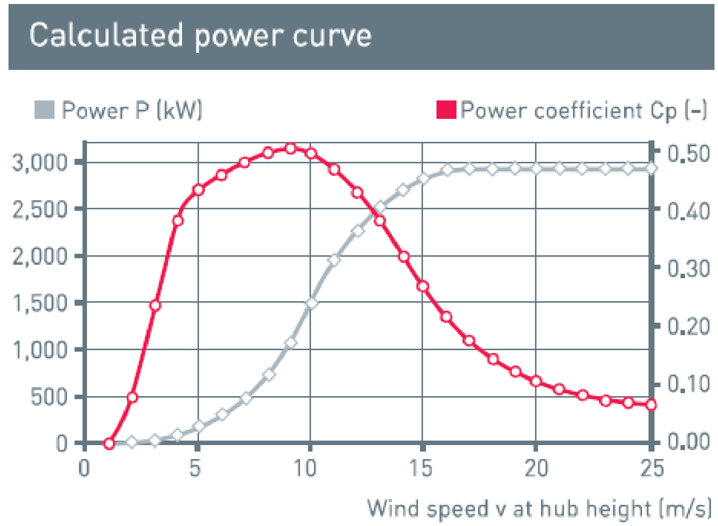


Figure 3.2: The power curve and power coefficient for Enercon E-82 3 MW wind turbine as is used for the case studies. (Source: Enercon product overview leaflet.)

Figure 3.1 represents the energy that the wind contains in relation to wind speed, with a wind speed of 8 m/s the energy is around 300 W/m^2 and at 16 m/s the energy is eight time higher. Albert Betz a German Physicist, formulated in 1919 a theory, called Betz limit or Betz law, which says that you can only convert less than 59 % of the kinetic energy in the wind to mechanical energy using wind turbine. If all the energy that the wind contains is extracted by using wind turbine it would mean that no energy would pass through it blades and the wind turbine would stop. The Betz limit [C_p] is unique to each wind turbine type and is a function of wind speed that the turbine is operating in. The real world limit is considerably below the Betz limit of 0.59 with values of 0.35-0.45 to be common [61]. Figure 3.2 represent the power output and the power coefficient [C_p] in relation to wind speed for an E-82 3 MW wind turbine as is used for the case studies (discussion regarding the choice of wind turbine is found in section 3.4).

The power of wind increases with the third power of wind speed, meaning if the wind increases two times, the energy it contains will increase eight times. When calculating what power can be extracted from the wind with a wind turbine, the Betz limit introduced above needs to take into consideration in addition to the rotor swept area of the turbine. The formula is given below with equation (1).

$$P = ½ * \rho * V^3 * C_P * A_R \tag{1}$$

Where: P is energy production [W]
ρ is air density [kg/m^3]
C_P is power coefficient
A_R is rotor swept area [m^2]
V is wind speed [m/s]

For the calculation in section 5.3 is the air density considered to be 1,252 kg/m^3 but in general the heavier the air is, the more energy a wind turbine produces. The air density is determined by height above sea level, temperature and atmospheric pressure; the more that the height is the less pressure and lighter air, the higher temperature the more lighter air and therefore less production. The power coefficient is set to 45 % which is often used for large wind turbines [62] [61].

3.2 Wind farm planning in relation to nuisances, environmental and visual factors

Wind turbines and especially wind farms are highly visible elements in a landscape and serious efforts have been done in order to reduce the effects they might have on the surroundings. Simple geometrical patterns of a wind turbines alignment often work well in flat areas to minimise the visual effects, while in hilly landscape it often works better that the turbines follows the altitude contours. [59]

The colour of wind turbines might have influence on how well they blend to the landscape, for instance a light grey might suit well on over casted days. Some wind turbines have green colour on the lowest part of the tower which then gradually fades out as it goes higher on the tower.

Noise is considered to be a minor problem today thanks to improvement in wind turbine design, and the area affected by sound only extends a few rotor diameter´s distance from the wind turbine according to Krohn at Danish Wind Industry Association [59]. The latest wind turbines are considerably quieter than older models where particular noise from the gear and generator was high. Also have improvements in blade design resulted in lower noise level. However, has the noise level from the older types of wind turbines caused that the noise myth is tenacious amongst many people resulting in high concerns a wind turbine is planned in their vicinity.

A low frequency noise can emit from a wind turbine, a low frequency noise is technically defined as a noise within the frequency range of 10-160 Hz. According to the Danish Environmental Protection Agency no evidences are found that low frequency sound is more dangerous than other forms of noise [63].

Birds are rarely bothered by wind turbines. Studies from Denmark indicates that power lines are of much bigger danger to birds than a wind turbine and that birds tend to change their flight route some 100-200 metres before the turbine and pass above at a safe distance. There is though slight difference depending on species how quick they get accustomed to wind turbines so erecting a wind farm close to a migration route or a bird sanctuary therefore depends on species in question. [59]

When the sun´s rays passes through a wind turbine´s rotating blades it will cast a flickering shadow on the surroundings. This flicker has the potential to induce photosensitive epilepsy seizures however the risk is low with large modern models and if proper planning is adhered to [64,65]. Furthermore can shadow flicker cause distraction to vehicle drivers. A careful planning and the use of good software, such as WindPRO, can help in resolving this problem by placing the turbines in a way to avoid major inconveniences for the neighbours and arranging that the wind turbine stops during those minutes when the flicker occurs at sensitive locations.

3.3 Locations of case studies

The criteria for choosing wind farm location for this thesis is that they must have good or decent wind resources so the production of electricity will be satisfactory and a weather mast must be placed close by. The area needs to have necessary infrastructure such as transmission lines, roads and even port near-by for easy transportation of wind turbines during the installation time. The location needs to be in the vicinity of inhabited area or other area that people regularly visit, such as a recreational area or a tourist site in order to investigate people's opinions when such an object is located close by; lastly needed the locations to be within reasonable driving distance from Reykjavík due to practical reasons when conducting interviews.

The chosen location one is at Svartsengi. A site that is located in the vicinity of the Blue lagoon which is a geothermal spa and one of Iceland best known tourist location with over 460,000 visitors during the year [66]. Figure 3.3 shows the location of the wind turbines at Svartsengi in relation to the location of the Blue lagoon spa; the image is created by using WindPRO and Google Earth.

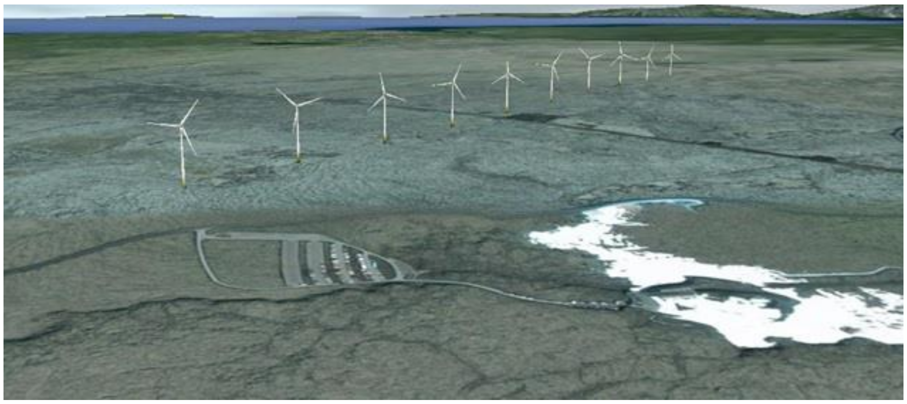


Figure 3.3: The wind farm site at Svartsengi. The Blue lagoon spa is in lower right corner.

Location number two is located in the outskirts of Akranes who is a town with around 6500 inhabitants [2], figure 3.4 shows a computer generated image of the wind turbines location in the outskirts of the town.

Figure 3.4: The wind farm site at Akranes.

These locations have decent wind resources and all necessary infrastructures, transmission lines are located close by as figure 3.6 shows, and they have good road infrastructure. At both locations is a port located within 10 km distance, and a weather mast is placed in the vicinity. Their location in a vicinity of populated area and a recreational area allows that in the interviews and the survey phase it was possible to give respondents and interviewees actual values on nuisances such as noise and shadow flicker, it was possible to show pictures representing visual effects that the wind turbines might cause and it was possible to calculate the economic feasibility of a cooperative with real production values.

The wind resources for those sites are considered to be decent. In a research conducted by IMR, which is a meteorology research centre in Iceland, a weather research and forecasting model was used in order to calculate weather in Iceland from 1995 to 2011 with a 3 km mesh size [67]. The results gave indications towards the wind resources for the entire island and assume the wind energy that an area possibly could give. Figure 3.5 shows the annual average for the wind density in 100 meters elevation above sea level according to IMR. The red circle marks the sites at Svartsengi and the green one the Akranes site.

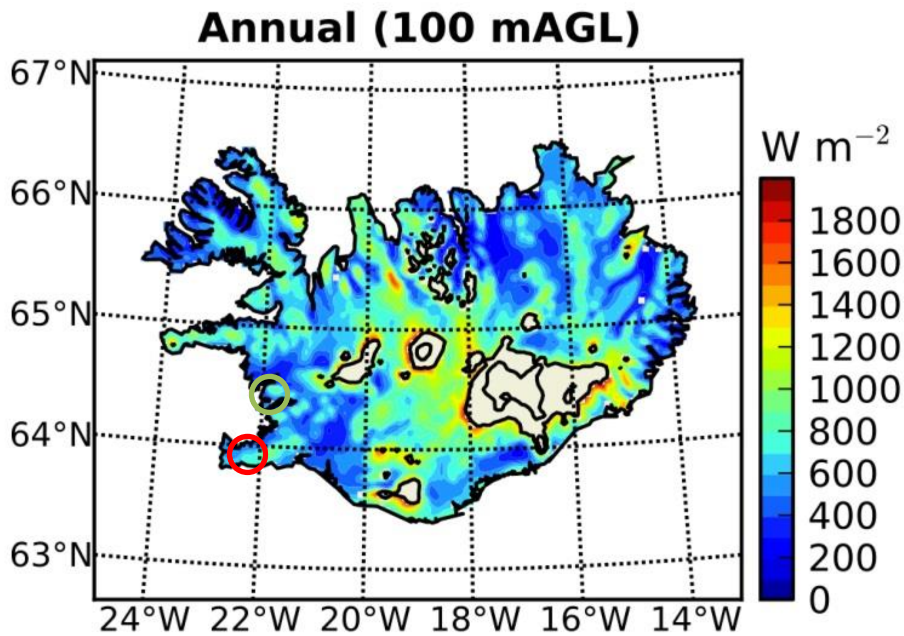


Figure 3.5: Calculated annual average wind density in w/m2. [67]. *The green circle represents the Akranes site and the red circle represents the Svartsengi site.*

Visible, but maybe not clearly, is that the wind density at the two sites is at slightly higher level than at other coastal areas where infrastructure and population are present, the highland area is not considered to be feasible due to the lack of infrastructure and populated areas.

3.4 Number and types of wind turbines

The subject of wind power is a vast and comprehensive and in order to make fit within the framework that this report has, have results from other studies regarding wind energy in Iceland been used.

Sensitivity analysis of feasibility with more or less wind turbines is not done for this research, the topic has been studied in a master thesis by Smári Jónasson where it is stated that cost reduction occurs with increasing number of wind turbines and that the internal rate of return will double if number of wind turbines will increase from one to ten [62].

Therefore is the number of wind turbines for this thesis set to ten for both of the case studies.

Analysis of most optimum wind turbine for conditions in Iceland is the subject of a master thesis by Kristbjörn Helgason [68] where 48 locations around Iceland are studied in terms of wind resources, infrastructure and feasibility for 47 types of wind turbines to indicate the potential of wind power harnessing in Iceland, using all combination of wind turbines and locations. The results are that 3 MW Enercon wind turbine is the most feasible option at location Garðskagaviti on the Reykjanes peninsula.

The location at Garðskagaviti is just a stone throw away from the measurement site of Svartsengi location so it is assumed that the wind conditions are similar, and in order to maintain equal comparison for the both sites it is decided that the Akranes site will be identical to the Svartsengi site in terms of wind turbine type, number and layout. Based on these arguments an E-82 3 MW Enercon wind turbine is chosen as the preferred wind turbine for the both case studies.

3.5 Connection to the transmission system

The Icelandic TSO Landsnet, is the owner and operator of the only electricity transmission system in Iceland. The TSO is owned by Landsvirkjun (65 %), Iceland State Electricity (22.6 %) and two other local energy providers. The transmission system includes all transmission lines with 66 kV voltage or greater in addition to a few 33 kV transmission lines and 72 substations [69]. The transmission system delivers electricity to the heavy industry and to distribution systems which then distributes the electricity to end users.

Figure 3.6 shows the transmission system, transformer- and substations. All power plants, 7 MW or bigger are obliged to connect to the transmission system at feeding points that are 19, distribution connection points are 57 and big users are five. The transmission system consists of well over 3000 km of high voltage overhead transmission lines, besides a few underground lines. [69]

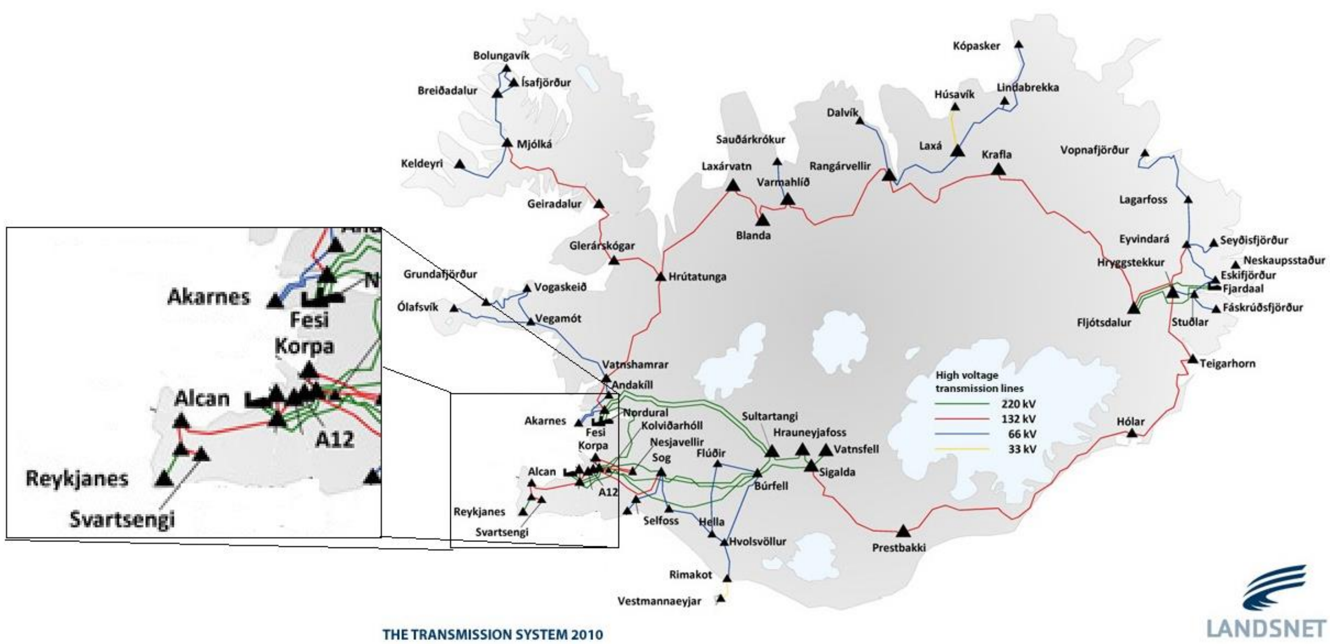


Figure 3.6 The Icelandic transmission system including substations and transformer stations. The fold-out picture is an enlargement of the transmission system on Iceland south-west corner [70]. *Image edited by the thesis author.*

The price for connecting a wind farm is in relation to the distance to nearest connection point. A price for 132 kV line like there is at Svartsengi is 240,000 €/km [71] so in order to keep a wind farm capital cost down, a location as close as possible to a connection point which is capable of withstand installed wind farm capacity is preferable.

The figure above shows that Svartsengi has 132 kV transmission line and a substation and at Akranes is 66 kV transmission line and a substation. Since both wind farms are uniform with installed power of 30 MW it is necessary to know if the lines have necessary capacity to receive power from the wind farms.

Many aspects needs to be taken into consideration when connecting a power plant to existing transmission line, such as the transmission line length and voltage drop in addition current load on the line. For this thesis a comprehensive calculation of a transmission line capacity is not undertaken due to complexity, but instead a general rule of thumb is used.

According to Tore Wizelius, a Swedish professor at Gotland University is the general rule of thumb that a 40 kV line is capable of carrying 18 MW, and a 220 kV line 132 MW [72]. By using linear interpolation the value of 34.5 MW for 66 kV line and value of 76.3 MW for 133 kV line is calculated, giving indications that current transmission lines are capable of carrying the power from the wind farm when no other conditions are taken into the account, such as current load on the lines. For the calculation of economic feasibility presented in chapter 5 no extra cost as a results of transmission line reinforcement is added.

3.6 Projection of wind speed to higher altitudes

The decisive factor for how much energy a wind turbine is able to produce is the amount of wind that passes through its blades. The magnitude of the wind is directly linked with the speed it moves on, and that speed is different depending on altitude and landscape. To get most accurate wind speed values measurements taken in appropriate heights are advisable. In the case of the Svartsengi and Akranes sites such measurements are not available but weather measurements in ten meters height are. In order to get realistic values for wind speed in the hub height of 84.6 m, which is the hub height of the Enercon E-82 3 MW wind turbine, is the wind speed projected by using mathematical formulas.

Two types of formulas are often used for the vertical projection of wind speed, the power law (2) and the log law (3):

Equation for the power law

$$U_z = U(z_R) * \left(\frac{z}{z_R}\right)^{\alpha} \tag{2}$$

Where:

- U_z is the projected wind speed
- U is the wind speed at measured height Z_R
- Z is the projected height
- α is the Hellmann exponent

Formula for the log law

$$U(z) = \left(\frac{U_*}{\kappa}\right)\left(\ln\left(\frac{z}{z_0}\right)\right) - \Psi\left(\frac{z}{z_A}\right) \tag{3}$$

Where:

- U_z is the projected wind speed
- U_* is friction velocity
- κ is von Kármáns constant
- z_o is roughness length
- L_* is Monin-Obukhov length

In a report by Stefan Emeis [73] the power law and the log law are compared, the results are that both formulas offers nearly perfect fit of wind curves under stable conditions in flat terrain and little less perfect fit under unstable conditions.

The power law is well known and widely used method, its simplicity is a benefit where there is only one constant, the Hellmann exponent, that is needed to be found. Some early works has indicated the exponent to be 1/7 ≈ 0.14 [74], studies in Iceland have showed that the exponent is ranging between 0.08-0.16 [75], while the exponent total range is 0.06-0.60 depending on location [76]. The exponent describes the friction between the earth's surface and the air movement where it slows downs as the friction gets higher. An exponent close to zero represents near frictionless surface such as the ocean while a higher exponent represents a surface with higher friction.

According to report by Blöndal and Sigurðsson is the value for the area surrounding Keflavík airport close to 0.14 [75,77]. The Svartsengi site is located in the vicinity of Keflavík airport and shares the same surface which mainly consist of lava, the Akranes site has little different surface that mainly consists of flat agricultural land. For this thesis are the wind speed values projected to 84.6 m from 10 m, using the power law and exponent of 0.14 for both wind farms locations in order to maintain coherence between the two sites.

3.7 Modelling with WindPRO

For this thesis the modular based software package WindPRO was used for planning and design of the wind farms used as case studies. WindPRO consists of several modules where each has specific purpose when either a single wind turbine location is designed or large wind farms [51]. WindPRO uses WAsP technology for wind energy simulations and generation of wind resource maps by considering orography and roughness. WAsP is developed by DTU wind energy and predicts wind climate, wind resources and power productions from wind turbines and wind farms [78].

These tools models the wind flow over terrain, creates wind statistics, generate wind maps and predict the output of wind turbines. WindPRO was used to create images of planned wind farm sites and to assess the noise impact, shadow flickering and zones of visual influences.

3.7.1 The wind farm layout

As mentioned in section 3.4 are the wind turbines used for both sites ten E-82 3 MW Enercon wind turbines. They are places in a uniform straight line with a distance of 250 m between. The distance between them is three times the rotor diameter and is determined by how they are placed according to the dominant wind direction. If they are placed across then three times the rotor diameter, if along the most dominant wind direction then at least five times the rotor diameter as the foremost turbines are more likely to create wake effect [79].

3.7.2 Roughness classes and obstacles

A rule of thumb when determining whether something should be characterized as an obstacle:

> *"Obstructions (buildings, water towers, etc.) located within 1 km of a turbine or met tower should be characterized as obstacle if they are within distance of 50 times the height of the object and if the top of the obstruction is higher than ¼ of the hub height or higher in elevation"* [51].

Only the Svartsengi site had obstacles that fulfilled these conditions, within one kilometer of the wind turbines is a machine house for a geothermal power plant approximately 20 m in height, and in the vicinity of the met mast are few obstacles higher than 20 m such as a water tank and a shipyard.

A change from smooth to rough surface will increase the surface frictional stress and lead to that the surface wind will slow down. A roughness class and roughness lengths are characteristics of the landscape use to evaluate wind conditions at a potential wind farm site [80]. A roughness class (Rk) 0 represent a water surface with no or at least very small friction, while surface class 3 represents area where many and tall obstacles are, such as town or villages, sheltering hedgerows, forests or very rough and uneven terrain is apparent.

The Svartsengi site is placed in a lava terrain with one obstacle within one km radius; the met mast for the site is placed in few kilometres distance with low raised buildings surrounding it. The lava was set to Rk=1 and the area surrounding the met mast was set to Rk=3.

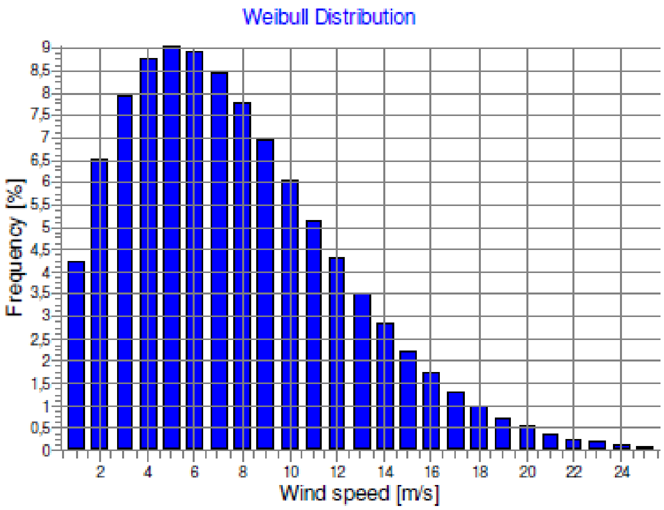
The Akranes site is located in the vicinity of a village which was set to Rk=3 while area surrounding the wind farm can be classified to Rk=2 as an area with some small houses, large boulders, and some hedgerows within distance of 500 meters from the turbines. The wind turbines are placed at the foot of a mountain which is classified as having Rk=2.5.

3.7.3 Wind analysis

The wind speed data is collected from weather stations located in 10 m height above sea level, it was then projected to the hub height using the power law as described in section 3.6. Once loaded to WindPRO a Weibull distribution graph and sector wise frequency rose was extracted and evaluated.

A Weibull distribution is a statistical representation that tells how often certain wind speeds will be seen at a location with a certain average wind speed. This representation helps in assessing the site out from how which wind speeds most often will occur, and is useful when determining a suitable wind turbine in terms of cut-in and cut-out speed.

A sector wise frequency rose, or sometimes called wind rose, is a graphical tool used in order to give concise view of how wind speed and wind direction are distributed for a certain location



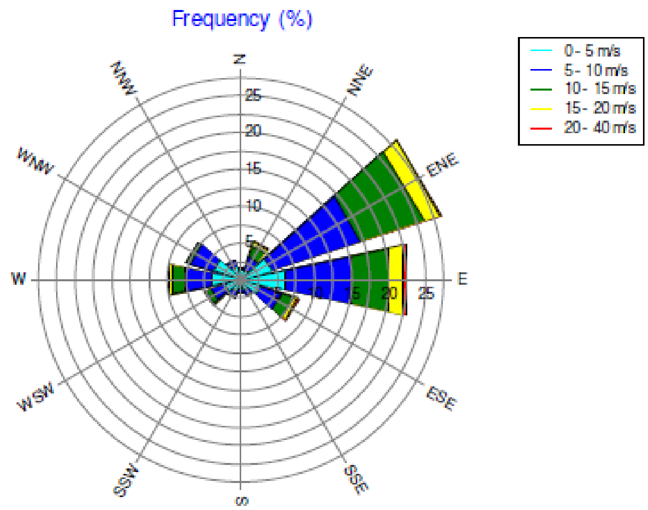
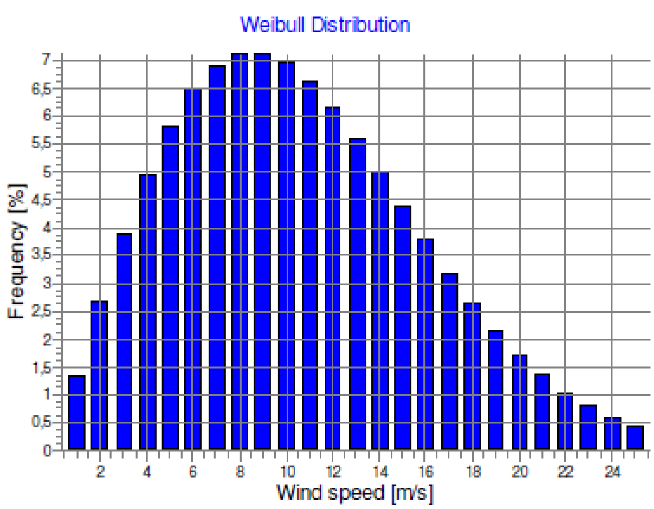


Figure 3.7: Weibull distribution for the Akranes site. (Source: WindPRO)

Figure 3.8: Sector wise frequency rose for the Akranes site. (Source: WindPRO)

Figure 3.7 represent the wind speed scattering for the Akranes site. Most frequent are wind speeds from 3.8 m/s to 6.5 m/s. The Enercon wind turbine used for the sites has cut-out speed ranging from 28-34 m/s which means that for this particular site it will never shut down due to high wind speeds. The wind rose, presented by figure 3.8, gives interesting results, for nearly 50 % of the time the wind is blowing from the east and east-north-east direction causing minimum stress on the yaw drive and components of the wind turbine.



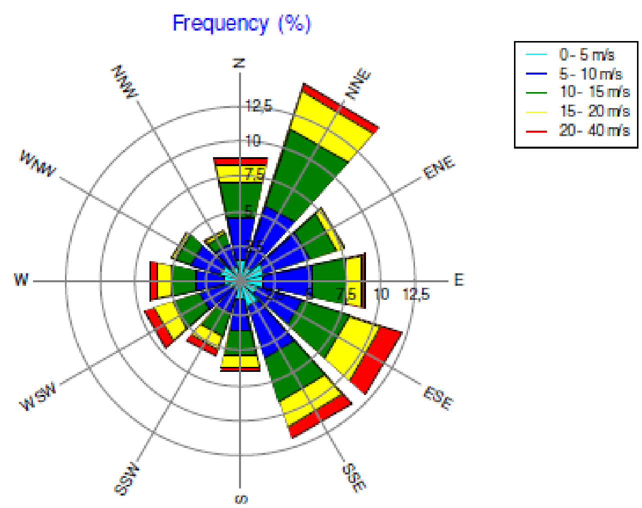


Figure 3.9: Weibull distribution for the Svartsengi site. (Source: WindPRO)

Figure 3.10: Sector wise frequency rose for the Svartsengi site. (Source: WindPRO)

The distribution of wind speed at the Svartsengi site that figure 3.9 describes, is far more scattered at higher wind speeds than at the Akranes site. Most frequent wind speeds are from 6.5 m/s to 10.2 m/s and wind speeds over 24 m/s occurs occasionally. The wind rose shows that the wind is more distributed at different wind directions than at Akranes, possibly causing more wear on yaw drive and components accompanied. The most frequent wind direction is from north-north-east, east-south-east and south-south-east.

3.7.4 Local site wind resource mapping

A local wind resource map describes the wind resources within a predefined area in order to optimise the layout of a wind farm so the wind turbines are placed so they yield as much energy as possible. Based on wind data in combination with WAsP calculation a wind resource map can be generated with WindPRO. The result is a map where every single point within the predefined area is calculated in terms of possible energy production when taking into consideration losses in wind speeds due to contour elevation, roughness and obstacles, wake effect and other instances which might cause less energy production.

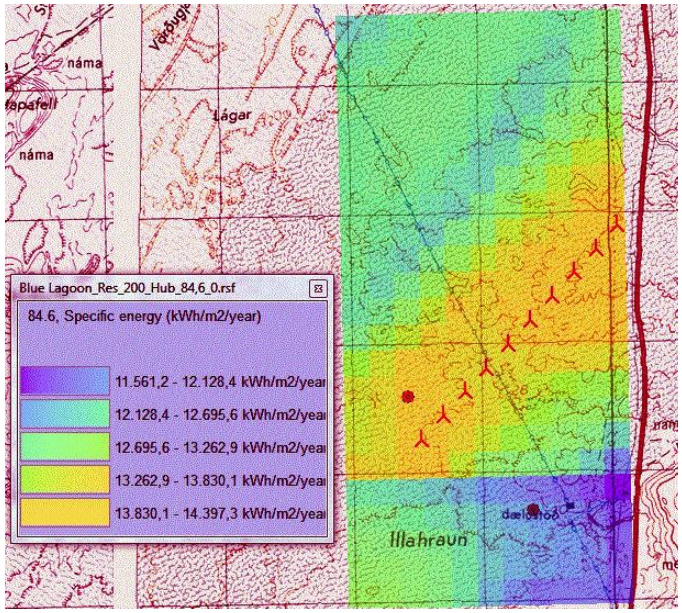


Figure 3.11: A wind resource map for the Svartsengi site. (Source: WindPRO)

In the case of the Svartsengi site is the wind turbines aligned so they yield highest energy as possible according to the resource map. Measured wind speed data from 2002 to 2012, projected to hub height, from a weather mast is used for the mapping of both sites, since it was assumed that a long-term reanalysis wind data would not represent present wind resources. The yellow color represents an area where possible energy production is approximately 14 MWh/m^2 per annum, while the surrounding areas are less. The blue area in the lower right corner is where the Blue lagoon spa and the machine house for the Svartsengi geothermal power plant are located. The lower area of the site has mountains on two sides causing less wind in addition to the masking effect that the machine house has on the wind resources. The layout of the wind turbines is chosen so they are placed within the yellow area which has the best wind resource giving higher production values.

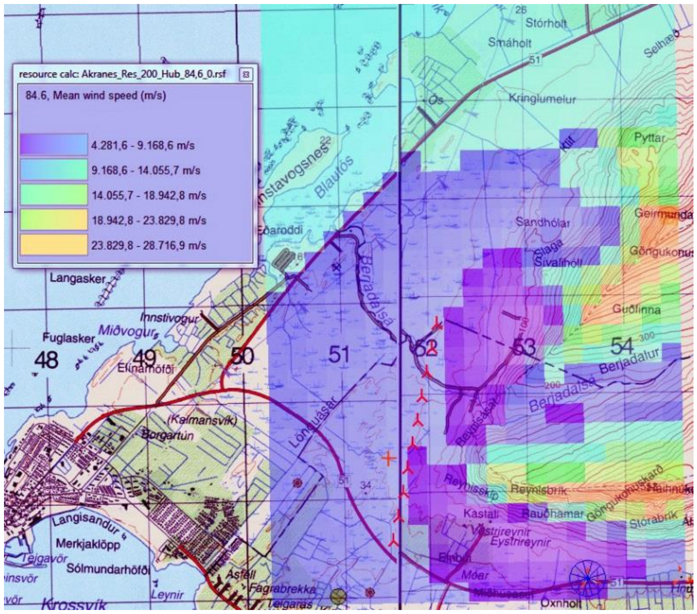


Figure 3.12: Wind resource map for the Akranes site. (Source: WindPRO)

In the case of the Akranes site, the scenario is a little bit different from the Svartsengi site. The town is in the lower left corner of the figure dominated by the town local mountain, Akrafjall Mountain on the right. The highest peak of the mountain is in 643 meters above sea level and is relatively flat on the top. The wind turbines location was chosen to be at the foothills of the mountain and in the vicinity of the town. The wind resource maps shows that besides an obvious better wind resources on the top of the mountain, that a better wind resources are found either very close the town, or further away from it (to the upper right corner of the figure). The preferred wind turbines location are, like described in section 3.3, that the wind turbines would be situated close and very much visible from the village, almost in people´s backyards, and aligned in a same manner as at the Svartsengi site. It gave considerable restrictions in choosing the most preferable wind turbine location and alignment. The position shown in figure 3.12 gives relatively poor production values in relation to other locations in the area, and therefore not a feasible option in relation to other locations in the area. But since the thesis has the aim of investigating people´s view towards wind power projects, where at least one wind farm is designed and placed in “people´s backyard” this location is chosen for the thesis even though it gives poorer production values than it could if the turbines would be placed elsewhere.

3.7.5 Measure-Correlate-Predict

Essentially two methods exits in order to predict future wind resources at a wind farm site [81]:

1. Correlate on-site wind data recorded at a long-term reference station.
2. Use only on-site wind data

In order to calculate a site´s long-term average wind speed a standard measure-correlate-predict method, shortened to MCP can be used. MCP is used for long-term correction of on-site measured wind data based on correlation with long-term reference data [51].

For this thesis the method was used using the MCP toolbox in WindPRO. The MCP toolbox in WindPRO calculates possible future production values according to method one listed above, with uncertainties and losses such as wake losses, wind data long-term correction and other wind related losses. The toolbox provides direct access to different MCP methods, linear regression MCP, matrix method MCP, Weibull scale MCP and wind index MCP. For the MCP calculations done for the thesis the chosen calculation method was linear regression method since ground stations providing high frequency data do, as a rule of a thumb, work better with linear regression method [82].

The measured wind data for the sites originates from meteorological masts owned and run by the Icelandic met institute which is projected to hub height as described in section 3.6. The data covers time period of 10 years from 2002 to 2012. And in order to use suitable long-term wind data, MERRA reanalysis data available from 1983 and recorded in the vicinity of the sites is used.

MERRA reanalysis data is a dataset consisting of historical weather and climate data observations from various sources, mainly satellites, radiosonde and radars measured over given time and then assimilated and loaded to database from where it is possible to extract various values, such as wind speed, over given time period for a given location around the globe [52].

3.7.6 Noise

At the time being there are no regulations in Iceland regarding noise from wind turbines, but chances are that when these regulations will be made that they will be based, to some extent, on Danish regulations. Therefore Danish regulations are used for the purpose of validating if the chosen location is according to regulations. According to these regulations, a wind turbine may not produce more noise than 39 dB at 8 m/s and 37 dB at 6 m/s the most noise-exposed point if placed close to a residential and summerhouse areas. If a wind turbine is placed in an open land then the noise limit is in the most noise-exposed point 44 dB at 8 m/s and 42 dB at 6 m/s up to 15 meters from neighbouring dwellings [83].

For clarification a sound level at 35 dB is equal to a noise which occurs in a quiet bedroom at night or in a quiet library. Sound levels at 45 dB are equal to an average home conversation or as the lowest limit of urban ambient sound. 55 dB is equal to conversational speech in 1 m distance or conversation in restaurant or office. Sound levels above 70 dB might start to annoy some people while sound levels above 90 dB might damage hearing if exposed to the sound over 8 hours. 100 dB is equal to jackhammer or a farm tractor. [84]

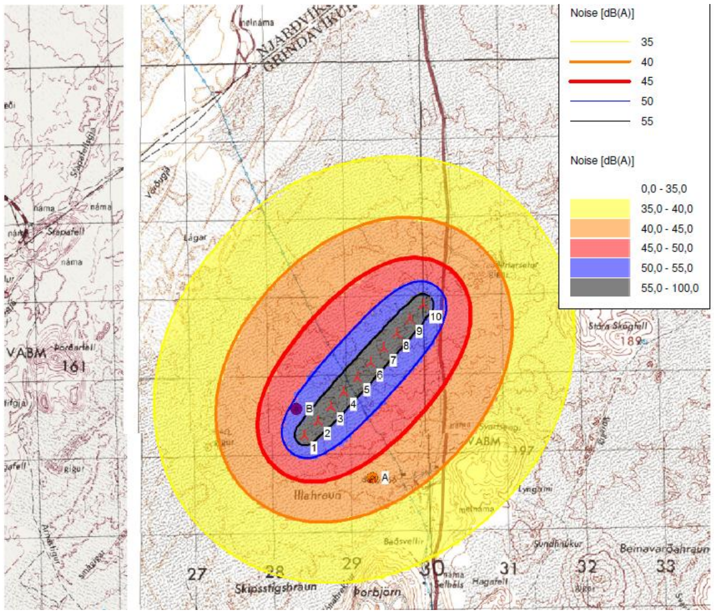


Figure 3.13: Noise from wind turbines situated at Svartsengi. (Source: WindPRO)

Figure 3.13 show the areas affected by noise at the Svartsengi site, with wind speeds at 8 m/s which is the wind speed that occurs in 7 % of instances as figure 3.9 shows. The Blue lagoon spa is situated by the orange dot marked with “A”. The yellow colour represents the area affected with 35-40 dB noise, the orange area where the Blue lagoon spa is placed within, is exposed to 40-45 dB with wind speeds of 8 m/s. These measurements do not take into account masking noises from other sources in the area.

In the case of the Blue lagoon spa which is placed in a lava field and in the vicinity of geothermal power plant, there are high chances that the 45 dB would not be audible when other background noise is taken into consideration.

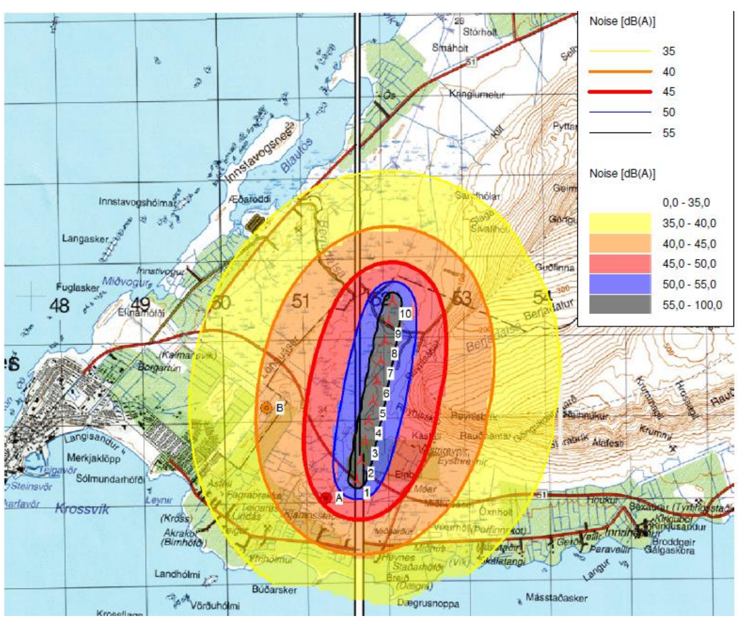


Figure 3.14: Noise from wind turbines situated at Akranes. (Source: WindPRO)

For the Akranes site which is situated in the vicinity of residential areas, the most outermost houses are affected by slight noise from the wind turbines. Figure 3.14 shows that some houses would be affected by 35-40 dB at 8 m/s (yellow area). Few residential houses are placed in an open area within the orange and red area, and they would then be affected by sound levels ranging from 40-50 dB at 8 m/s which is in upper level of allowed noise. Furthermore would the wind farm limit considerably the possibilities for further expansion of the village, questioning the feasibility of the location?

The figures presented in this section were used in the interviews conducted for the thesis in order to get people reactions, views and opinions when presented to actual values, in this case noise values.

3.7.7 Shadow flicker

From the surveys and interviews conducted a strong indication was experienced towards that Icelanders have considerable lack of knowledge on subjects regarding harnessing of wind power with wind turbines. One of the aspects that most respondents didn't have any knowledge about was the flickering effect which the rotating blades of a wind turbine cause when the sun rays shines through it and generates blinking shadows, called shadow flicker. This phenomenon that was discussed in section 3.2 occurs during a limited amount of time in a year depending on the position of sun in terms of altitude and the height, direction and distance to the point of nuisance. The effect might cause, though it is not likely, epilepsy seizures as a result of photic stimulation. In a report where the health impacts caused by shadow flicker are studied, it is doubted that they have any effect on people´s health [85].

In Denmark there are no laws regarding shadow flickering but general guidelines that implies that 10 hours is used as the limit. In the UK an assessment must be made at all dwellings within ten rotor diameters of the turbine location [51].

The following graphs are generated with the shadow flicker tool box in WindPRO and show the amount of hours in the year this effect can cause nuisances to the people living or visiting the area. The calculations are based on a worst case scenario.

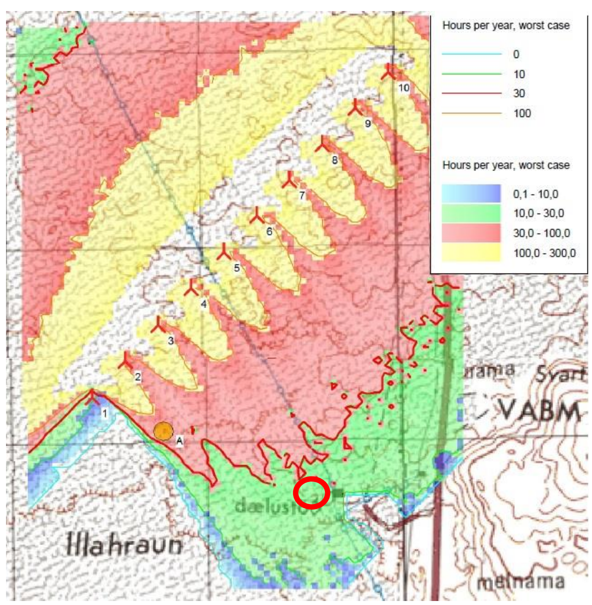


Figure 3.15: Areas affected by shadow flicker from the wind turbines placed at Svartsengi. (Source: WindPRO)

Figure 3.15 shows the areas affected by shadow flicker at the Svartsengi wind farm site. The Blue lagoon spa is situated where the red circle is placed within the green area, which means that visitors might experience the blinkering effect for 10-30 hours per year. However for this particular site i.e. the Blue lagoon spa, and due to how it is located in a lava field with few meters high lava walls surrounding it, the effect might be minimal and not cause any nuisances to the people who are enjoying themselves and relaxing in the spa.

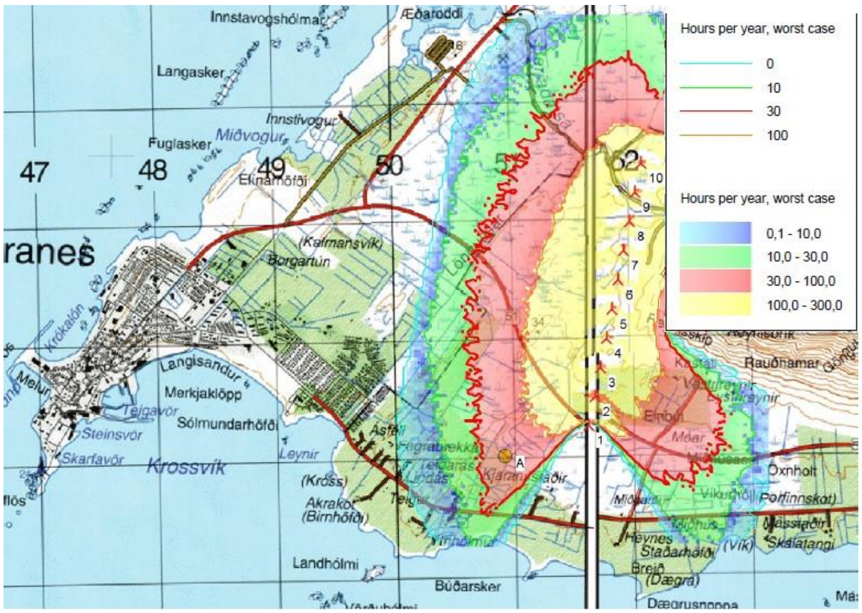


Figure 3.16: Areas affected by shadow flicker from the wind turbines placed at Akranes. (Source: WindPRO)

The shadow flicker effect would not reach the main inhabitant area of Akranes, but however there are few houses placed in open area closer to the wind farm that would be affected by the phenomenon for 30-100 hours per year. The area that is affected by the shadow flicker reaches approximately 1.5 km from the wind turbines towards the village and limits future use of the land affected by the shadow flicker for further use as an residential area, making the chosen location of the wind turbines questionable.

The figures presented in this section were used in the interviews conducted for the thesis in order to get people reactions, views and opinions when presented to actual values, in this case shadow flicker values.

3.7.8 Zones of visual influences (ZVI)

The areas which the wind turbines will have influence on in terms of visual impact can be determined by using the ZVI module in WindPRO. It calculates the visual impact of wind turbines on the landscape and the spots from where you will be able to see one or more wind turbines. The ZVI analysis is useful in discussions regarding local and regional planning and when assessing alternatives projects or wind farm planning proposals [51].

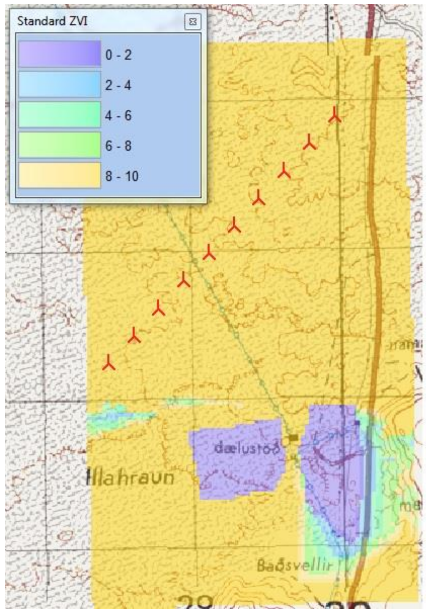


Figure 3.17: ZVI assessment for the Svartsengi site, the colors represent the number of visible wind turbines from a certain point. (Source: WindPRO)

At Svartsengi the machine house and the steam from the geothermal plant blocks the view to the wind turbines considerably when located in the area close to it. The purple area on the left is the location of the Blue lagoon spa which is placed approximately two to three meters below the surrounding lava field. The colours represent the number of wind turbines visible from a certain point and for a person enjoying a nice warm bath in the lagoon the wind turbines would not be visible or at least a very small portion of them. However would they be all be visible when accessing the area by road, causing annoyances for some people as the survey results presented in chapter 6 tells.

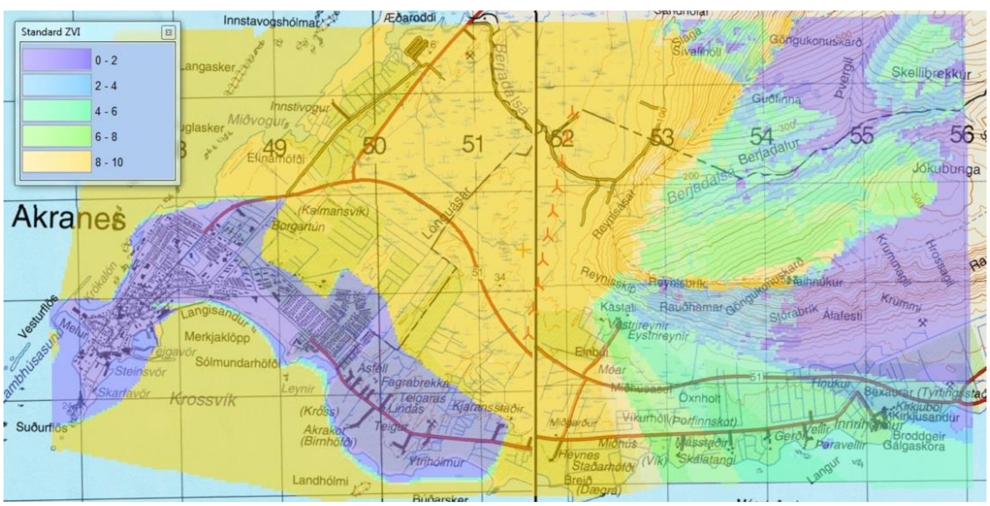


Figure 3.18: ZVI assessment for the Akranes site, the colors represent the number of visible wind turbines from a certain point. (Source: WindPRO)

In the case of the Akranes wind farm site, the wind turbines would not be visible within the town to large extent. The housing in the town consists of one family houses and three to five story buildings, where the newest residential areas situated in the edge of the town mostly are low raised one family houses while the older part of the town has higher buildings. From the edge of the village the wind farm would be more visible and so as when approaching the village, while when located in the older part the wind farm would be less visible. The town local mountain, Akrafjall Mountain, is a popular trekking destination where many climbers approach the mountain from the side that faces towards the village. When climbing the mountain the wind farm would be highly visible from the slopes, and might interfere with some people´s perception of being in the unspoiled nature, but nevertheless is the village itself also very visible from the slopes which might reduce the visible interference caused by the wind turbines. When the top of the mountain is reached the view to the wind turbines will gradually fade out allowing the hiker to enjoy the unspoiled view towards the surrounding fjord and mountains.

3.7.9 Key values

Below are listed main results and values from WindPRO and compared between the two case studies sites. The –10 % value is to compensate for uncertainties of energy production and is a part of a risk analysis for financial calculation. The 10 % value will in some cases not be sufficient as the calculated production value depends heavily on the terrain conditions and the wind data used for this purpose [51].

	Svartsengi	**Akranes**	**Explanations**
AEP	129 GWh	81.4 GWh	Annual energy production, based on10 years of measured data projected to hub height
AEP (-10 %)	116.1 GWh	73.2 GWh	With -10 % compensation due to uncertainties
AEP MCP calculation	110 GWh	78.5 GWh	Long-term corrected calculation, based on 29 years of reanalysis- and measured data (figure 5.3)
AEP MCP calculation (-10 %)	99 GWh	70.6 GWh	With -10 % compensation due to uncertainties
Capacity factor	44.2 %	27.8 %	Actual output of the wind farm divided by potential output
Capacity factor MCP	37.7 %	26.9 %	
Park efficiency	94.1 %	93.3 %	AEP divided with Gross production (no losses)
Park efficiency MCP	92.1 %	94.1 %	
Mean WTG production	11.6 GWh	7.3 GWh	Average production of single wind turbine
Mean WTG production MCP	9.9 GWh	7 GWh	
Full load hours	3871 hr/yr	2441 hr/yr	Hours in a year that the wind turbine is on maximum energy yield
Full load hours MCP	3303 hr/yr	2354 hr/yr	
Mean wind speed at hub height	11 m/s	8.1 m/s	
Mean wind speed at hub height MCP	9.5 m/s	7.9 m/s	

Table 3.1: Key values for the two wind farms at Svartsengi and Akranes with long-term corrected MCP values extracted from WindPRO.

The wind analysis in section 3.7.3 showed that the wind resources at the Svartsengi were superior to the wind resources at the Akranes site, so it is of no surprise that the energy production at Svartsengi, capacity factor and efficiency is higher there than for the Akranes site. The MCP calculation gives lower production values since the calculated long-term correction gives indication to decline in wind speeds for both sites. Typical capacity factors are up to 50 % so a capacity factor of 44.2 % as it is for the Svartsengi site is acceptable while the factor at the Akranes site below 30 % is less favorable.

4 Reviewing social acceptance of wind power

This section of the thesis is devoted to reviewing literature studied and interviews conducted regarding social acceptance of wind power. Furthermore this chapter contains review of views on utilization of energy resources in the Icelandic highlands, followed by summation of main results drawn from literature study and interviews.

4.1 Literature review on social acceptance of wind power farms

When developing and raising a RE solution such as wind farm several barriers have been identified. Painuly developed a structure for identifying these barriers by dividing them in categories and elements within the categories. Several categories were identified including one called *"Social, Cultural and Behavioural*". One barrier within this category is social acceptance with key elements such as lack of knowledge, aesthetics, non-belief in the technology, and preference for other energy sources [86].

A number of articles and reviews have been written about social acceptance of wind farms and projects and means to increase public satisfaction have been pointed out. These means and methods all have a common denominator when it comes to planning of wind farm projects but the actual execution varies to some extent depending on geographical location, community type and social conditions.

In an article by Jobert, Laborgne and Mimler; *Local acceptance of wind energy: Factors of success identified in French and German case studies* [87]. A few factors are pointed out that the authors count as being crucial when designing a wind farm. They are:

Site specific:

- Visual impact, how the wind farm fits into the landscape. Former use of the territory and people perception of it. Ownership of the territory, communal or private. Local economic situation and role of tourism.

Project management:

- Local developers and contractors. Transparency and local participation to the project. Creation of local network of support about the project by the developers. Ownership of the park, financial participation of the local population.

These factors are based on three case studies in France and two in Germany. The first case in France is located in Southern France in the Languedoc-Roussillon region approximately 50 km west of Montpellier. The planning period was until 2004, and in the period of 2002 to 2004, 27 interviews were conducted to approximately 200 residents of the area that the project is affecting. Like other areas nearby this area receives numerous tourist and the exact location of wind turbines was previously used as recreational area. The developer was from a local town and the entrepreneur as well.

This project received strong dissatisfaction from the local people and a coalition of winegrowers and the tourist industry launched a juridical appeal against the building permit which was rejected later. The coalition was worried about the area would get an industrial stamp if the wind farm would become reality and that the area would lose it sense of "authenticity" reducing the amount of tourist visiting the area. In the planning process the developer gave out no information to the public and it was just when the building permit was announced that the people heard about the existence of the project. This caused general dissatisfaction resolving in the coalition against the project.

In order to reduce the damage the developers hired a local journalist and young locals who lobbied for the project and helped them to build a network of friends and allies. Step by step, a coalition in favour of the project was established and the farm was finished in 2004.

The second case in France is also in the Languedoc-Roussillon region and the developer was the same as in the previous case. Due to previous problems the developer now searched for a more isolated area for erecting four wind turbines. And since the commune was in dying need for new economic opportunities it reacted very positively to the developers proposals.

As before, the information given to the public was very little with just one small meeting for the local actors. At same time a major controversy about toxic dumping was occurring in the community which had positive effects for the wind farm project where numerous citizens saw the wind farm project quite harmless in comparison to the toxic dump and the park was realized in 2004 without complications. Nevertheless the citizens expressed a strong wish for more public participation in the future.

The third case is located in agriculture and tourist area on the coastline towards the Atlantic Ocean, the wind turbines location is close to bird protection zone. The park consists of eight turbines where three of them are owned by the local authorities.

Public meetings were frequent where the wind park was described as a possible tourist attraction. An influential association administrated the bird protection zone which was integrated into the project process by convention to finance an analysis of the parks impact on the reserve and maintaining an employee for the zone. Later the association organized visits to the zone to see the birds and the wind turbines. In the year followed by the parks opening, an estimated 100,000 persons visited the area to the great satisfaction of local actors.

Both German cases were conducted in 2005 in Rheinland-Pfalz region located in the mid-west part of Germany. For the first case there was a public information meeting where about 200 inhabitants were given realistic ideas of how the landscape would change with visualizations, photographs and other material. The area planned for the wind turbines was former military area which needed new use. The developer also included photovoltaic, biomass and biogas in the park and stated it as an “energy park”.

The concept was largely celebrated by the people and after public discussion people were allowed to buy shares in the energy park. The realization of the park was in 2002.

The other German case was located on a private land in altitude of 300 m in a low mountain range; the land was commonly used for outdoor activities. The initiative to the project came from the developer’s side that was from outside of the region; the commune hoped that the private landowners would not be interested in renting their land for a wind farm but that was not the case. When a local newspaper reported on the plan, information meetings were held against the planned wind farm, with arguments such as “*that the private landowners would benefit while the rest of the population would suffer*”. A demonstration followed with the mayor being one of the main speakers, a petition against the turbines was signed by five hundred people and lawsuits were raised resulting in a delay of the project.

Caused by change in regulation the developers were able to skip the public hearing process if the wind park would have less than 20 wind turbines, this caused great frustrations among the opponents of the project and the park came to a realization in 2007. [87]

In an article by Kaldellis. *Social attitude towards wind energy applications in Greece*. The author points out general opinion towards wind power projects in Greece where there has been a rapid concentration (before 2005) of very large wind turbines limited to few geographical areas. The author conducts a survey in several areas where wind parks are considered to be a feasible option, the surveys emphasis on: "*The degree of public knowledge towards wind energy, the public awareness towards environmental issues and personal annoyance and the public attitude towards existing and new wind parks".* [88]

Among the main results drawn, that the necessity of public information is high when it comes to the wind energy sector. This conclusion harmonizes with the conclusion in the previously described cases where the importance of transparency and giving out proper information to the public is one of the main elements towards successful project. The study also shows that in the windy areas with large amount of wind turbines, people are more negative towards new farms; mainly due to the high wind power concentration, and especially if it happen during short time period; therefore is over exploitation not recommended. Furthermore gave the study indications towards that people might be interested in wind farm projects and therefore probably more positive towards them if they would by financially tangled to them through ownership.

Another conclusions drawn, is that people are mostly satisfied with existing wind parks, but however fairly negative towards new installations. There was clear line between acceptance of new wind farms between the Greek mainland and Greek islands, where islanders were more in favour of wind farms while mainlanders more against. The reason is not clarified clearly in the article but it is addressed that more wind farms have been erected in the mainland than in the islands. The most troublesome outcome according to the author is.

> *"is existence of a specific minority that is strongly against wind energy applications disregarding any financial benefits of all these projects".*[88].

Those are the people that already have made their minds up on a certain subject and cannot be changed no matter what arguments are drawn up.

In another report *"The inclusion of social aspects in power planning"* by Ribeiro, Ferreira and Araújo the authors address the inclusion of the social dimension when it comes to planning of power systems. In the report it is stated that although it may be costly and difficult, the involvement of the public in the planning process will lead to more widely acceptable outcome [89,90].

In a master thesis work *"Social Acceptance of Wind Power in France"* by Maxence Quatrehomme the author outlines general public opinion in France towards wind power farms and points outs ways to increase general public contentment on that matter. One the main conclusions from this project are that the local acceptance in France towards wind energy projects drops in accordance to increase in installed wind turbine capacity, thus the more an area or region is exploited with wind turbines the more will public acceptance drop. Another conclusion is, like in the most previously discussed literature, that involvement of the local public in planning process is essential for gaining acceptance of a project. [91].

Corscadden, Wile and Yiridoe state in an article, *"Social license and consultation criteria for community wind projects"* that key elements for social acceptance are that a high level of consultation and early communication to the inhabitants is preferred by both the community and developers. That community-based projects are more favourable and the use public meetings and online forums for receive expression of ideas and feedback on the project is recommended which will both benefit for the stakeholders as well as the public. [92]

In the report *"Áhrif Hólmsárvirkjunar á ferðamennsku og útivist"*(e. Effects of Hólmsárvirkjunar hydro power plant on tourism and recreation) by Sæþórsdóttir and Ólafsson are introduced outcome and influences of planned hydro power plant in south Iceland, a resource that has been categorized in pending class (see section 1.3 and figure 1.9), on tourism and recreation in the area affected by the plant and related structures. Data was collected with a survey and interviews with tourists in the area and stakeholders in the tourist field.

That area is at the edge of the highland area, an area in the centre of Iceland and elevated higher than 400 meter above sea level. The area has no infrastructure except dirt tracks, a primitive hut and a toilet. About 90 % of travellers around the area experience it as unspoiled. The distribution of travellers in the area is that 9 % were eager nature conservationists 36 % were moderate nature conservationists, 53 % ordinary travellers and 2 % are urbanites. This distribution applies to most of the south highland area [93].

A majority of the visitors to these areas wants to get out in the unspoiled nature, are sensitive to the distortion of it and do not want any major development in it. Most of the respondents were against the power plant, both tourists and tour operators. They thought the area would not be unspoiled anymore and visual impacts would be negative. Few persons thought though that the access to the area would improve and that would be positive for the travel industry. Most people thought that hydro power plant would be better than geothermal plant since they are more easily adaptable to the landscape.

Most people were negative towards transmission lines but many of the foreign respondents said that they have become immune against them because how common they are in their home country. [93]

4.2 Interviews regarding social accept in Denmark

In an interview with Søren Stensgaard who is former lead person of the Samsø energy island project, a project with the aim of making the Danish island of Samsø sustainable in terms of electricity. Interesting viewpoints based on his experience in the field of social acceptance of wind power emerged. One of the solutions towards making the island electricity sustainable was by erecting land and off-shore wind turbines on and around the island.

According to Søren the islanders were relatively positive towards the project since they were a part of a development that they wanted to happen. But on the other hand if this development would have been something that the people didn't want to occur, than he said that people would be more likely to be negative.

> *"If one is a part of a development and receives something in return, than it is a way to get people to be positive. If on the hand it is development which one has not asked for, or don't get anything in return, then one has permission to be negative."* [94]

This viewpoint was also agreed on by Inge-Dorthe Larsen, chairman for a wind turbine cooperative in Samsø, who said that the energy island project helped in order to get people's contentment and that they are generally pleased with the wind turbines. Regarding supply and demand for shares, she said that it is relatively easy to sell shares and there is always a buyer available.

Asked what means Søren consider to be important in order to get people's acceptance, he answered:

> *"To get people do be positive, is to invite them to be participants in the planning process, get people to be active participants in the process in deciding where the turbines should be placed and so on. Other thing is to allowing people to gain money on possible profits, and there are many people that profits considerably by owning a share in a wind turbine."* [94]

He takes one example of a near-shore wind farm project placed in Aarhus Bugt close to Samsø, where the islanders were interested in being a part of. But there was not listened to any arguments of the local people or any provision at Samsø, which surprised the locals, resulting in resistance to the project from the islanders.

To get peoples acceptance is sometimes difficult he says, some people wants wind turbines while others do not and to get people to participate in the planning process can be difficult, but it is worth it in the long run. Søren advises if certain location is not accepted by the locals, than look at the second best option, or third best.

> *"This thing with the accept, that is important."* [94]

Regarding financing of cooperatives, Søren says that the banks were willing to give loans to buying shares with guarantee in the share itself, he furthermore adds that shares in wind turbines with Danish support scheme are very safe investment. The support scheme includes guaranteed electricity price for ten years, if that would not be the case the investment would be more uncertain. The support scheme has though now ended according to Inge-Dorthe.

If people do not benefit from a construction or an item that might cause nuisances for people living close to it or in any other ways have some interests regarding the area it is placed on, then people might become negative towards it. Economic arguments outweigh all other, even nature arguments according to Søren. [94]

> *"What's in it for me? And if you answer it then you are going somewhere. If not, then people will start to complain about nuisances that the wind turbines generate. Economic arguments are the most important, secondly are nature arguments. And one must take complaints seriously."* [94]

4.3 Summary

In summary of the reviewed research it is assumed that few key factors are decisive for social acceptance of wind power projects and these factors are mutual for both Iceland and other countries where people lives according to western standards. The conclusion that is drawn from the literature study is that it is key essential to involve the public in the planning process and hold information meetings.

Don´t over exploit an area, since the contentment drops in accordance to installed capacity on it.

Furthermore, does a financial benefit change people perception towards wind farms, either by income to the local community or by offering people to buy shares in wind turbines in a cooperative that in time might give them yearly revenues. The term *"What's in it for me [local people]?"* a wind farm planner should keep in mind.

Another valuable argument is the usage of the land where planned wind farm is supposed to be, is it used as recreational area or is historically or naturally important or valuable, what will it used for when the wind turbines have been erected? Both former and future use is important.

Community-based project are likely to be more accepted and that the labour working on the project both during the installation and in the operation time is from the local area. People are more positive towards existing wind farms than new wind farms, giving the perception that in the end people will accept wind turbines and wind farms in their area.

Finally from the Icelandic report, that the majority of tourists, both local and foreign are against construction in the highland and that they want to keep the highland untouched and unspoiled.

5 Wind energy cooperative

In this chapter are wind turbines cooperative discussed and the economic feasibility is assessed in relation to conditions in Iceland. The calculations involve estimation of future development of wind resources at the case study locations, assessment of possible electricity price development in Iceland. And an estimation of operation and management costs, capital cost and a sensitivity analysis of economic feasibility of a cooperative.

One of the results from the literature study is that financial benefits have large effect on public accept of wind power projects, for example by allowing people to buy a share in wind farm or wind turbine through a cooperative. Wind energy cooperative is an association of owners of wind turbines where each owns a part or number of parts in single or number of wind turbines in a wind farm. The model was initially designed and developed in Denmark where families were offered tax reduction for generating their own electricity [95]. In Denmark wind power has gained considerable high acceptance with establishing of wind energy cooperatives playing a major role [96].

A person that buys a share in cooperative, receives regular income from electricity sale, the income is dependent on number of shares owned, the electricity price and the amount of electricity that the wind turbine or turbines produces and is sold to a market. The number of shares for a wind turbine cooperative in Denmark depends on estimated yearly electric production of the wind turbines or the wind farm, one share is equivalent to 1000 kWh. A price of share is the total cost of the project or turbine divided by the total amount of shares.

In the Danish island of Samsø such a cooperative has proven to be successful. In 1999 Samsø authorities decided on making the island sustainable for electricity by raising eleven wind turbines that should be owned by the local people through a cooperative, in order to get support from the locals. In 2002 were ten offshore wind turbines erected where one of them is owned by a cooperative of people. In the beginning people bought shares more of a vision to be part of a sustainable energy island, and gradually the number of owners increased and today there are over 340 shareholders to a wind turbine, both local people and non-local and a general contentment is amongst the shareholders about their ownership [97].

In this thesis is the Danish model is used as a platform for assessing the feasibility of similar cooperatives in Iceland using production values from the two wind farms discussed in chapter 3. The yearly electricity production of the wind farm in Svartsengi is calculated to be 116 GWh and 73 GWh for the Akranes site, when 10 % loss for uncertainties is taken into the account. The production values found the building block for the calculations of economic feasibility of wind energy cooperative for the two case studies wind farms.

5.1 Price of wind power projects in Iceland

Some difficulties is associated in assessing the price of wind power projects, firstly the price is dependent on location in terms of transportation costs, infrastructure and so on, secondly is the wind turbine market driven by individuals quotes [68] and therefore is a price hard to get without actual offer from a producer.

According to the European Wind Energy Association (EWEA) is the price 460 € pr. m^2 [37] which counts as being 0.85 M€ pr. MW for the case studies that consists of ten E-82 Enercon 3 MW wind turbines with a rotor diameter of 82 m. According to Commission of the European Communities the price is 1 M€ to 1.2 M€ for installed MW [38].

One of the research posts in the Icelandic wind energy project is to evaluate and estimate the future price of wind energy projects in Iceland [33]. In a newspaper article it is stated that the price for the two wind turbines which were erected in Iceland in January 2013 is about 300 Misk [98] which is 1.04 M€/MW. In an interview with Margrét Arnardóttir, the project manager for the wind energy project at Landsvirkjun, the total price for the installed wind turbines including all posts is around 480 Misk (1.67 M€/MW) [39]. This number is for the pilot project and includes posts that in next projects will be cut out or lower. Few weeks after the interview with Margrét a new cost assumption was given, stating the price to be 1.16 M€/MW.

With these arguments in mind the price for installed MW wind energy in Iceland is set to 1.2 M€.

5.2 Operation and maintenance costs

The estimation of costs associated with operation and maintenance is a difficult one to undertake. The operation costs includes cost components such as administration, insurance, land rent, regular maintenance and spare parts associated etc. The maintenance cost is related to wind turbine type and size, the location of the wind turbines in terms of accessibility, climatic conditions, if they are exposed to salinity and in case of Iceland, ash and the age of the wind turbine, where maintenance increases with age etc. [99].

According to the Danish wind turbine owner's association (DWA) is the estimated price of yearly O&M costs for larger than 2 MW wind turbine 21,500 €/MW [99]. In an email from Margrét dated 15th of May 2013, she states that the O&M cost for the Icelandic wind energy project is according to their calculations 4 per cent of total investment cost [100]. In case of one 3 MW wind turbine, as is used in the case studies, it would mean a yearly O&M cost of 144,000 € annually but 64,500 € if the price from Danish wind industry association is used.

In a research on wind turbines economy written by project group consisting on Danish experts from EMD International, Risø, EA Analyse, the Danish wind industry and the Danish wind turbine association it is given that a O&M cost increases as a wind turbine gets older [101], according to figure 5.1.

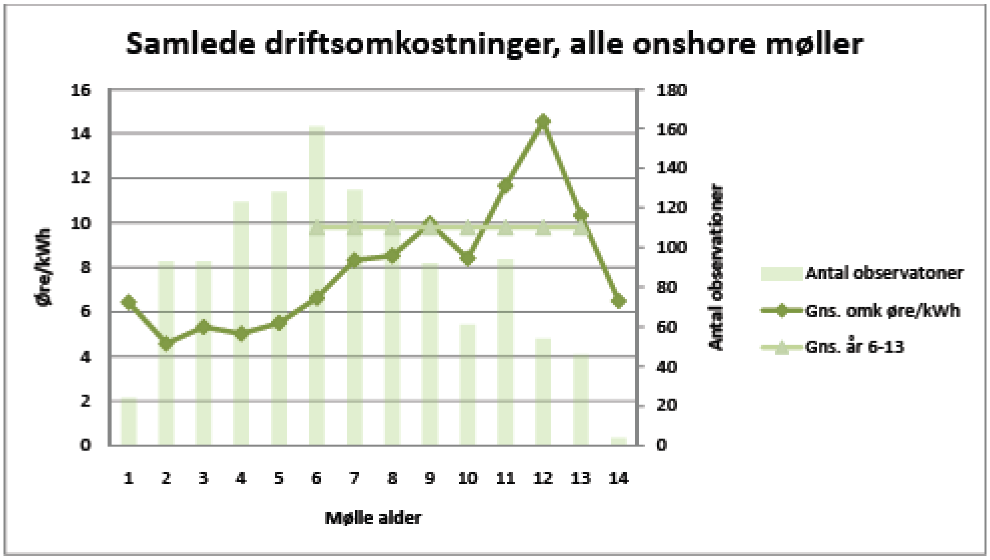


Figure 5.1: O&M cost in Danish øre/kWh for all wind turbines bigger or equal to 600 kW. [101]

In the report it is stated that the period from years 6-13 represents the O&M cost during the wind turbine lifetime since after year six the wind turbine is no longer warranted [101]. That price is 10 øre DKK/kWh (13.43 €/MWh)

It is a fact that the O&M costs are declining rapidly due to improvements in technology causing less service maintenance. In a press release dated 1st of November 2012 from Bloomberg New Energy Finance, it is stated that the average price for full service O&M for on-shore wind farms have fallen by 38 per cent from 2008 to 2012, or just over 11 per cent per year. [102]

The price of 10 øre DKK/kWh (13.43 €/MWh) listed in figure 5.1 is based on data available until 2010 and according to the Bloomberg press release has the price declined since then, therefore is the price lowered by 33 % (11 % for each year) to 9 €/MWh, which fits decently to DWA estimations that the price of O&M for 2 MW wind turbines or bigger, is 6 øre DKK/kWh (8 €/MWh) [99]. From 2013 it is assumed by this thesis author that the price will continue to drop considerably until 2020, where it will maintain a 1 % declination until 2025 where it will level out. Figure 5.2 shows the estimated cost development for the case studies until the year 2038 based on numbers from Landsvirkjun, DWA and wind turbines economy report.

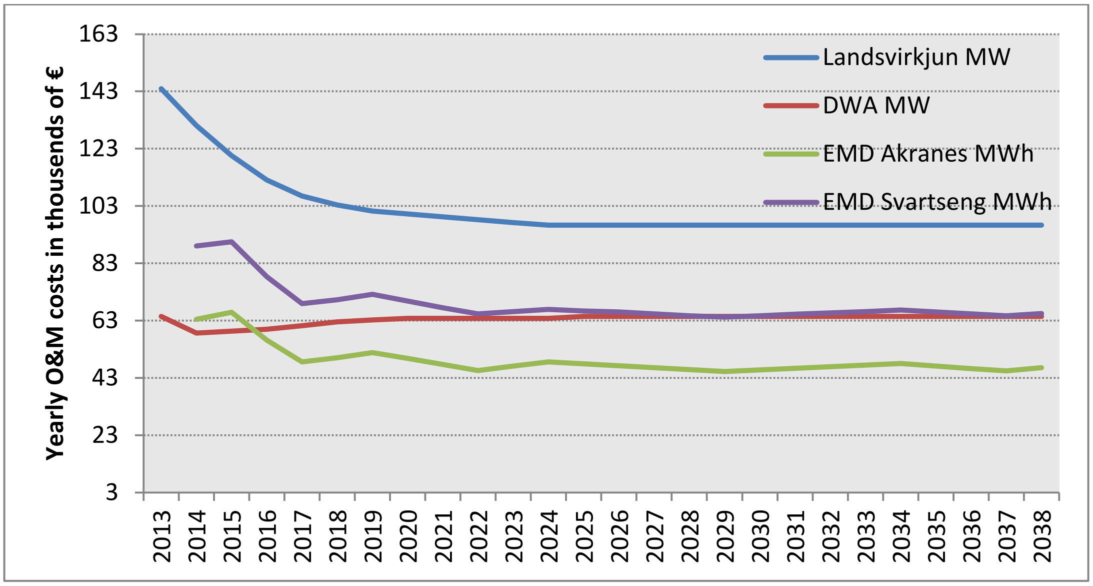


Figure 5.2: Assumed O&M cost development during the case study lifetime.

The O&M costs based on data from Landsvirkjun (blue line) and DWA (red line) are costs in relation to installed MW, while the green and purple lines are based on adjusted numbers, which originates from the report made by Danish experts, of O&M costs relative to production in MWh.

For the calculation of economic feasibility of wind energy cooperative in section 5.5 is the O&M cost of MWh used since a tear and wear on wind turbine is related to production, and the production is connected to wind speed and high wind speeds give more stress on the components of a turbine. It is therefore assumed that O&M costs based on production gives more reasonable results.

5.3 Possible future development of wind resources and energy production for the case studies

Wind resources changes over time, that fact is the source of the main uncertainty regarding wind farms and wind energy utilization.

For both site locations the annual mean wind speed has declined in recent years, or by 0.87 % at Akranes and 0.8 % at Svartsengi. Since the energy in wind increases by third power as equation (1) section 3.1 shows, it is not possible just to lower the energy production in same proportions as the reduction in wind speed is. Therefore the annual energy production AEP was calculated according to equation (1) during 29 years period from 1983 to 2012 for both locations, giving values seen in figure 5.3.

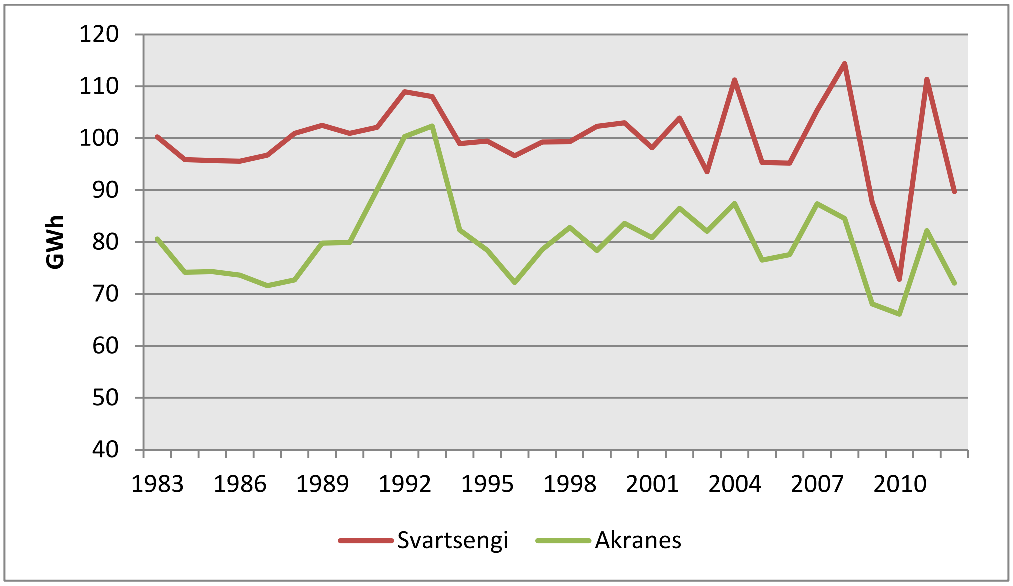


Figure 5.3: AEP for the two wind farms using MERRA wind data from 1983 to 2002 and on-site measured wind data from 2002 to 2012 which was projected to hub height.

The calculated AEP in recent years shows more and fiercer fluctuations than before, especially is the period from 2008 to 2011 interesting with a large drop of 32 GWh during that time, this might indicate some inconsistency in measurements. But however were the period from 2008 to 2011 exceptionally mild and with considerably lower wind speeds in south-west and western part of the country those in previous years according to the Iceland meteorological office [103]. Figure 5.4 shows the monthly average wind speed from 2002 to 2012 at the weather mast located close to Svartsengi, the red circle indicates the period where there is a large drop in energy production according to figure 5.3. A reduction in wind speed from 8 m/s to 7 m/s mean an energy reduction of 33 %, while a change from 6 m/s to 5 m/s mean an energy reduction of 42 %, this might explain the inconsistency apparent in figure 5.3.

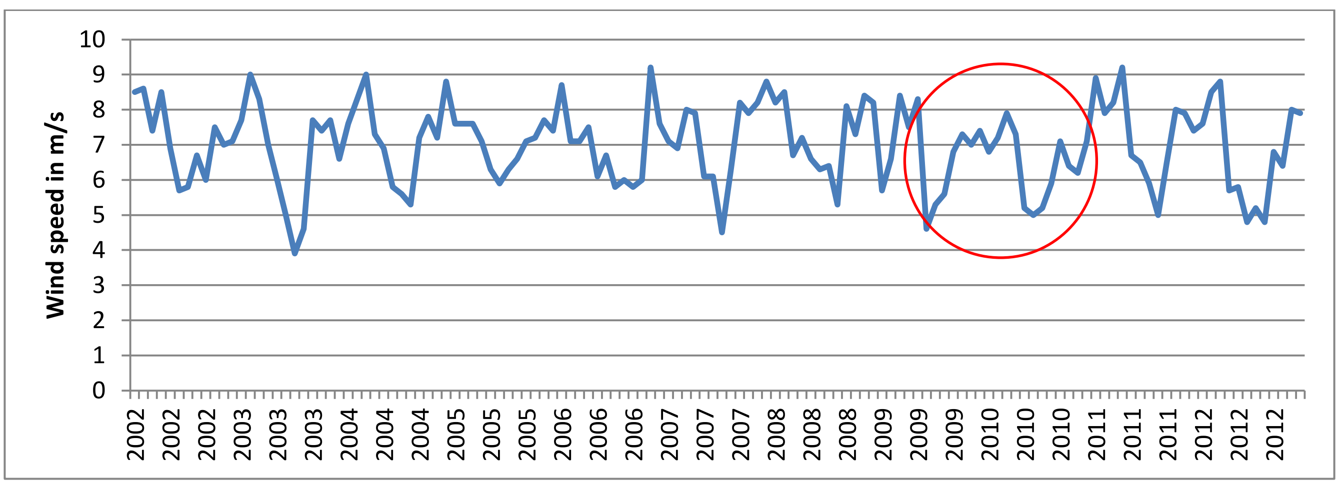


Figure 5.4: Monthly average wind speed for location near Svartsengi. (Data source: Iceland Meteorological Office.)

A MCP calculation gives an AEP value of 70.6 GWh for the Akranes site and 99.1 GWh for the Svartsengi site. The uncertainties and losses associated with possible future electric production with wind turbines are numerous such as wake losses, availability losses, turbine performance losses, electrical losses, environmental losses (due to icing, lightning's, hail, temperature, etc.), reduction losses (e.g.

due to momentarily reduction in production to reduce noise, avoid shadow flicker, migration of birds etc.) [51].

For the sake of simplification only few uncertainties and losses were added to the calculation since it only should give indications towards if the cooperative is feasible or not. Therefore only 5.9 % wake effect loss and 5 % turbine performance loss was added. 5 % uncertainties are added to the wind data and the power curve and 0.3 % to 1 % to every 10 m for the model extrapolation based on terrain description. These values are estimated to be relevant under good conditions in simple terrain [51] as is found at both case study sites in Iceland.

The input parameters for losses and uncertainties will give variable deviation from the standard production values which will deteriorate throughout the time evaluated. The variation values are presented in table 5.1 below.

Years	**Akranes**	**Svartsengi**
1	13.0 %	10.5 %
5	5.8 %	4.8 %
10	4.1 %	2.2 %
20	2.9 %	1.9 %
25	2.6 %	1.1 %

Table 5.1: Variability values for estimated AEP 25 years ahead until 2038.

These values presented in table 5.1 are multiplied with AEP values given by the MCP calculation and give variable electricity production ranging from 89.7 GWh to 109.5 GWh at Svartsengi and 66.5 GWh to 79.7 GWh at Akranes; the variation is highest in the first years and then evens out due to increased uncertainty in long-term prediction. For the feasibility calculation the estimated production values are allowed to fluctuate between the high and low limits throughout the turbine lifetime in order to give some indications towards possible income based on the production and electric prices. The production graph from 1983 to 2038 is shown in figure 5.5 together with the linear reduction.

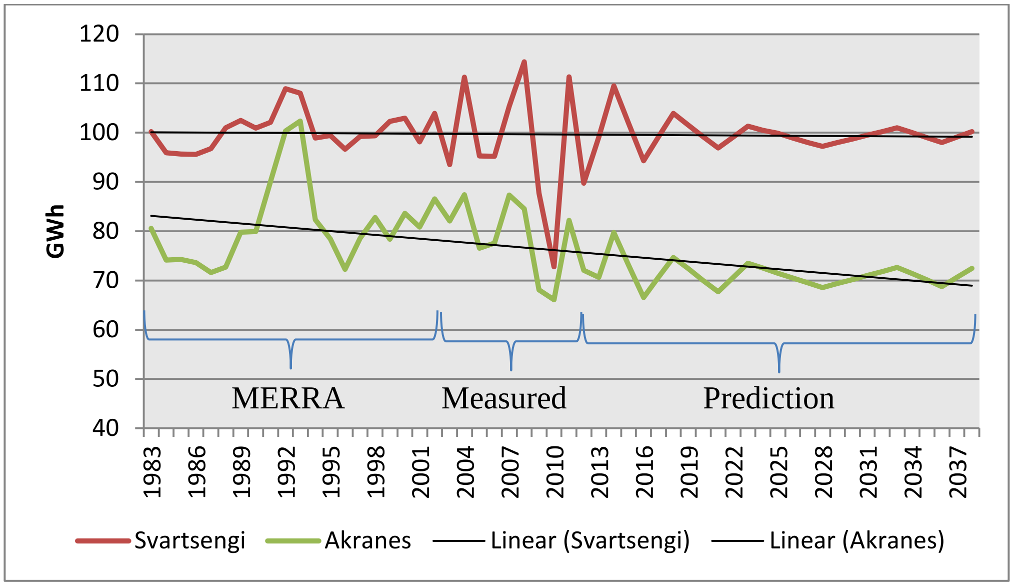


Figure 5.5: AEP from MERRA reanalysis data from 1983 to 2002, from measured wind data from 2002 to 2012 and estimated according to MCP calculation tool in WindPRO.

The site at Svartsengi is expected to maintain, to large extent, similar production values but the production tops will be less, but the site at Akranes is expected to decline in production in upcoming years. This prediction is of course subject to considerable uncertainties, for example might the quality of MERRA data be questionable along with the obvious question regarding future development of wind resources in Iceland. However is this prediction considered to be plausible and is used in the calculation of economic feasibility of cooperative together with estimated development of electricity prices presented in section 5.5.

5.4 Possible future development of electricity price

To assume the income, shareholders might receive from their ownership in wind turbines the future price of kWh of electricity in Iceland must be validated. First the price changes from few years back is investigated and secondly two scenarios for future price are introduced, these scenarios are:

1. The price will maintain the same linear increase based on past years prices.
2. Submarine cable, connecting Iceland to Europe’s electricity grid and making Iceland active participant in the European spot market. Assuming that the price will follow the same curve as above until the year when the cable is operational, then the price will rise for 20 % during three years period and from that point it will gradually decline after few years increase.

The electricity price in Iceland is at time being two folded; on one hand the consumers pays for the electricity production and on the other hand for the distribution. The distribution is a monopoly where the consumer must pay one certain company for the distribution, which company depends on where the person lives. However for the electricity, the consumer can choose which producer he buys electricity from. For example is the distribution utility on the area that the Svartsengi site is located at, HSOrka which runs the geothermal plants at Reykjanes peninsula and OR is the distributor for the area that the Akranes site is located at, OR owns and operates the geothermal power plant Hellisheiðarvirkjun and few others. It is assumed that the electricity from the wind turbines will be competitive to the electricity prices that these companies offer.

Scenario 1: Linear progression

In a report written by Jón Vilhjámsson at EFLA engineering [104] is the evaluation of electricity prices from 2005 to 2010 described for different types of consumers, from values presented in the report a liner progression curve and formula are calculated to estimate possible future increase in price of kWh until 2038. Possible price development based on the linear growth from previous years and calculated from 2013 until 2038 is presented in figure 5.6.

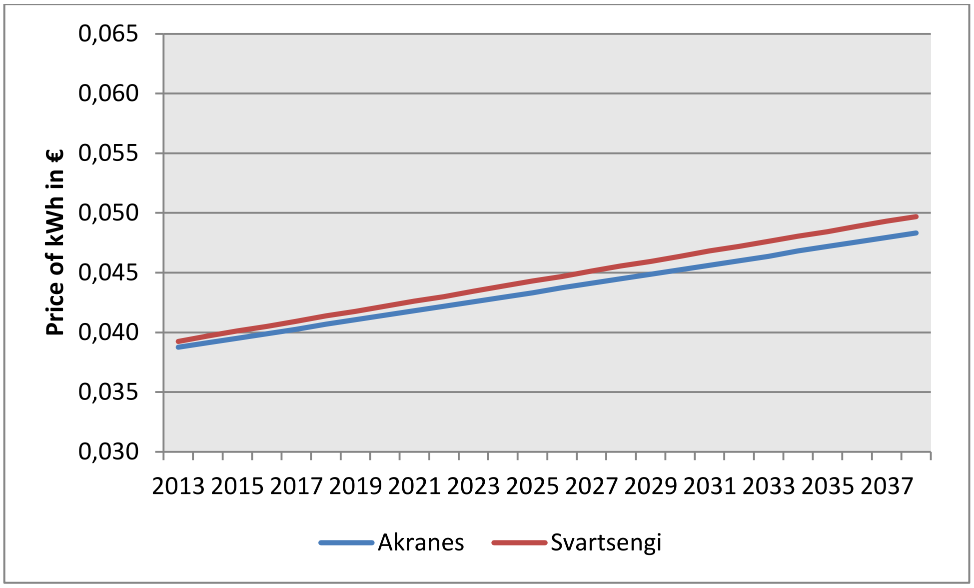


Figure 5.6: Possible price development until 2038 if the price will follow the same linear increase as it did from 2005 to 2010.

The increase in the price during the 25 years is approximately 20 per cent and is the development considered to be reasonable and used for the calculation of economic feasibility that is the subject of section 5.5.

Scenario 2: Submarine connection to Europe

By establishing electricity connection to bigger markets in Europe with submarine cable and become active participants in the European spot market, it is considered that the electricity price to Icelandic consumers will increase by 20 per cents [105,106] in the beginning of the operation time. It is furthermore assumed that the connection could be operational in the year 2022. And the price of electricity will increase by the 20 % in 4 years from 2021 to 2024 from there it follows possible price development based on experience from other Nordic countries that have wind power in conjunction with hydro power and are members of active spot market where the price has slightly decreased [107]. The price development which is considered to be reasonable is presented in figure 5.7.

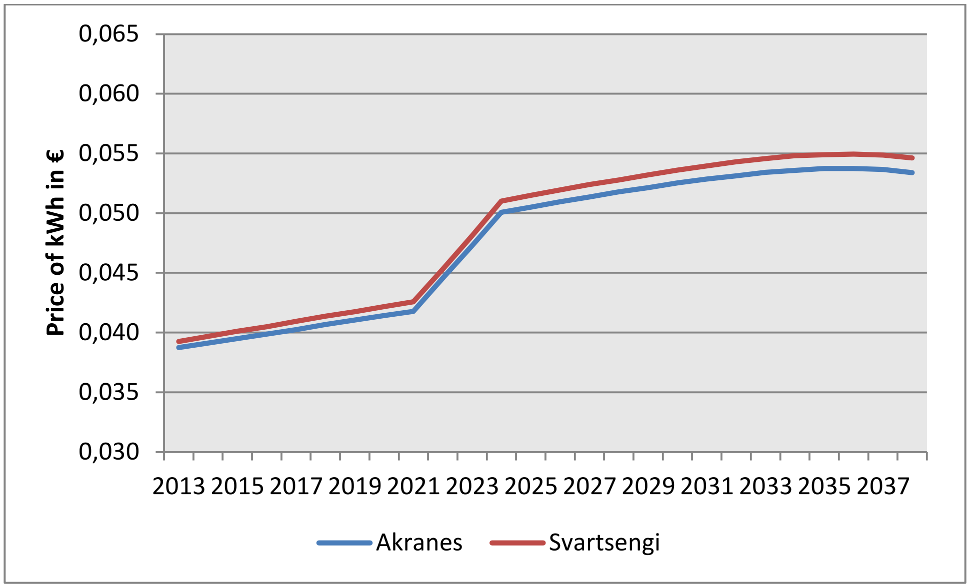


Figure 5.7: Possible price development until 2038 if a submarine cable is establish, causing increase of 20 % between the years 2021 and 2024, from that point it follows possible curve based on experience from the Nordic countries.

At the moment there is no active electricity market in Iceland so the price is more or less decided by the producers and the price is somewhat dependent to external conditions such as tariffs decided by the TSO Landsnet, distribution utilities etc. An Icelandic electricity market focusing on intra-day trading (ISBAS) was ready to be operational on November 1st 2008, and a spot market was planned to follow when sufficient experience was reached with ISBAS and intra-day trading [108]. But all these plans were postponed for indefinite time due to the economic crisis that hit Iceland that same autumn. What affect an electric market would have on the development of electricity prices in Iceland is hard to say but spot markets are likely to increase competition and benefit to both the consumers and hopefully most of the producers and dealers [108].

In the neighbouring Nordic countries the ability to store energy in hydro reservoirs has proven to be cost-efficient way to integrate wind power to existing energy systems where hydro power is governing. And in Denmark, which has a large share of wind power, has the ability to sell excess electricity, including from wind turbines, on spot market led to a slight decrease in electricity prices. [107]

This might also be the case in Iceland causing the linear growth to be less or even gradually fade out over time when more wind power has been implemented and spot market trading have become a reality. In the feasibility study that is the subjects of next section it is assumed that these considerations only have effect in scenario two.

5.5 Economic feasibility of wind energy cooperative in Iceland

The calculation of feasibility of wind energy cooperatives is thought as giving indications towards if joint ownership of wind energy projects in Iceland is in fact feasible option in terms of payback time and possible income a shareholder might receive during the wind turbine life time.

Like mentioned in previous section, the price of the wind farm designed for this study is decided to be 1.2 M€/MW and production calculated to 73.2 GWh at Akranes and 116.2 GWh at Svartsengi. These values are key sensitive for the design of the cooperative where the number of shares and price is determined by them.

	Akranes	**Svartsengi**
Number of shares	7329	11,614
Price of each share	491 €	310 €

Table 5.2: Overview of number of shares and price based on where one share equals 1000 kWh/year.

The nominal interest rate (is. nafnvextir) have since November 2012, been at 6 % and in April 2013, the inflation measured to be 3.3 % [109]. Using formula (4) the real interest rate (discount rate) is calculated to be 2.61 %.

$$Real\ interest\ rate = \frac{(1 + nir)}{(1 + inflation) - 1} \tag{4}$$

For the feasibility study the net present value of investment is found where the incoming and outgoing cash flow is calculated covering the wind turbines entire life time of 25 years. NPV can be described as the "difference amount" between the sums of discounted cash inflows and outflow. It compares the present value of money in the future, taking inflation and returns into account [110].

The outgoing cash flow is the initial investment cost i.e. the cost of share and all operational and management cost which was described in section 5.2. The incoming cash flow is the yearly revenues from electricity sale. It is assumed that the wind turbines will become operational in the beginning of the year 2013 and income will be paid to the shareholders one year later. Unforeseen occurrence such as damage or malfunction of the wind turbine that is normally covered by the shareholders or manufacturer if the wind turbine is still in warranty is not included in the calculation. It is therefore assumed that this calculation is a "best-case scenario".

Figure 5.8 describes the NPV and payback time for one share with no reduction in capital costs such as tax redemption, and on income based on electricity prices as shown in figures 5.6 and 5.7. Buying more shares just multiplies the investment cost and income in same proportions and therefore does the payback time not changes for investment of one share or 100, but of course is the income for 100 shares hundred times higher than for one share.

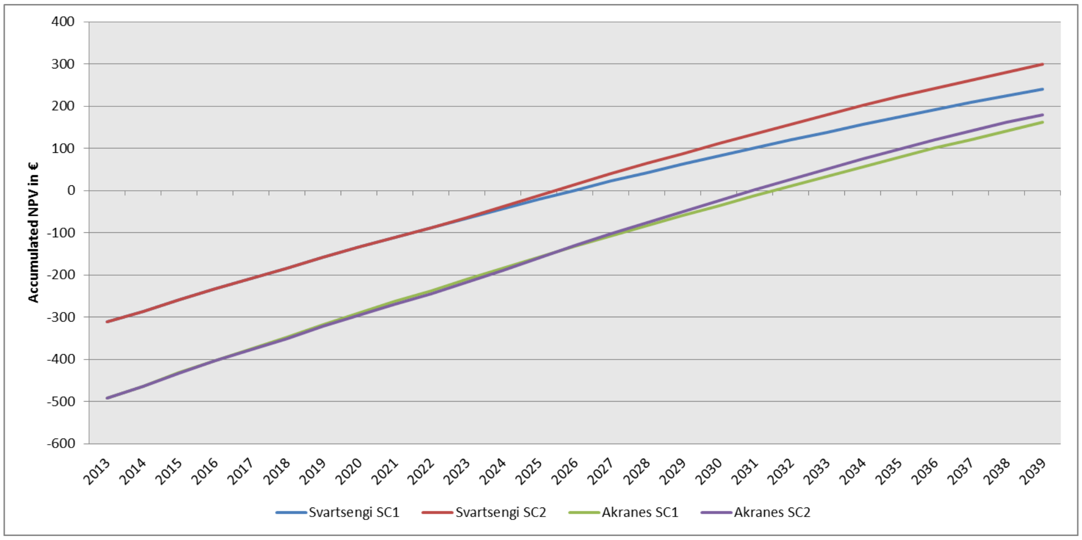


Figure 5.8: Accumulated NPV pr. share and payback time of investment with no reduction in capital costs and price as shown in figures 5.5 and 5.6. SC1 and SC2 mean scenario 1 or scenario 2.

In this case it would take 13 to 14 years for a shareholder in the Svartsengi cooperative to get initial investment cost paid back, depending on price development. If that person would buy in the Akranes cooperative, it would take him seventeen to eighteen years before he gets his money paid back.

5.6 Sensitivity analysis of feasibility

Like previously mentioned in section 5.1 the capital cost was set to 1.2 M€/MW. The price of wind energy on global scale has been declining and globally is the price estimated to be around 1 M€/MW [32]. So what effects would decrease in capital cost by 200,000 € in addition to 10 % tax reduction from the Icelandic government have?

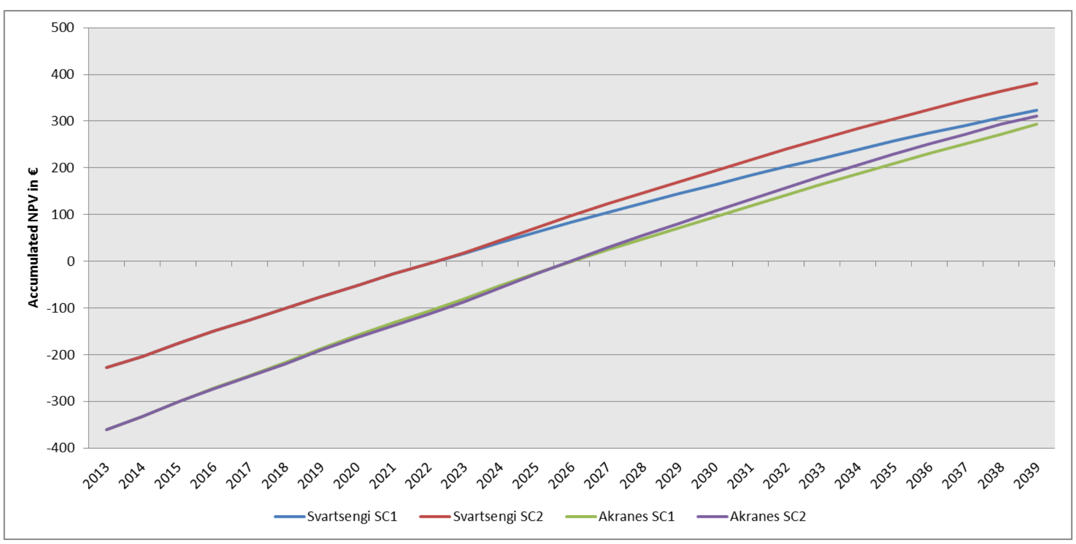


Figure 5.9: Accumulated NPV and payback time with reduction in capital cost by 200.000 € and 10 % reduction in total price caused by tax reduction.

Figure 5.9 represents a scenario where the capital cost has been lowered to 1 M€/MW in addition to 10 % reduction in total price due to tax reduction by the government. The payback time would then by ten years after initial investment for the Svartsengi cooperative, while the Akranes cooperative investment would pay itself back in thirteen years.

So what conditions would there need in order to make the cooperative not feasible in economic terms? Firstly, the capital cost and thereby the investment cost would need to be high. Secondly, the government would not give any tax reduction. And thirdly, the selling price of electricity would be less than anticipated.

In an interview with Haraldur Magnússon, who is at the moment the only person who sells electricity from wind turbines to the grid, he said that he is receiving 2-4 isk/kWh (1.25-2.5 c€/kWh) depending on season [111]. A electricity price reduction by 37.5 % from 3.9 c€/kWh which it was in January 2013, to 2.5 c€/kWh equaling the highest price that Haraldur receives, would result in that only the Svartsengi cooperative would become feasible, but then just barely since the payback time are twenty or twenty two years. The Akranes cooperative would not be feasible. Figure 5.10 shows the accumulated NPV and payback time for the scenario.

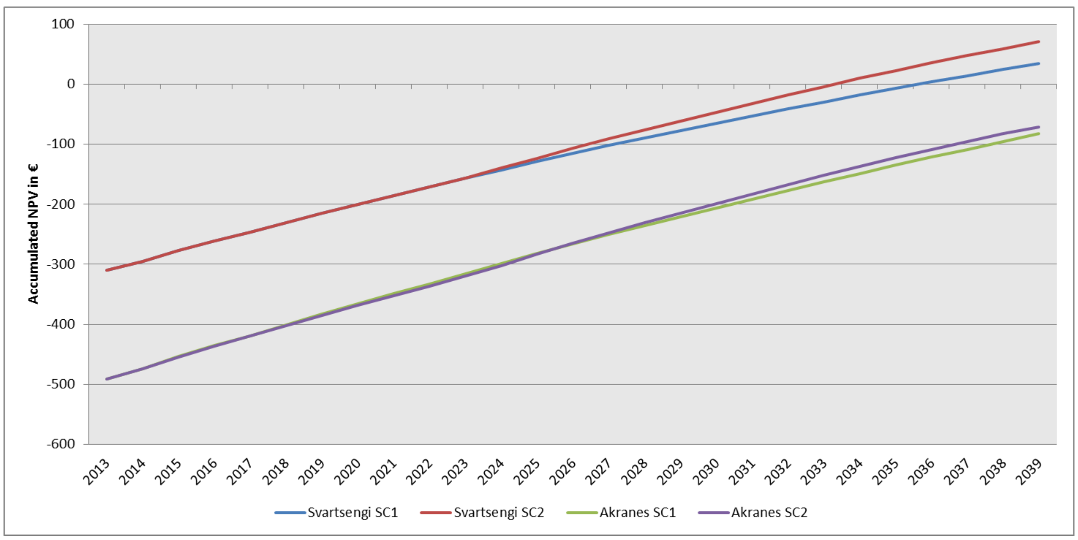


Figure 5.10: A scenario with a decrease in electricity price by 37.5 %.

However if the electricity price would stay stable at 3.9 c€/kWh throughout the wind turbines lifetime the feasibility of the Akranes cooperative would become questionable with twenty one year payback time while the investment for the Svartsengi cooperative would be paid back in fifteen years, while a drop to 2.5 c€/kWh would make neither cooperative feasible. Figure 5.11 shows the accumulated NPV and payback time for the scenario.

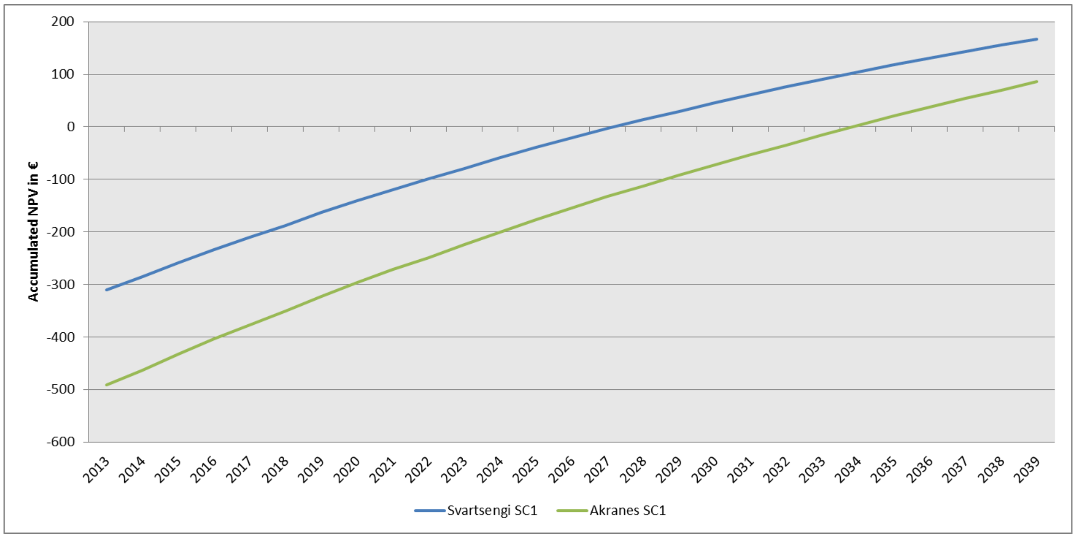


Figure 5.11: A scenario where the electricity price is stable to 3.8 c€/kWh during the turbine lifetime.

If it is continued to use the price development scenarios presented in section 5.4 but the investment cost is raised, then an increase by 40 % to 1.68 M€/MW would make the Akranes cooperative not feasible and lengthen the payback time of the Svartsengi cooperative to eighteen and twenty years making the feasibility questionable. Figure 5.12 shows the accumulated NPV and payback time for the scenario. A massive increase of 90 % to the capital cost would make the Svartsengi cooperative not economic feasible as well as the Akranes cooperative.

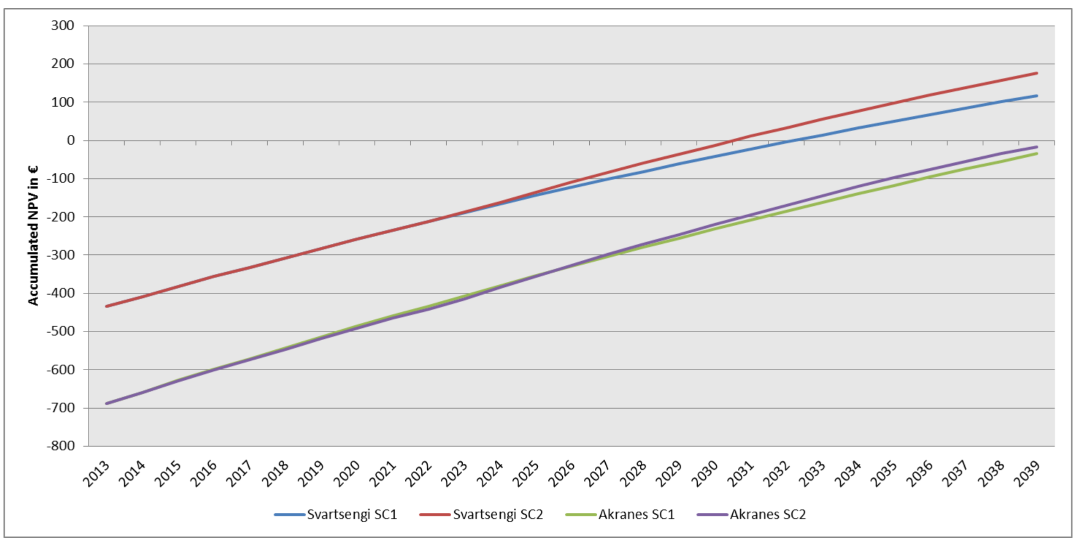


Figure 5.12: An increase by 40 % in capital costs.

The above evaluation of the economic feasibility of wind energy cooperative in Iceland is subjected to many uncertainty issues, such as the discount rate which influences the payback time considerably. For example, an increase of one per cent will lengthen the payback time for about one year for the Svartsengi cooperative and three to four years for the Akranes cooperative. The development of discount rate is closely related to financial stability both locally and globally, for recent years Icelandic authorities has managed to lower the nominal discount rate from about 18 per cent in late 2008 to early 2009, to 6 per cent as it is now (May 2013) [109]. And how will this development continue, will it stay the same, will the stability increases causing lower rates and less inflation or will there be another crisis in next 25 years?

Other issues not discussed in this study are the financing of the investment, for example would 50 shares cost about 15-25,000 € depending on a cooperative, and most people would need to take loan for such a high amount. And what would the interest rate be on that kind of a loan and how would the interest rate change during time? If a loan is taken for a share, then most definitely the payback time will be longer, but what conditions banks and other loan institutes will grant for that kind of a loan is difficult to assess and could be a subject to a whole another and different kind of study.

Other issues, such as the electricity price is difficult to foresee and therefore must this study only be taken as an indication towards if a cooperative might be economic feasible for the buyer or not. And might it be? Yes, there are indications that it might be, only when considerable increase in capital cost or decrease in electricity price is the case the cooperative will not become economic feasible.

The change in capital cost would need to be so dramatic that it is not considered to be a realistic threat, but a drop in electricity price could have considerable effects. For example would a drop by 20 % make the Akranes cooperative on the verge of being feasible, but a lower investment cost would though compensate.

6 Views on wind energy projects in Iceland

This chapter focuses on outcomes from surveys and discussions from interviews. Firstly a brief description of how the interviews and surveys were made followed with description of how and where the surveys were promoted. The outcome from the surveys and interviews is divided to two subchapters, one focusing on viewpoints of Icelandic people and authorities as well as tourism; and the other on viewpoints of tourists and people in tourism.

Landsvirkjun has declared that one of the research aims in the research project of erecting two wind turbines in south-central Iceland is to investigate social impact of these [33]. Furthermore is one of Landsvirkjun goals to create support and solidarity about its projects by:

1. Inform the public better and earlier about planned projects
2. Conducting informed and professional dialogue
3. Be in the lead with environmental issues and be more critical
   [41]

With this in mind the research in this thesis focuses on people's viewpoints towards wind power projects in Iceland and ways and methods to increase general contentment on these. It is targeted towards local Icelandic people, tourists visiting the country, stakeholders within the tourism and administrative bodies. The viewpoints are found by conducting two surveys one in Icelandic for the Icelanders and the other in English for foreigners. And by carrying out interviews to people within tourism, community administration and pioneer in wind energy harnessing in Iceland.

The surveys were conducted on the internet and promoted through social media, forums and web blogs. Since surveys only gives superficial views on phenomena studied and only give limited depth and understanding on what might lay behind people opinions on the subjects [42] a series of interviews also were conducted. The interviews were carried out by meeting the interviewees face to face in Iceland and by telephone conversations. Few interviewees didn't have the time for a meeting and answered questions sent to them by email. The interviews were conducted in Iceland from 15th to 17th April 2013.

Surveys based on questionnaires are ideal when collecting simple information about people views or behaviour on certain subjects and other basic information about people´s attitudes [112]. The surveys were designed by the researcher and SurveyXact, which is a web-based survey system, was used for collecting answers and analysing the results. An important aspect was to define the sample of those who would be affected by a wind power project or projects, and group it so the sample reflects the total population. A great emphasis was on that the surveys were promoted among the widest group of people with different opinions on subjects like environmental protection or utilization and living within different areas of Iceland, both the great Reykjavik area or in the rural areas of Iceland.

The surveys were conducted over eighteen days from 2nd of April 2013 to 20th of April 2013, and promoted steadily during that time on various web pages by posting a link to it. No emails were sent out or any other methods were used for the promotion. In total of 577 persons responded, 451 to the Icelandic survey, where 333 (74 %) finished and 126 to the foreign survey where only 43 (34 %) finished. Why so few persons finished the English survey is not clear since it was simpler and shorter than the Icelandic one, but one of the reasons can be how it was promoted.

How people answered certain questions in the Icelandic survey decided on which questions they got afterwards, e.g. if person answered to be land owner he got questions regarding if he or her would consider to lease a part of his land to wind farms while those who are not land owners didn't get the latter question. This made the number of question to be as few as possible and the respondents could finish the question list quicker and only getting relevant questions. In the English survey all respondents got same questions. Total number of questions for the English survey was 11 and 12 to 15 for the Icelandic one depending on answers.

72 % of the respondents were male in the English survey while 28 % were female; the Icelandic survey had nearly even distribution between males and females or 49 % male and 51 % female.

6.1 The promotion of the surveys

When promoting a survey it needs to be clear what type of individuals you want to answer the survey and their distribution needs to be equal and represent the total population of a group, in this case the Icelandic population and foreigners visiting the country. The promotion was executed in the way that webpages (forums, blogs etc.) and social media groups were identified and categorized after subjects, for example if the subject were about nature conservation than it was assumed that people participating in the survey after seeing the survey link in those pages would rather be negative about wind power projects, in same manner it was assumed that people visiting the survey after seeing the survey link on pages or forums with utilization as main subject would rather be more positive towards wind power projects.

The survey system SurveyXact allows users to promote their question list in many ways such as by sending out emails with link to the survey, printing out the question list and sending it to respondents or distribute a link on web pages. The last option was used in this case and was the posting of the survey link distributed equally between all groups in order to get view points from as most diverse group as possible.

The webpages that the link was posted on were chosen carefully in order to get the widest possible sample of respondents. There was a slight difference in how the webpages were chosen for the Icelandic survey and the English one, where for the Icelandic one there was assumed that users of webpages covering environmental issues were more against further utilization of energy resources and further development of heavy industry plants in Iceland and therefore probably against wind energy. In a same manner it was assumed that users of webpages promoting more heavy industry and further utilization of energy resources would be for wind energy. Furthermore it was assumed that users of webpages of certain communities who had praised for heavy industry plants would be more positive towards wind energy while users of webpages of communities where there is decent or good employment situation would be more negative.

Considering that the majority of travellers visiting Iceland are there to experience the nature most focus was on travel websites with sections covering Iceland. To even out the sample the survey was also promoted on webpages about renewable energy and business opportunities.

Social media webpages were most frequently used such as Facebook, Twitter and LinkedIn, but also forums and blogs.

Groups, pages and wall were used when promoting the survey on Facebook and LinkedIn. Groups are closed “communities” connecting people with same or similar hobbies, from same town or village or something else, to promote, share and discuss relevant topics, while pages are normally an “area” or profile of businesses, originations, associations etc. normally on Facebook. Wall is here meant as the researcher´s own Facebook area.

For the research, a number of groups on Facebook and LinkedIn were joined covering subjects such as Iceland in general, friends of Iceland, Scandinavia networking which is a business portal focusing on Nordic countries, renewable and wind energy groups, and various community groups where a link and description of the project were posted where it appeared in the main posting area.

A link and similar description was also posted on various Facebook pages, such as farmers in Iceland, association of Icelandic aluminium smelters, community pages, travel- and environmental pages, Facebook page of Icelandic Airwaves, which is yearly music festival attracting young people and other music enthusiasts from all around the world. When posting on Facebook pages the post appears in small window next to the main posting area.

Short messages, or tweets, with link to survey were posted on Twitter mentioning all above groups that also are using Twitter.

About six posts were posted on travel forums, TripAdvisor, LonelyPlanet and VirtualTourist, with description of the project and link to survey.

Few replies were made to relevant blog posts with very short description and link to survey.

And finally a description and link to survey was posted on researcher own Facebook wall and friends were asked to share as much as possible.

6.1.1 Complete listing of sites that the survey was promoted at

In table 6.1 are listed all sites that the surveys were promoted at. Sites having Icelandic names are those who Icelanders visit and read, while the sites with English names are read by all people regardless of nationality.

Facebook groups	
Keflavík og Keflvíkingar	Local group for people living or have lived in the town of Keflavík, south-west Iceland
Hornfirðingafélagið	Local group for people living or have lived in the town of Hornafjörður, south-east Iceland
Stykkishólmur og Hólmarar	Local group for people living or have lived in the town of Stykkishólmur, west Iceland
Ísafjörður og Ísfirðingar	Local group for people living or have lived in the town of Ísafjörður, the westfjords
Styrkur og velunnarar Þórshöfn	Local group for people living or have lived in the town of Þórshöfn, north-east Iceland
LinkedIn groups	
Friends of Iceland	For people interested in the country. Subjects regarding arts, culture, travel etc.
Scandinavian Networking	Group for professionals with interest in Scandinavia
Wind energy professionals	Group for professionals within wind energy
Renewable energy world	Group with professionals and people interested in renewable energy
Facebook pages	
Náttúra Íslands	Icelandic environmental association
Inspired by Iceland	Travel promotion of Iceland

Icelandair	Airline in Iceland
Iceland naturally	Travel information and hub
Iceland Airways	Music festival in Iceland. Mainly young people from the arts and culture scene.
Visit Reykjavík	Reykjavík travel promotion
North Iceland	Regional travel promotion
South Iceland	Regional travel promotion
East Iceland	Regional travel promotion
West Iceland	Regional travel promotion
Visit Reykjanes	Reykjanes peninsula travel promotion
Akranes	Hub for the town of Akranes
Samtök ungra bænda	Young farmers association hub
Álver á Íslandi	Hub for the association of aluminium smelters
Orkubloggið	Facebook page for popular blog about energy issues in Iceland
Facebook wall	
The researcher‘s own wall	Survey link shared amongst friends and friends-friends
Twitter	
The researcher‘s own twitter	Short messages marked with numerous twitter accounts, such as: Inspired by Iceland, Iceland Airways etc. Resulted in suspension due to spamming.
Forums	
Trip Advisor	Travel forum
Thorn Tree	Lonely Planet travel forum.
Virtual tourist	Travel forum.
Blogs	
Ómar Ragnarsson	A blog by well-known reporter and environmentalist. Link posted as comment to two blog posts about subjects slightly related to wind power

Table 6.1: Listing of social media sites that the surveys were promoted at.

6.1.2 Results of using social media for promotion of surveys

Decent responses were from posts on travel forums but for two of the forums a promotion of surveys was considered to be spamming and the posts were deleted shortly after posting and threatened that the account and the user would be suspended.

Using Facebook, good responses were from posting on the researcher´s own wall and asking friends to share. Approximately two to three were answering every five minutes or so, for the few hours after the first post. The activity gradually decreased as time passed by and almost no activity was after 24 hours. Posting in Facebook groups gave similar results, though was the activity little less but stayed for longer period. Posting in LinkedIn groups gave less responses to the survey but more activity in terms of comment to the post both in the group and emails sent to the researcher.

Posting on Facebook pages turned out to be not successful, hardly no new respondents were 24 hours after posting, probably due to low visibility of posts that other users than admin posts there.

Posting short messages on Twitter gave bad results, there was considerable traffic to the survey first page, but no one answered any question. Twitter is based on short messages and the user environment there is fast with new messages and posting popping up almost constantly. Perhaps is the speed so much that the users don’t give themselves time to use few minutes to answering a survey.

Promotion of the survey as comments on relevant blog posts gave decent results, occasional users answered the survey during the first hours.

6.2 Local people viewpoints on wind power projects in Iceland

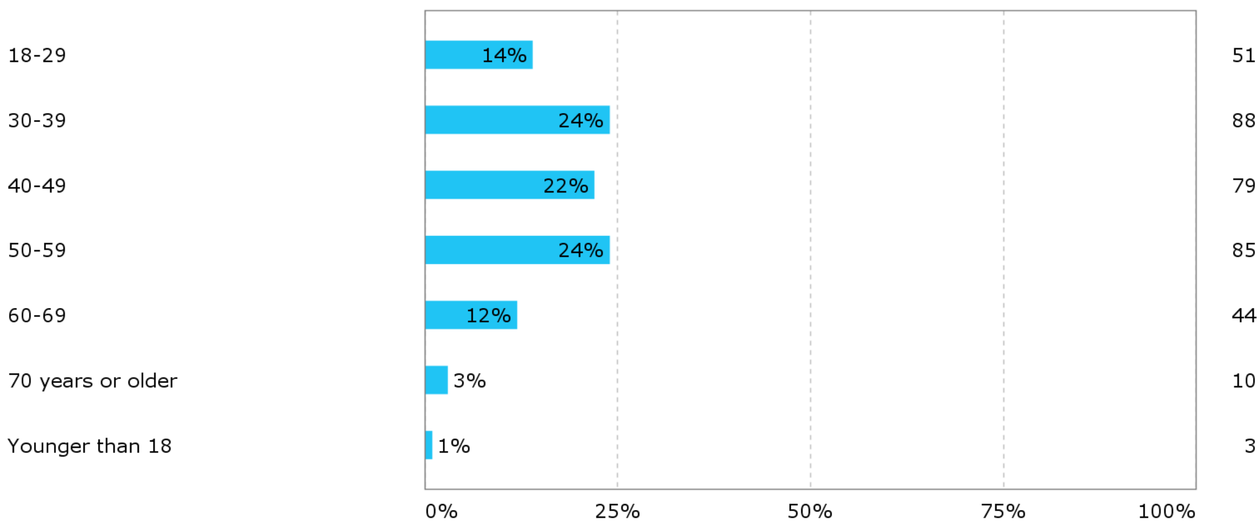
The answers were categorized by people‘s residential area, urban area including people from the Reykjavík area and people living abroad, people living in rural area with inhabitants over 200 and people living on a farm or on a farm like area with less than 200 inhabitants.

The questions were divided to following categories:

- General questions about age, gender and area of residence.
- Current view on hydro- geothermal and wind power.
- What would increase their contentment; options based on results from literature study and interviews with Danish specialists.
- Classification of importance of various subjects from important to insignificant, e.g. about how important it is to be part of the planning process, ownership, size of wind farm and so on.

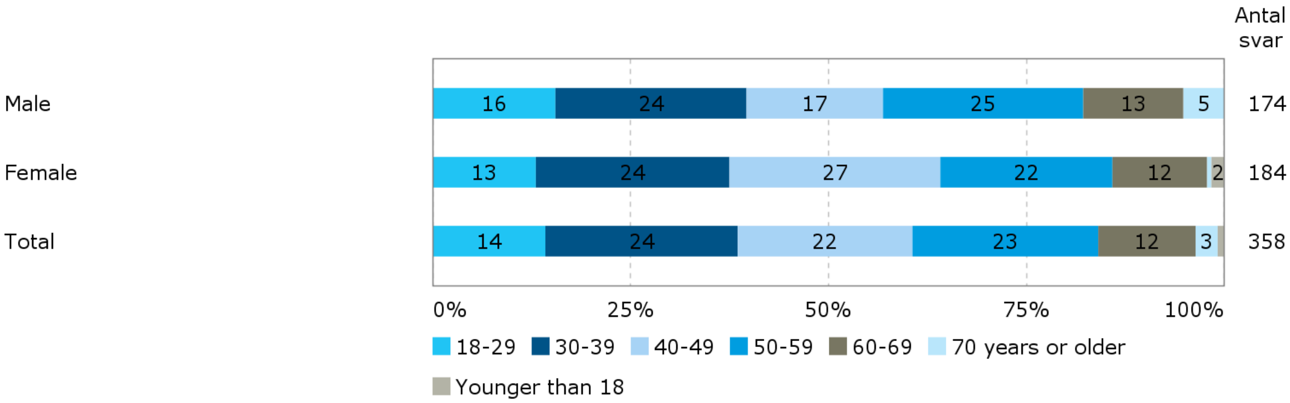
6.2.1 Age, gender and residence of the respondents

The age of the respondents is distributet relatively evenly between the age groups of 30-59, the distribution is presented in the chart below.



Survey-chart 1: The age distribution of respondents.

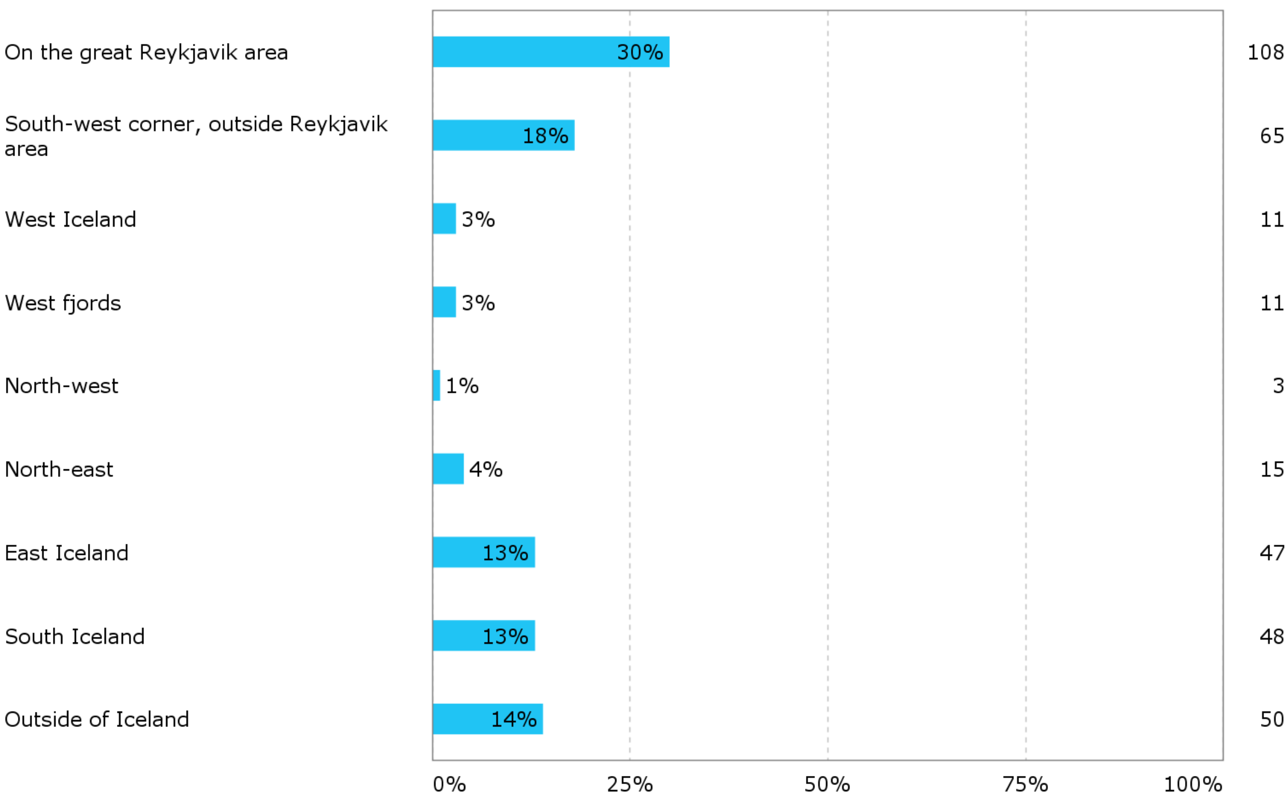
Most participants in the survey are in the age group 30-39, or 88 in total. Just merely less are respondents in the age of 50-59, or 85. Respondents at the age of 40-49 are 79 and at age over 60 are 54, while those who are younger than 29 are 54. The distribution of age in terms of gender is also quite even like Survey-chart 2 shows.



Survey-chart 2: The distribution of age crossed with gender.

There is a nearly even distribution between males and females in all age groups though have women in the age group 40-49 answered the survey a bit more frequently.

Most respondents live in the Reykjavik area or 30 %, the south-west corner has 18 % of all respondents. These two areas lie next to each other and make up about 71 % of island total population.



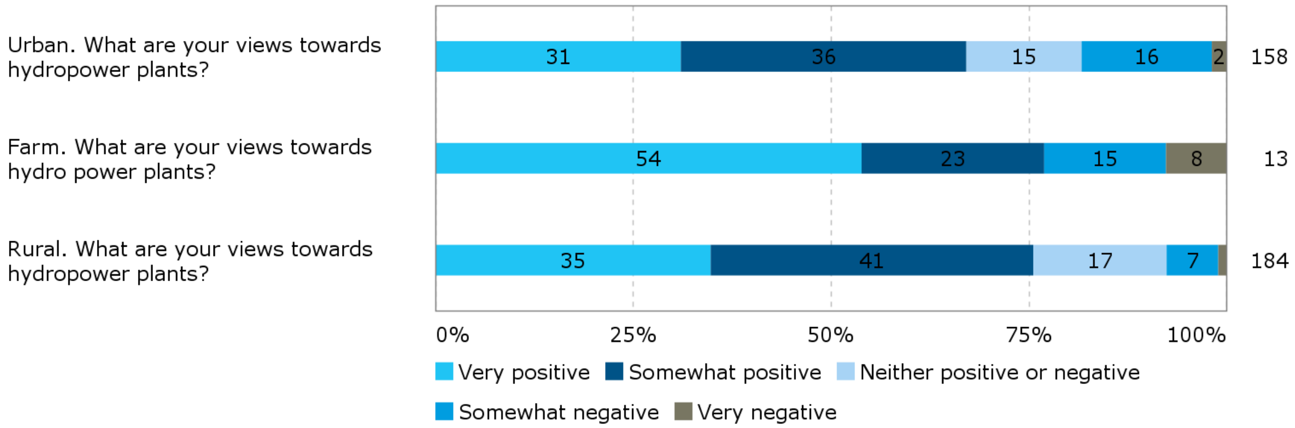
Survey-chart 3: Living area of respondents.

Other areas have fewer respondents, especially the west part of country including the West fjords, and from the north part of the island. Noticeable is the share of respondents living outside of Iceland or 14 % of total share. This might be high share but in the year 2010 36,202 persons with Icelandic citizenship lived outside of the country [113], that is about 11 % of the total population of 320,000, is the share not that high.

It can be argued for that some rural areas ought to be classified as urban when the population of them has reached over 5000 inhabitants. Areas in Iceland outside of the Reykjavík area with inhabitants over 5000 are according to Statistic Iceland only four, thereof are two with population over 7000 [2]. This given, are all groups besides Reykjavík area and outside Iceland, classified as rural to limit the number of questions.

6.2.2 Current views towards hydro-, geothermal- and wind power plants

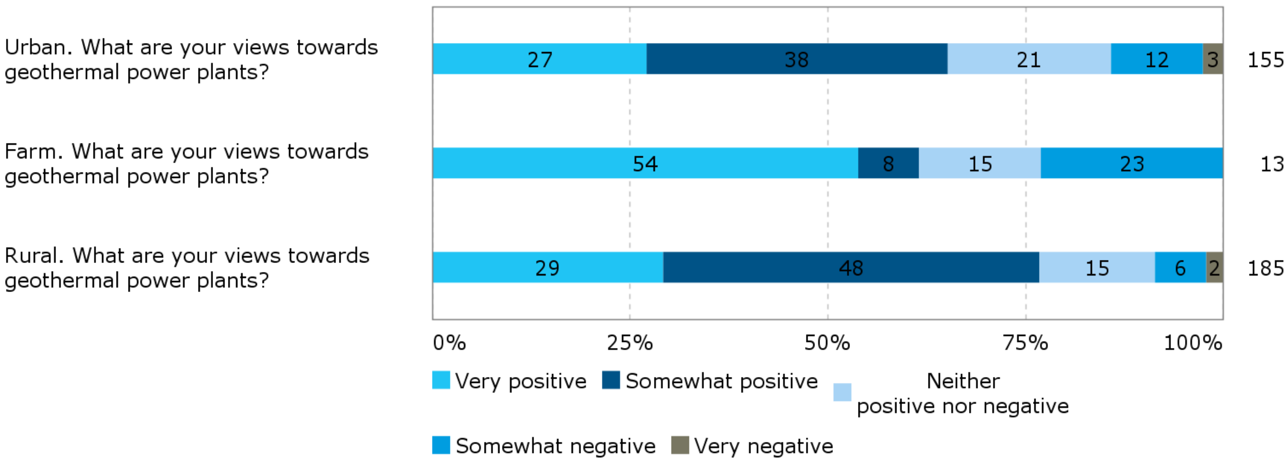
All the groups got the questions “What are your views towards hydro- geothermal and wind power plants?” The views are presented in Survey-charts 4-6 shown below.



Survey-chart 4: Views towards hydro power plants.

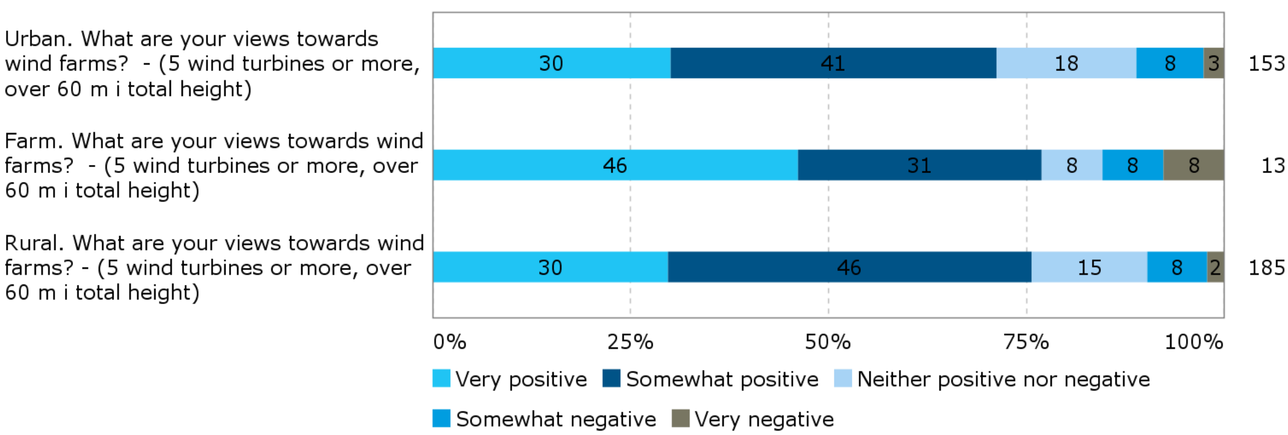
The vast majority is for hydro power plants, people living on farm or under farm like conditions are considerably more positive while urban people are not as much positive. 77 % of farm people and 76 % of rural people are very positive or somewhat positive towards hydro power plants while 67 % of urban people are.

The groups views towards geothermal power are somewhat less positive, farm people are though quite positive with 54 % very positive, while rural and urban people have 29 % and 27 % share.



Survey-chart 5: View towards geothermal power plants.

It seems that people living in rural areas are considerably more positive towards geothermal power with 77 % very positive and somewhat positive compared to 62 % of farm people and 65 % of urban people. When looking at the distribution of answers to areas of Iceland, it shows that people living on the south-west corner are relatively satisfied with geothermal power with 86 % very positive or somewhat positive where 46 % are very positive. That is interesting when taking into account that numbers of geothermal power plants are placed within the area. People views towards wind farms are shown in Survey-chart 6.



Survey-chart 6: Views towards wind power farms.

As before, are people living on a farm the group that is most positive with 46 % very positive compared to 30 % for urban and 30 % for people living in rural areas. In general is the contentment most evenly distributed between groups for wind farms where the distribution for very positive and somewhat positive are 71, 77 and 76 per cent for wind farms; 65, 62 and 77 per cent for geothermal and 67, 77 and 76 per cent for hydro power. Table 6.2 shows the distribution clearer.

[%]	Urban	Farm	Rural	Mean value
Wind	71	77	76	74,7
Hydro	67	77	76	73,3
Geothermal	65	62	77	68

Table 6.2: Distribution of very positive and somewhat positive to resources options. The numbers are per cent value of the total sample.

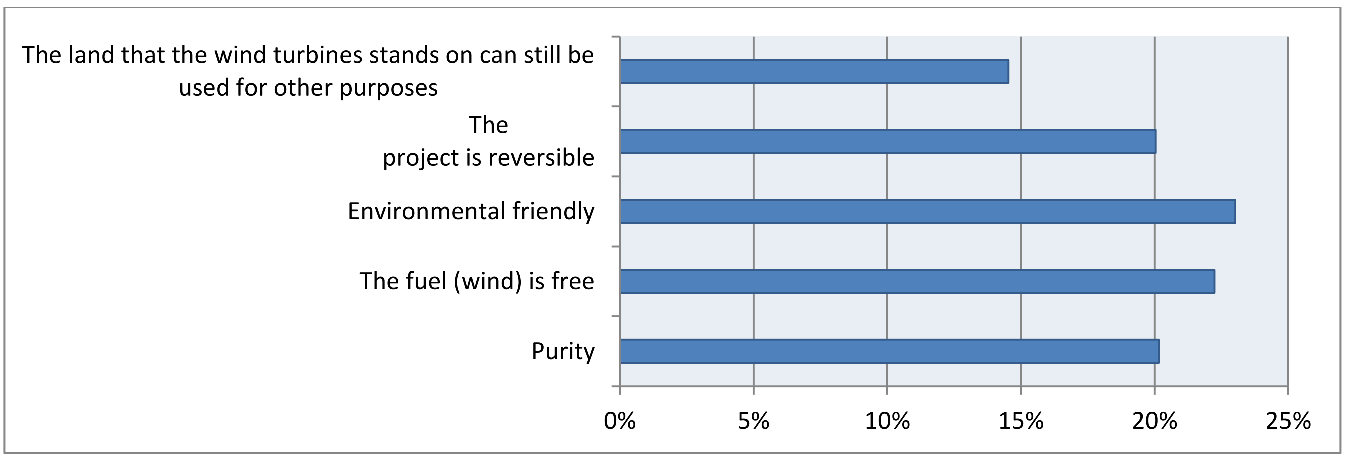
Regarding this subject, Sveinn Rúnar at the Icelandic tourist board (ITB) and Gunnar Valur at the Icelandic travel industry association (SAF) agreed on that tourism and energy production can well work together, but it should be noted that over 80 per cent of foreign visitors visit Iceland because of the unspoiled nature and it is therefore important to preserve undisturbed areas of land and landscape [114,115].

Regarding wind energy, Sveinn says that such a construction should not interfere with tourist's perception of the area they are visiting in terms of visual effects, noise and other nuisances [115]. Gunnar says that SAF has not formed an opinion on such a structure, but points out that it is clear that no one will be pleased if wind turbines are placed in the vicinity of tourist attraction that might block a view and demolish landscape and wilderness perception [114].

The director of ITB, Ólöf Ýrr, agrees on this viewpoint and adds that wind turbines could be interesting in making the society more sustainable, but it is important how it is done and organised. Visual impacts, disruption and people's perception of an area has a big impact [116].

6.2.3 Advantages and disadvantages of wind energy

When the survey groups were asked what they would consider to be the main advantage of wind energy, most respondents answered that they thought the method is environmentally friendly and that the fuel is i.e. the wind, is free.

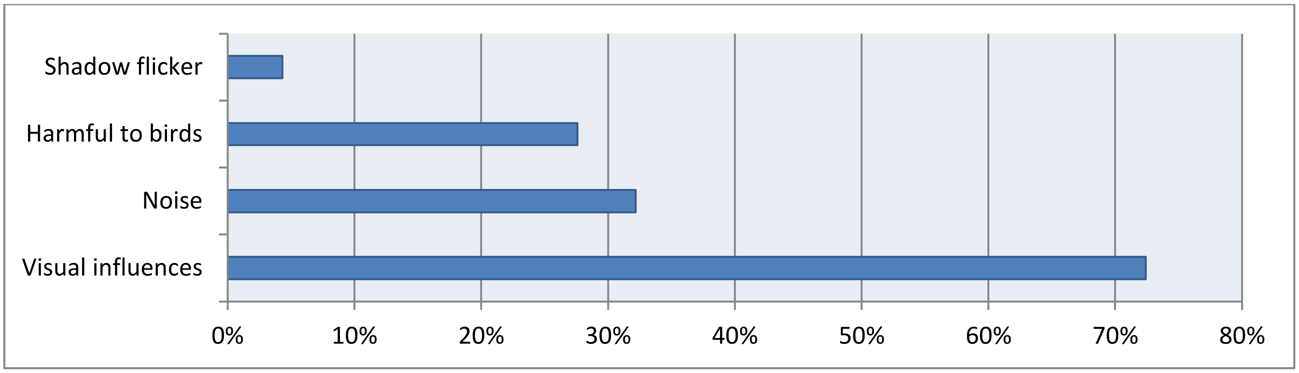


Survey-chart 7: Answers from all groups about what they consider to be main advantages of wind energy.

This question was supplemented with a field where the respondents could write if they thought other advantaged would apply, the answers were in Icelandic but below are few of them that are considered to be most relevant are translated from Icelandic to English.

- *Little waste if any.*
- *Increases farmer's possibility to live of the land.*
- *Plenty of wind energy in Iceland.*
- *There is something so cool seeing this.*
- *Rapid technical progress with regard to energy conservation to be used when wind doesn't blow.*

In same manner all groups were asked about what they consider to be main disadvantages of wind energy.



Survey-chart 8: Answers from all groups about what they consider to be main disadvantages of wind energy.

Most people are concerned about visual influences of wind turbines or 72.4 %. Noise and the danger they might cause to birds are also considered to be important while shadow flicker is considered to be less important.

Other comments on disadvantages are:

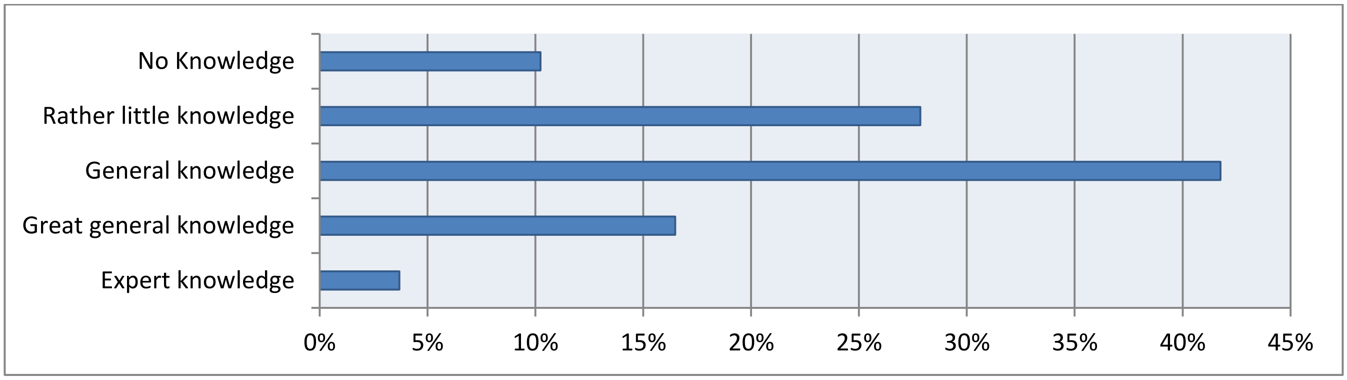
- *Energy costs too much compared to other energy sources (equivalent to 20 years and breakdowns) and must have a rigid network of other energy sources such as hydroelectric power plants.*
- *More expansive than hydro.*
- *Is feasibility certain?*
- *Costs.*
- *Not suitable where there is stable energy from hydro power plants. More suitable where you can reduce the production of coal- and oil power plants fast while the wind power is present.*
- *Local increase in temperature close to so-called wind farms.*
- *All these options and discomfort of people who are close to these mills.*
- *Vibration in the local area.*
- *Reliability.*
- *Difficult to use in Iceland due to wind speed.*
- *Too much wind.*
- *Current problems of storing energy.*
- *Unstable energy.*
- *It takes tremendous energy in creating windmill.*
- *Substantial energy is wasted.*
- *May not be too large in relation to the terrain which they are placed in.*

The fact that wind energy is more expensive than hydro- and geothermal power, some respondents are concerned about. Others think that there is too much wind in Iceland while some are concerned about discomforts that the turbines may cause.

Some of the comments received while the survey was conducted describe slight lack of knowledge, which perhaps is not strange when taken into consideration that wind turbines are almost entirely unknown in the Icelandic energy scenario where hydro power and geothermal power has dominated the debate.

6.2.4 Level of knowledge on wind energy

When all groups were asked about what they consider their knowledge about wind energy is, most people answered that they had general knowledge or rather little knowledge.



Survey-chart 9: All groups knowledge on wind energy.

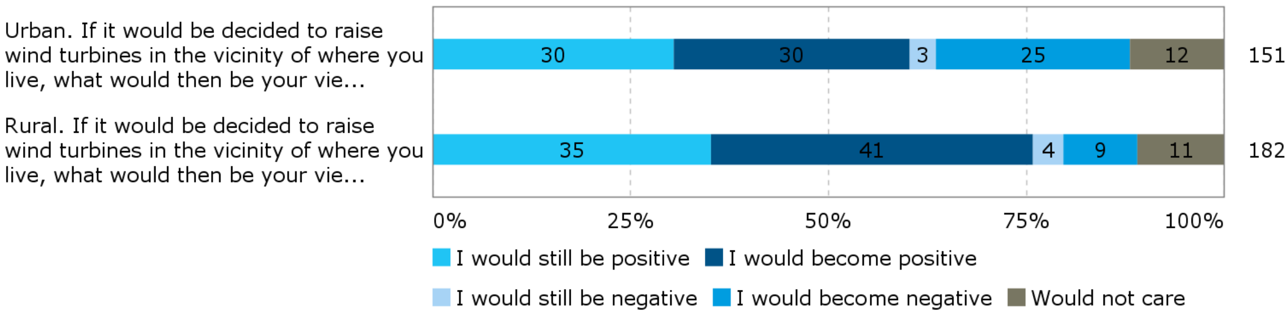
When viewing these numbers it needs to be taken into consideration that “general knowledge” about an issue in a country or an area where the subject is generally not well known, is not on the same level as “general knowledge” about an subject in a country or area where that issue is well known. For comparison, a preschool child might say that its knowledge on mathematic is general, meaning it can add and subtract for example. While asking the same question for a person in University, then its general knowledge on mathematic is far more superior then for the pre-school child. With that in mind it might be assumed that knowledge on wind energy amongst the Icelandic public is fairly little.

When Þorvaldur Vestmann, the manager of environmental and construction division of Akranes community, was given a print-out of effected area caused by shadow flicker he was amazed over how large area was affected by it and adds.

> *“The municipality hasn’t any opinion on this subject yet, since this is something completely new. I believe that the knowledge of this is minimal if any; for example is the shadow flicker something that I had absolutely no imagination to think there was a problem with, and I am very surprised to see this printout”* [117].

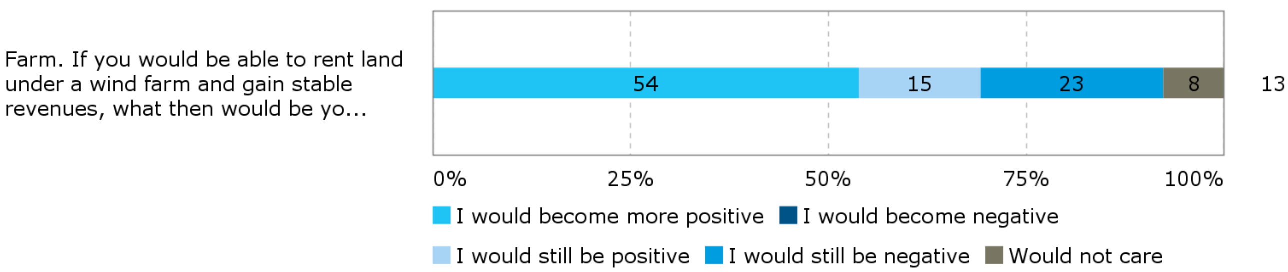
6.2.5 Views on if wind farm would be erected in the vicinity of their residence

When respondents were asked if what their opinion would be if a wind farm would be raised in the vicinity of where they live, the answers were that 30 % of urbanites and 35 % of rural meant that their opinion would not change from being positive towards wind turbines even though they would be placed close to where they live. 25 % of urban people would be negative if wind turbines were placed in the vicinity of where they live, while 9 % of rural people share this opinion as seen in survey-chart 10.



Survey-chart 10: Viewpoints to the question "What would be your opinion if wind turbines would be raised in the vicinity of where you live?"

A staggering share of 41 % of rural people would become positive if they were placed close by and 30 % of rural people share this opinion. In a similar manner this question was also directed to land owners but phrased differently. "*If you would be able to rent a land under a wind farm and gain stable revenues, what would your opinion be if wind turbines were placed in the vicinity?"*



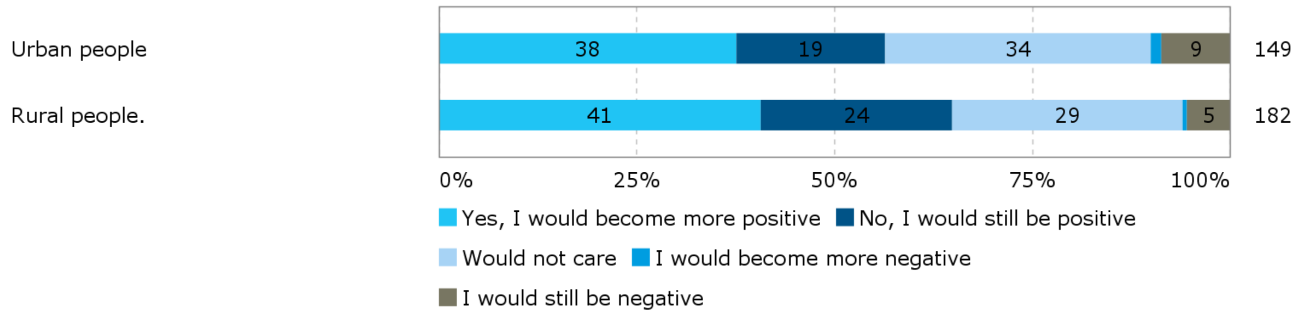
Survey-chart 11: Viewpoints of landowners who were asked what their opinion would be if they could gain steady revenues from leasing land.

A majority (64 %) of landowners would be positive; thereof would 54 % become even more positive, while 23 % said that they would be negative.

From this point people were asked about subjects that they thought would be important to keep them satisfied if wind turbines would be erected close to their living area. The questions were based on results from the literature reviewed in chapter 4.

6.2.6 Implementation of residents to the planning process

One element that was considered to be crucial in the literature was implementing local people to the planning process of a planned wind power project. Answering the question *"if you had the opportunity to participate in the planning process would it then change your attitude towards wind power (For example, as to come up with comments and/or recommendations)"* Survey-chart 12 shows that 38 % of the urban respondents and 41 % of rural respondents would become more positive, while 34 % of urban people and 29 % of rural people would not care.



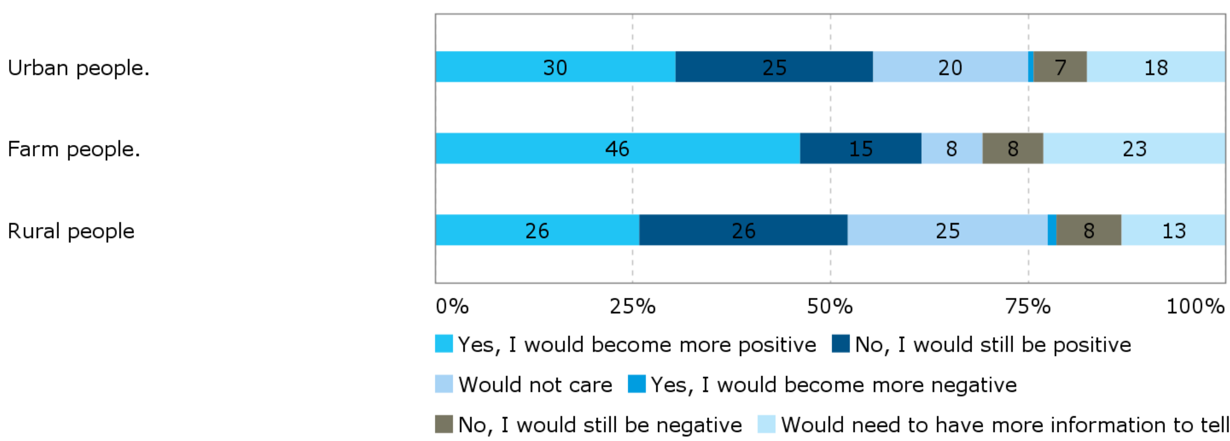
Survey-chart 12: Rural and urban people views on what participation would mean to their opinion.

Another question regarding this subject was asked later in the survey, where it was asked if it was important or not if the planning process was in cooperation with nearby residents, nearly 96 % said that it was so, confirming the viewpoints from the literature study.

Þorvaldur Vestmann at Akranes community said that it is most important that this kind of a project is cooperation and consultation with residents and local authorities [117].

6.2.7 Views towards cooperatives

Another important aspect drawn from the literature study is to allow people to buy shares in a wind farm through a cooperative. Especially people living under farm like conditions were positive towards this option while people living in urban and rural areas think that buying shares would be of less importance.



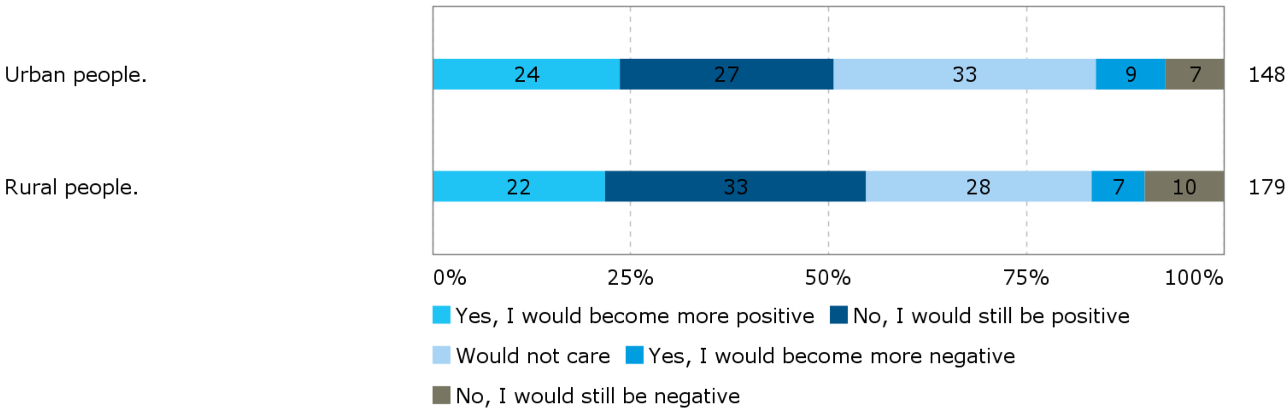
Survey-chart 13: Results of the question "if you would be able to buy shares in the wind turbine(s) and get regular income from electricity sales, would it then change your attitude towards wind power?"

Þorvaldur find it to be positive if residents could buy shares and benefits from it if such an effort would strengthen the residence in the area [117].

6.2.8 Opinions on making a recreational area in conjunction with wind farm

33 % of urban people would not care if an area where wind turbines are placed would be prepared as a recreational area and 27 % answered that they would still be positive, while rural people answered that 28 % would not care and 33 % would still be positive towards wind power. 24 % and 22 % would become positive.

When Þorvaldur was asked if he believed it to be positive if an area where wind turbines would be placed on and was previously inaccessible, would be made accessible for recreational use. He believed such to be and mentioned an example of hydropower plants in the highlands where an area no one ever visited before became more visited after the building of the power plant was finished [117].



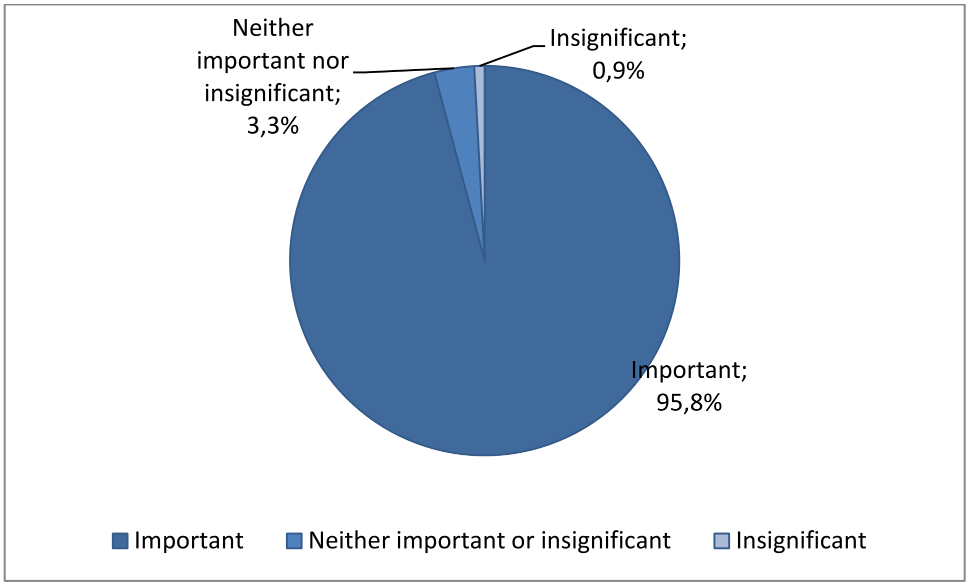
Survey-chart 14: "If the area where the windmills were located would be created as a recreation area where you could, for example, do sports and other recreation, would it change your attitude towards wind power?"

This question was not directed to people living on a farm or under farm like conditions since it was assumed that it would highly unlikely that such an area would be made for such a few people.

6.2.9 Level of importance to means that might increase social contentment on wind projects

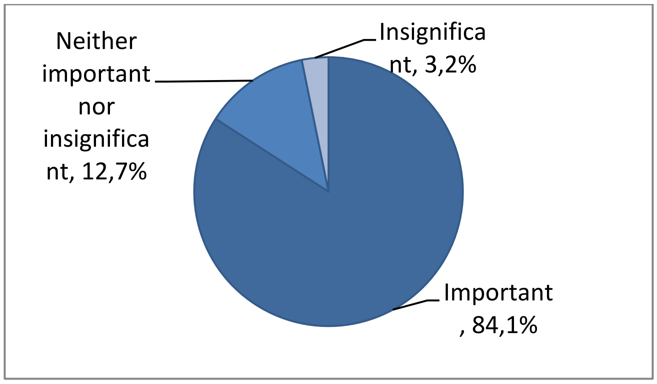
Finally respondents were asked about what they considered to be important in order to increase their contentment on wind projects. Series of issues were listed and participants could answer if they thought it was important, insignificant or neither.

A consonance was with all groups when asked questions regarding participation in the planning process. When asked if it was important or not that the planning process is in consultation with the residents, 95.8 % answered it was important while 0.9 % thought it was insignificant and 3.3 % thought it was neither important nor insignificant, survey-chart 15 shows the distribution.

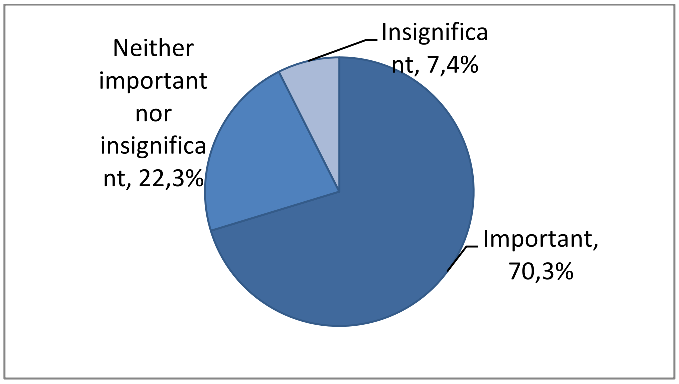


Survey-chart 15: Importance of consultation to the residents.

How this consultation should be conducted, a larger share of the respondents preferred that they would be able to monitor the progress of the project and give comments e.g. through website, than there would be held residents meeting regularly where the progress of the project is presented and where it would be possible to give comments and ask questions.

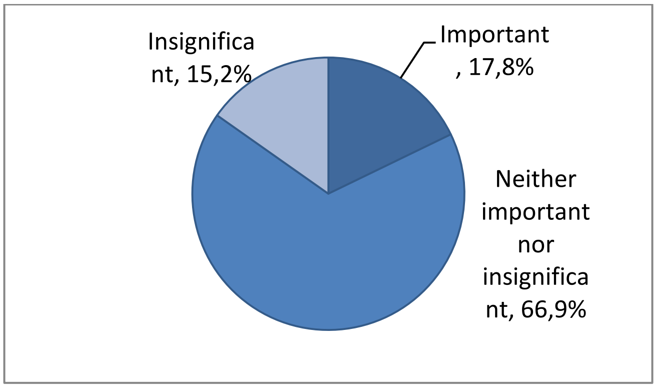


Survey-chart 16: Through website.

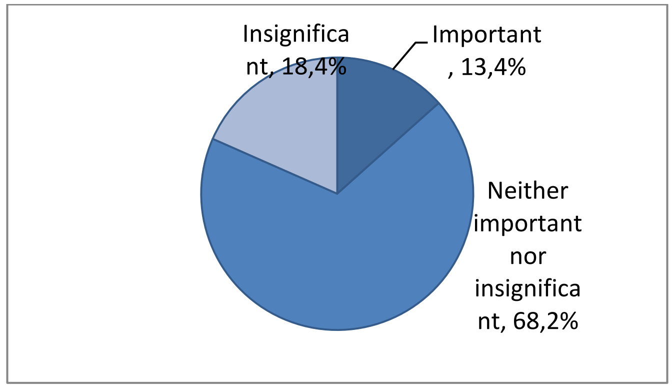


Survey-chart 17: With information meetings.

One of the arguments presented in the literature study, was that people strongly preferred to have fewer and larger wind turbines in their neighbourhood rather than many and small. When this viewpoint was asked to the respondents most people were regardless of number or size of wind turbines in their area.



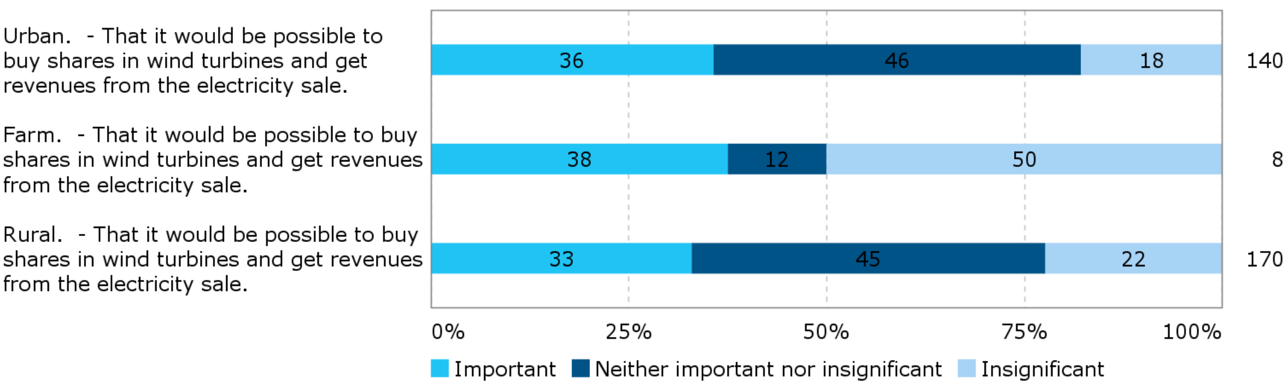
Survey-chart 18: Important to have few and big wind turbines.



Survey-chart 19: Important to have many and small wind turbines.

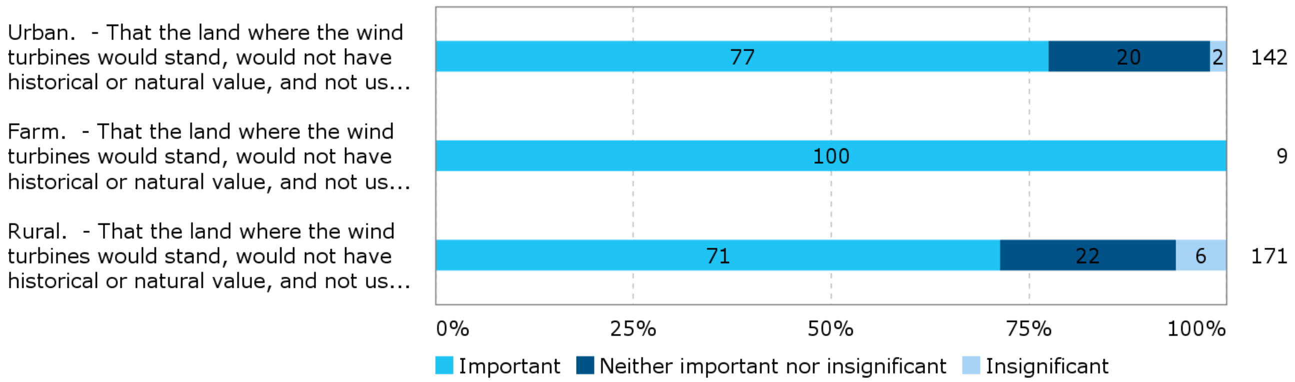
This result is in contrast to other researches that have been done on this subject where people rather have wanted big and few wind turbines within their vicinity [87]. One of the reasons is probably that Icelanders have no or very little experience with wind turbines, and are not familiar with having such an object close to their living areas. It is assumed by this thesis researcher that there is a chance that this viewpoint will change and be in consonance with results from the literature, to wanting bigger and fewer wind turbines instead of many and small.

33-38 % of respondents from all three groups agree on that it would be important to be able to buy shares in wind turbines and gain revenue in order to be content of having wind turbine within their living area. 45 % of rural and 46 % of urban people think it is neither important nor insignificant. Around 20 % of urbanites and rural people feel it is insignificant, while 50 % of farm people share this opinion. The size of the farm group sample is however small and might distort the general opinion of that group.



Survey-chart 20: Importance of being able to share and gain income by electricity sale divided by groups.

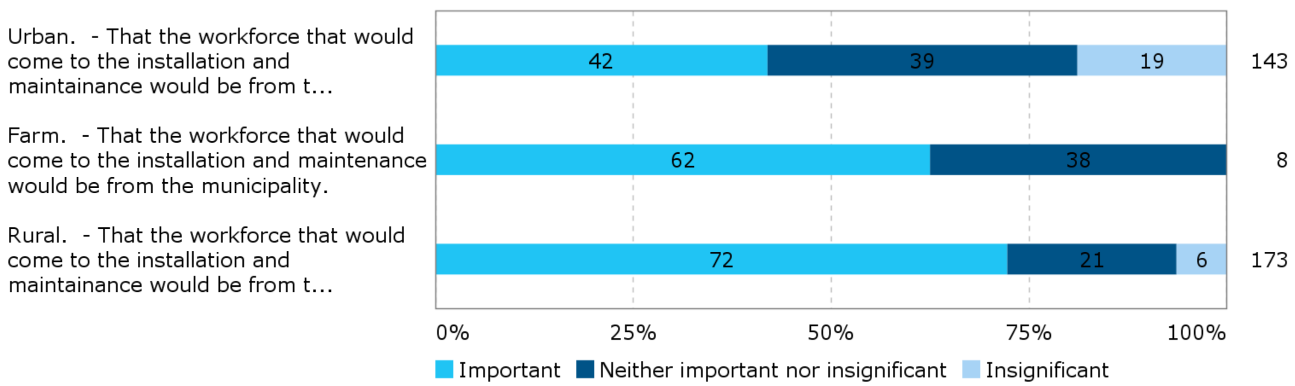
The importance of that the land where the wind turbines would be placed on in terms of historical and/or natural value and usage, such as if it used as an outdoor or recreation. A high share of the respondents think it is important that area is not valuable in these term or usage as survey-chart 21 shows.



Survey-chart 21: Importance of former land use, where wind turbines would be placed.

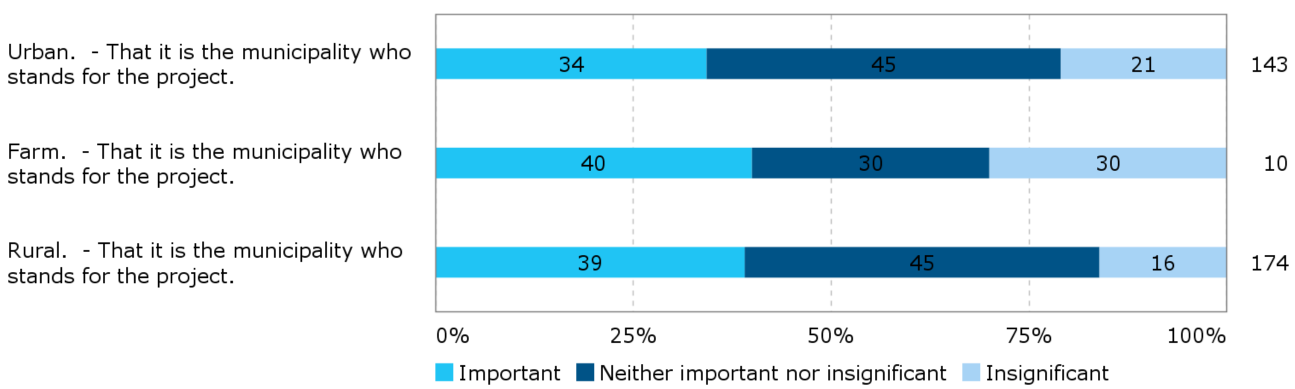
Last three questions were about who should stand for the project and who the service provider should be; in terms of if it should be someone within their municipality or outside of it. This subject was regarded to be important in according to the literature reviewed in section 4.1.

Urban people think it is least important that the workforce during installation and maintenance while rural and farm people think it is more important.



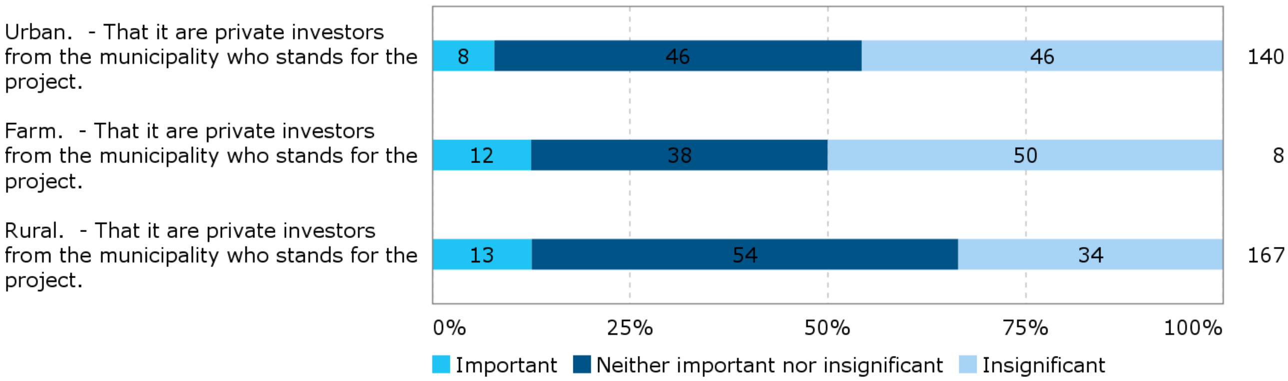
Survey-chart 22: Importance of local workforce.

While 34-39 % of respondents think it is important that the municipality is responsible for the execution of the project, most of respondents think it doesn't matter who it is or find it an insignificant argument.



Survey-chart 23: Importance of that is the local municipality who is responsible for the project.

And do all respondents nearly equally agree on that it is insignificant or irrelevant that a local private investors should be responsible for the project.



Survey-chart 24: Importance of if it is local private investors that are responsible for the project.

Other arguments that would have positive impact, translated from Icelandic to English, according to the respondents are:

- *The most cost-effective option would be used = Hydro.*
- *The alternatives for generating electricity were viewed and judged inferior.*
- *Lower price on electricity would be a good choice.*
- *If the consumer cost of energy would decrease significantly.*
- *Wind farms should not be in the vicinity of populated areas if there is talked about many turbines.*
- *It was not visible from roads or inhabited areas.*
- *That I don't see them or hear them.*
- *Number one, two and hundred at this doesn't spoil the view on untouched wilderness or beautiful scenery. Could be out in the sea or in the outskirts of towns.*
- *Location would be by far the most important aspect.*
- *There are not many areas here in Snæfellsnes peninsula that I would like to see wind turbines on, perhaps in the mountains. It is the visual pollution that I'm afraid of, but otherwise very positive towards wind turbines.*
- *That they fit into the surroundings where they are placed, for example big or small depending on the surroundings.*
- *Nature conservationists are babbling about visual pollution from transmission lines, what they will say about wind turbines that are visual- and noise polluting. We should stay to the energy we have and drop any plans for wind turbines.*
- *Avoid visual pollution and the impact on animal and bird life.*
- *That it is not erected where there is large immigration of birds.*
- *Investigate noise and bird deaths.*
- *If it were possible to convince me that wind energy would be more efficient than the energy we have, I would maybe change my mind. I have travelled extensively in Denmark and Germany and the noise from the mill is a very big problem there.*

- *That the number and/or size of the wind turbines would never be so great and/or big that it causes sound pollution. Sound pollution is not only measured in noise, but also in steady sound that causes constant stress of people's hearing.*
- *Solve indisposition issues before the project is started, it's very important.*
- *That they are safe and cannot cause damage.*
- *The reliability was at the forefront.*
- *Measurements that take into account noise and alleged local temperature changes around the wind turbines will be made available to all those living around the area where the turbines would be situated.*
- *The ownership share could not be too high, or have some limitations so it would not just be the private companies with large capital that could benefit on the electric sale.*
- *For local authorities to own a share in wind turbine, partly or entirely I think is a great idea.*
- *The project was not at taxpayer expense.*
- *Important that there are public entities that are responsible for the installation of wind farm, not individuals with profit perspectives.*
- *Ensured that outdated and underutilized wind turbine will be taken down, clear provisions for such in agreements.*

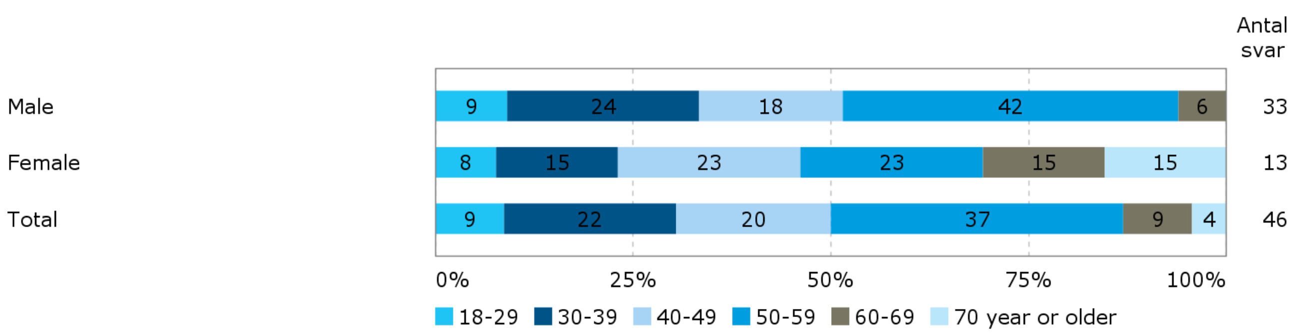
6.3 Foreigners viewpoints on wind power projects in Iceland

The tourist survey was simpler than the Icelandic survey, all respondents received same questions and participants were not divided in groups. The questions were divided to following categories:

- General questions about age, gender and if wind turbines are placed close to where they live
- Numbers of visits to Iceland and argument for why people should visit the country.
- If his or her perception of a tourist attraction would change if wind turbines would be place in visual distance from or when arriving to the area.
- Opinion on possible solution to compensate for nuisance of wind turbines.

6.3.1 Number of respondents, distribution of age and gender

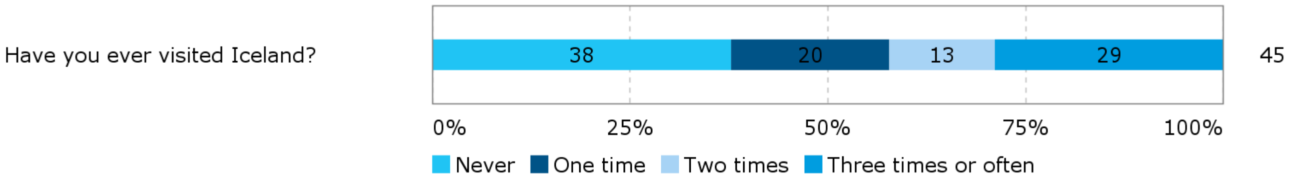
The participation in this survey was disappointing where only 46 respondents finished, while 80 people visited the survey without answering any question. Males were the majority of respondents or 33 while women were 13. People in age group 50-59 answered the questions most frequently or 37 % of all participants, people in the age group 30-39 were 22 % of total respondents.



Survey-chart 25: Distribution of age and gender of respondents in English survey.

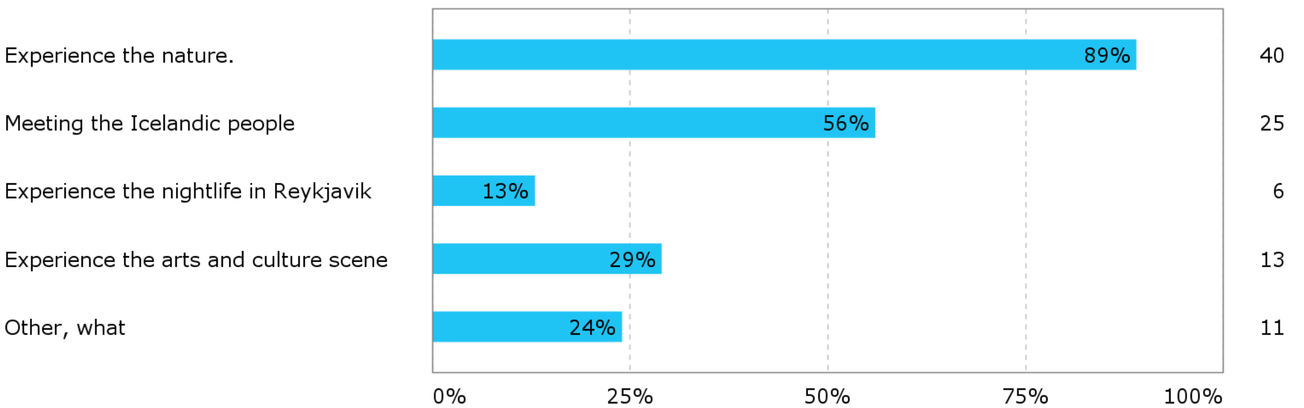
6.3.2 *If they had visited the country and why*

When the survey was promoted people who are interested in, or had visited the country, were asked to participate, with that in mind and the fact that 62 % of the respondents had visited Iceland once or often it's assumed that the majority of the respondents have some basic knowledge on the country geology, environment and infrastructure.



Survey-chart 26: Number of visits to the country.

Of all respondents 20 % had visited the country one time, 13 % two times and 29 % three times or often. 89 % if these respondents feel that people should visit Iceland to experience the nature, while 56 % thinks that meeting local people is worth the visit. Other motives are experiencing arts, history and culture scene, eating shark and photographing.

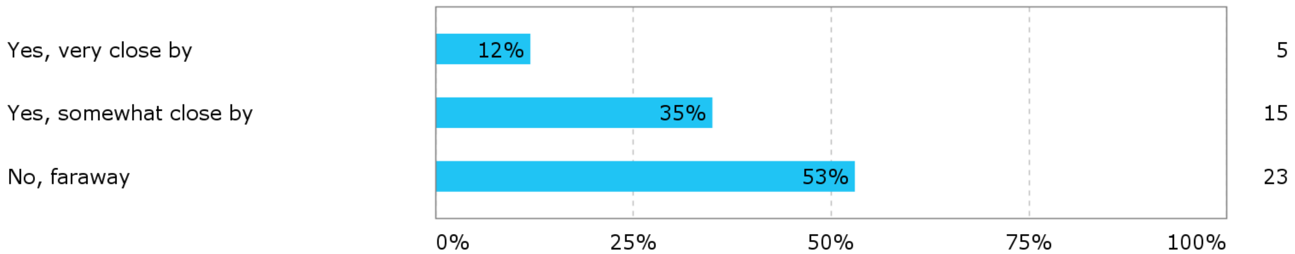


Survey-chart 27: Reasons for visiting Iceland.

The results harmonize with other surveys done for the Iceland tourist bureau where approximately 80 % say that the nature is main reason for visiting the country [114,115,118]. Sveinn at ITB, mention that tourists who come to Iceland seeks to experience the spectacular and unique landscapes, volcanoes, hot springs, glaciers, waterfalls and uninhabited wilderness that is not disrupted by people [115].

6.3.3 *Closeness to wind turbine from respondents home*

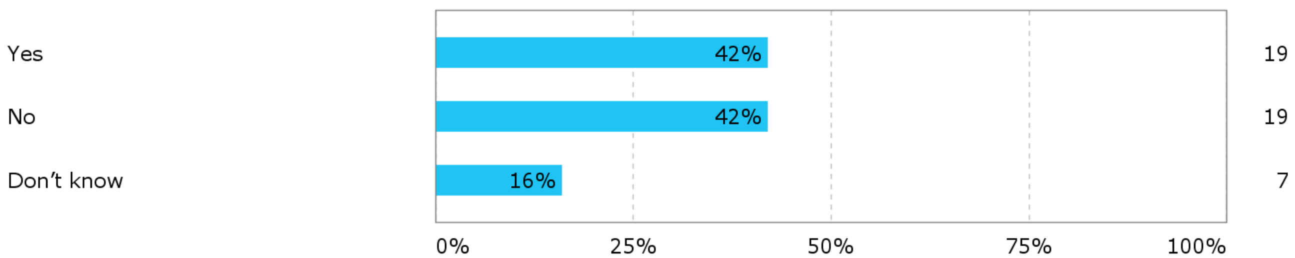
12 % of those who participated in the survey have wind turbines placed close to where they live and 35 % somewhat close by. 53 % didn't have any wind turbines close to where they live.



Survey-chart 28: Closeness to wind turbines from the respondent's home.

6.3.4 People's perception towards wind turbines if placed close to a tourist attraction

When asked if their perception of a tourist attraction would change if wind turbines are placed close by it then yes said 42 % and same share of respondents said no, 16 % didn't know if their perception would change.

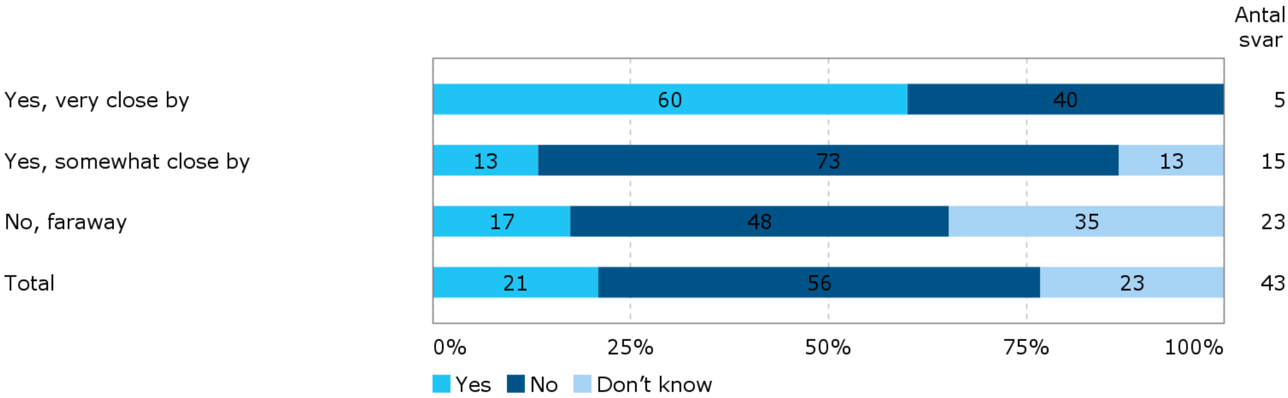


Survey-chart 29: Share of respondents that assumed that their perception would change if wind turbines would be placed close to a tourist attraction.

This question was supplemented with a comment field, and many comments were in a way that an area where wind turbines would be placed on would not be untouched and unspoilt anymore. Others assumed, since Iceland has abundant of geothermal power should wind turbines not be erected there.

- *Disastrously - appalling blight, in return for minuscule environmental benefit.*
- *It's bad for the nice landscape.*
- *Negative. They are blight on the landscape. They are noisy. I am not convinced they are safe.*
- *Iceland is already over-exploited. I visit to 'get away from it all' and experience an unspoilt wilderness. Also, I just don't see why there is a need for it. I support wind farms here in the UK but in Iceland geothermal energy already supplies the needs of the small population.*
- *Why to use wind turbines when so much geothermal energy is available.*
- *Break up the features of the landscape. From a photographic point of view. No issue with the technology and I am very pro wind energy, However in Iceland case they have more than enough Geothermal energy sources to supply the national Grid. I would have a supporting view if they were burning fossil fuels.*
- *Negative and positive. Negative in that the degree of 'wildness' would alter (reduce), but positive in recognition that wind turbines are one of the most 'elegant' power generation developments, so a good compromise. Is geothermal not more competitive though?*
- *Positive. I guess it could be called recycled energy, it may be environmentally friendly and the wind is free.*

If the answers from Survey-chart 28, where participants were asked if they live close to a wind turbine, is crossed with Survey-chart 29 in order to get indications if people that actually live close to a wind turbine are more negative than people who do not. The results are that 60 % of people that have a wind turbine as a neighbour thinks that their perception of an area would change if wind turbines would be placed close to tourist attraction while 40 % thinks it will not change while majority of peoples who have wind turbines placed somewhat close by or far away assume that their perception will not change.



Survey-chart 30: The question is if your perception would change if wind turbines would be placed close to a tourist attraction. The chart is based on results from Survey-chart 28 crossed with answers from Survey-chart 29.

Gunnar Guðjónsson who owns and operates a company offering boat trips for tourists on a glacier lake in an unspoiled area of the highlands, believes that wind turbines would ruin his customer's perception of being in the unspoiled highlands if they were placed within visual distance from his operation area. Better would be if they were placed where no one would see them. He furthermore thinks that a location in the vicinity of a populated area would be different. [119]

> *"The location in a place like the Blue Lagoon or in the vicinity of Reykjavík is different since one is not in an unspoiled area, but in built-up area where the perception is different."* [119]

He furthermore adds that it is maybe not advisable if they were visible when you are in the Blue lagoon. Guðrún adds that the machine house for the Svartsengi geothermal power plant is already visible when you are in the lagoon [120]. She adds that Iceland already has a reputation of using clean and sustainable energy, and wind turbines produces clean energy so it all fits together and she doesn't see anything wrong with placing wind turbines in the vicinity of a tourist attraction [120].

A user of LinkedIn posted on a thread where the survey was promoted on:

> *"Iceland seems like such a sustainable place already, with things such as geothermal greenhouses, naturally heated water for homes, etc. I think that wind turbines would fit in nicely, wherever they go.*
>
> *However, unless the remote, scenic tourist destinations have especially good wind resources (Class I or better), I would prefer to see turbines nearer to population centers (but still the legally required distance from houses), as the natural quietness and se-*

cluded-ness is one of the things I liked most about the Icelandic countryside and would be slightly changed by wind turbines.

That said, it would only be a small portion of rural land occupied by wind farms, as the electricity demand is not so high as to necessitate many turbines, and there would still be plenty of turbine-free space." [121]

Some of the participants posting on the thread were questioning why there was a reason to implement wind energy to the country energy mix when it already has abundant of geothermal power:

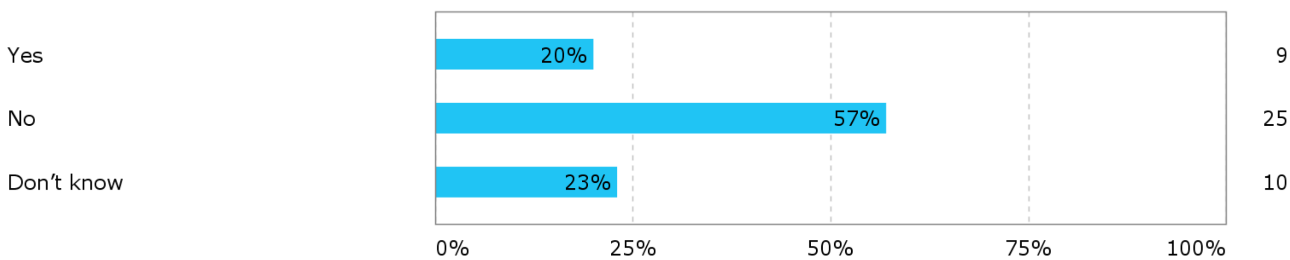
"The question is.......why Iceland is going to install wind energy when the power and heat energy comes from geothermal resources?" [122]

Another user answered with a reply which describes concerns about utilization time and sustainability of geothermal energy, an issue that has been considerably discussed in Iceland.

"Even geothermal eventually runs out (essentially the heat can be drawn out faster than can be transferred from surrounding rock)." [123]

6.3.5 If wind turbines would be close but not visible from a tourist attraction

When survey participants were asked if there's perception on an area would change if the wind turbines would be placed close but not visible from an attraction, 57 % thought that their perception would not change while 20 % thought that it would change.



Survey-chart 31: Share of respondents that assumed that their perception would change if wind turbines would be placed close but not visible from an attraction.

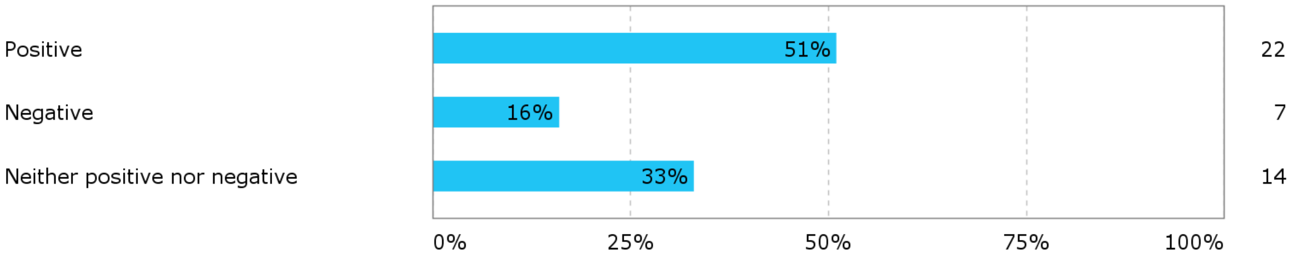
Comments to this question were:

- *Well hidden turbines that wouldn't ruin the view from/at the attraction site.*
- *I love visiting Iceland for the sense of freedom the natural environment gives you. I would only find wind farms acceptable around the Reykjavík area, where tall buildings have already detracted from the natural environment.*
- *Although in i.e. Namaskard [geothermal area in north-east Iceland] you shouldn't install wind parks. No matter where you will install it is a distortion for the bird's population, where Iceland has a lot of. Once more, don't do it.*
- *The beauty of Iceland is that the Earth has shaped itself - human artefacts would spoil that natural beauty.*
- *Negative - I avoid wind energy where-ever and whenever possible. Would travel for kilometres to avoid it.*

Gunnar thought that it would have less impact on his customers if the wind turbines only would be visible when approaching his operation area and not from the area itself [119].

6.3.6 Views on making a wind turbine area accessible

To compensate for visual and other annoyances that wind turbines might cause, an idea is, depending on importance or the area level of interest, to make it accessible to the public. That could be e.g. if wind turbines would be placed in a lava field that it would be made walking paths or sightseeing platforms etc. 51 % of the participants thought that this compensation would make them positive towards the wind farm, 16 % negative and 33 % neither positive nor negative.



Survey-chart 32: Views on compensation in form of increased accessibility

Asked if his attitude towards the location of wind turbines close to his operation area would change, if it would open for the possibility to access an area that otherwise would be inaccessible and could even attract more people to visit the area, and possibly result in more customers for him. Gunnar said that it would not change his opinion. Wind turbines should not be placed in an unspoiled area. He takes Kárahnjúkar (where the dam for Fljótsdalsstöð hydro power plant is located) as an example of a place where the dam project should have increased tourism which is not the case [119]. Guðrún feels that it would be useful and positive if the windmill implementation could open access to previously inaccessible areas. But she stress out that this is relative to areas and location [120].

Ólöf Ýrr can't see any benefits in making an environment humanized in connection with making wind turbine area accessible and is not sure if it will benefit [116].

Gunnar emphasises on that untouched and unspoiled areas should not tamper with. Rather where there already are some structures, such as transmission lines etc. [119]. Guðrún believes that foreigners who are tourists in Iceland are not as critical of wind turbines as the Icelandic people might be.

> *"they are more accustomed to this from their home and feel this more normal and don't consider it so much, since they are used to see this everywhere in their home country, as long it is little bit discreet."* [120].

A very good comment came from a user of LinkedIn on a thread which was started to promote one of the surveys.

> *"Many wind-generating projects have encountered grass-roots opposition. There seem to be two focuses. Most opponents of wind farms merely object on aesthetic grounds.... wind turbine farms constitute a jarring alteration of the landscape they are on. There are also many people who believe that wind turbines cause health problems.*

While this appears to be based entirely on folklore and pseudoscience, in the current paranoid atmosphere it has become a widespread belief. The objectivity of academic science has been so thoroughly compromised by the influence of industry and government that people do not take scientific reports seriously any more, leaving the field open to anyone who can whistle up a website to shape public opinion.

Wind-power is obviously a useful and practical addition to our energy tool-kit, but it is going to take sensitivity and good judgement to implement its use. Few people want to see wind farms dominating the landscape everywhere they look, no matter how useful they might be. Sites will have to be chosen carefully, and public concerns treated seriously. Remember, the nuclear industry was initially dominated by zealots who believed that they were bestowing a cornucopia of cheap, problem-free energy on the world, and blithely ignored public concerns about its safety."[124]

6.3.7 Planning and authority issues discussed in interviews

The interviews touched subjects that were not asked about in the surveys. These subjects were mainly regarding acquiring licenses from planning- and local authorities. Haraldur Magnússon, a farmer that owns and runs a wind turbine on his property, believes that people are little bit afraid of the organisational issues [111]. Margrét Arnardóttir, project manager of wind power at Landsvirkjun, says that it appears that local authorities and municipalities are afraid of allowing wind turbines to be placed within their jurisdiction and are just waiting and hoping that some other will take the first step in allowing it and gaining experience on the subject that they then would benefit of [39].

The researcher received few messages from farmers and landowners while the surveys were being conducted, where it was stated that they would have liked to erect a wind turbine on their property but the local municipalities did not allowed it since they were afraid that other would follow, resulting in visual contamination and other annoyances.

In March 2013, a license was given to a private investor to place two 600 kW wind turbines in a municipality at the south shore of Iceland [125]. Previously had the investor been denied of a license in the municipality where he currently lives where it was it was considered necessary to first establish a policy on wind turbines of this size and in a larger context [126].

Haraldur believes that a court decision that fell in June 2011 has considerable effects. There had a local municipality give an operating license for a pig farm. This protested nearby residents saying that the smell from it would decrease value of their land and houses and filed a suit. The court's decision was that the municipality ought to pay a considerable amount in compensation to the residents [127,128]. Haraldur believes that the court decision is precedent and municipalities are therefore afraid in giving licenses to a structure that might be controversial resulting in compensation of their behalf, to the neighbours of the structure according to previous verdict [111].

7 Outcome of the study

The chapter is devoted to presenting the outcome and results from the study. The chapter is divided to six subjections where each has a delimited subject. Firstly, subjects discussed in chapter 3 - wind farm design followed by subjects in chapter 4 – reviewing social accept. Chapter 5 – feasibility of cooperatives and chapter 6 – views on wind energy projects in Iceland. Finally the answer to the research question presented in chapter 1.4 is given.

7.1 Wind farm design

In chapter 3 two hypothetical wind farms were designed and placed on a location so a series of conditions would be fulfilled. Those locations were at Svartsengi in the vicinity of the Blue lagoon spa and at Akranes in the vicinity of a town with 6500 inhabitants. Both wind farms are identical in terms of installed capacity, number and size of wind turbines that are aligned in a single straight line.

The wind conditions at Svartsengi proved to be superior to the wind resources at Akranes, and yields the wind farm at Svartsengi 129 GWh annually while the wind farm at Akranes yields 81.4 GWh annually. The capacity factor at Svartsengi is 44.2 %, which is acceptable, while the Akranes site has a capacity factor of 27.8 %, which might be questioned if acceptable. Full load hours are fewer at the Akranes site or 2441 hr/year in contrast to 3303 hr/year at Svartsengi.

People visiting the Blue lagoon spa might be subjected to some annoyances from the wind turbines. Some shadow flicker might occur and in some conditions slight noise might be heard. The wind turbines will be very visible when approaching the site but in the lagoon itself only 0-2 of them might be visible. Only the people living in the outermost residential areas of Akranes might be affected by noise, while shadow flicker would not reach to the town. The wind turbines would be very visible for a person when approaching the town, but while that person is situated in the town itself buildings will block the view to the turbines to large extent. However will the wind turbines and the area which is affected by them, limit possible future expansion of the town considerably.

7.2 Reviewing social accept of wind energy

Number of articles regarding social accept of wind turbines was reviewed in addition to that two interviews were conducted to specialists about the subject. A report focusing on public view of utilization of highland area in Iceland for hydro power plant and dam was also reviewed.

The main results were in that way that it is considered to be very important that people affected by wind power project are consulted and involved in the planning process. Other mentionable results are, that is important that people might benefit economically from the project, either directly in form of ownership of wind turbines or indirectly e.g. by servicing or installing them. It was also considered to be important if the land where the wind farm would be placed on is not valuable in terms of historical or natural values. Overexploitation of an area will cause that dissatisfaction since the contentment drops in relation to number and size of wind turbines. Furthermore indicated the Icelandic study strong will from the public that highlands areas will be kept untouched and unspoiled.

There was a furthermore indications towards that people are more satisfied with existing wind turbines than new ones and that people rather prefer few and large wind turbines than many and small.

7.3 Cost analysis on feasibility of a cooperative

A cooperative of wind turbines is considered to be successful solution in order to gain public contentment on wind farms placed nearby their living area. A feasibility analysis was done in order to assess if that is in fact realistic option in Iceland.

The cost analysis, described in chapter 5, based on the two hypothetical case studies at Svartsengi and Akranes gives indications towards that a cooperative is in fact a feasible option in economic terms. The feasibility is of course largely related to cash flow i.e. income from electricity sale and outcome due to investment cost and operational and maintenance cost. The price of electricity is considered to have considerable effects, and for this thesis it is assumed that the price of kWh of electricity increases throughout the lifetime of the wind turbines shortening the payback time. A steady price of 3.9 c€/kWh, like it was in Iceland in January 2013, would mean that the feasibility would become questionable for especially the Akranes cooperative while the Svartsengi cooperative would benefit from higher production values. On the other hand would a reduction from 3.9 c€/kWh like it was in January 2013, mean that the feasibility would decrease significantly and at 2.5 c€/kWh neither cooperative would be economically feasible option.

The investment cost of 1.2 M€/MW is considered to be in the upper edge of the spectrum and it assumed to decrease, to some extent, in upcoming years when more experience is gained in Iceland on wind energy and wind turbines and with further development of wind turbines and wind turbines components. Globally the price has decreased during last years and if that development will continue it will further strengthen the feasibility of cooperatives in Iceland.

The operation and maintenance cost is an issue which is subjected to considerable uncertainties. Globally has the O&M cost decreased with better and more reliable wind turbines and it is assumed it will continue do so resulting in higher revenues to the members of a cooperative.

7.4 Views on wind energy projects in Iceland

The views were found by conducting two surveys and series of interviews with stakeholders that might be affected from a wind energy project. The results from the study, described in chapter 6, are categorised and presented below.

7.4.1 Views towards power plants

Most participants, who answered questions regarding their views on power plants in Iceland, felt that wind energy is most positive or somewhat positive. With nearly same share of general satisfaction is hydro power while most people were negative or somewhat negative towards geothermal power. Urbanites have most positive views regarding wind power and least towards geothermal power. People living in rural areas have nearly same positive opinion regarding all methods and people living on farms have the same positive views towards wind and hydro, note though that the sample of people living under farm like conditions is relatively small in relation to other two samples.

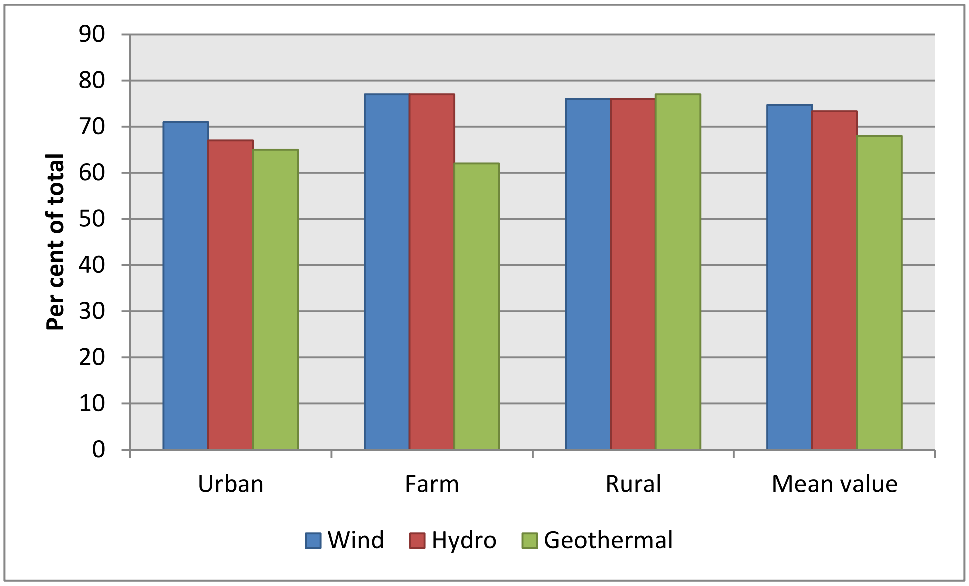


Figure 7.1: Share of the 333 survey participants how are positive or somewhat positive towards different means of energy harnessing.

All in all, it might be concluded that Icelanders are relatively positive towards all means of harnessing energy, and the high share that wind energy has, gives indications towards that Icelanders are interested in new methods in addition to current means in producing energy.

7.4.2 Concerns regarding wind energy

Most people are concerned about visual influences that a wind turbine or wind turbines might cause on the surroundings. Very strong views are that wind turbines should not be placed in unspoiled areas or anywhere where they could spoil a view, especially amongst tourists and people in tourism. If a suitable location for wind turbines would be in the vicinity of a tourist attraction, then most people would prefer that it would be placed in a way that it would cause as little disturbance as possible to the attraction, both in terms of visual disturbance, annoyances due to noise and disruption in the installation time.

Noise and bird fatalities caused by wind turbines is considered to be a somewhat problem amongst participants, while very few people states that shadow flicker is. Some comments regarding disadvantages of wind energy describes, to some extent, lack of knowledge on the subject which perhaps is not strange in light of, that wind turbines are in general unknown in Iceland.

7.4.3 General knowledge of wind energy in Iceland

By enlightening people about benefits and disadvantages of harnessing wind energy with wind turbines one might achieve discussions based on facts and be free of over-hasty judgement based on myths and prejudices.

The participants in the survey states that they have general or rather little knowledge of wind energy, but a general knowledge in a society where there hardly is any knowledge on the subject, is not the “same” general knowledge as you would find in a society where there is a high level of knowledge on the subject. And like it is mentioned before, many of the comments received indicate that the knowledge in Iceland regarding wind energy and wind turbines is generally sparse and affected by myths.

7.4.4 Ways to increase contentment of wind energy projects in Iceland

Beside that there was a strong indication amongst the respondents that it is not preferable to place wind turbines in an area which is unspoiled and/or important to the local people in terms of natural or historical value. Then consultation with the people affected by the structure and keep them informed is a key issue. Nearly all participants stated that it was the most important issue in order to make content, and is this view also confirmed by other studies from other countries as it is stated in chapter 4.

Allowing people to buy a share in the project has proven to work well in Denmark and other neighbouring countries. Most participants in the study say that it would increase their positivity towards wind projects in their neighbourhood, and the feasibility study introduced in chapter five gives indications that people could benefit economically in buying shares.

Creating a recreational area in conjunction with a wind farm gave mixed results amongst the participants, less than 25 % of the Icelandic participants think it would make them more positive towards such a project while others would still be positive, be more negative or don't care. This method was questioned amongst individual in the field of tourism and it would be needed to be assessed depending on location. Tourists were however more positive towards this option.

The size and number of wind turbines seems at this point not be important for the Icelandic people while studies from Germany, France and Greece indicates that people are more in favour of large and fewer wind turbines. This will probably change as times goes by and more experience is gained regarding wind turbines in Iceland and more resemble views from other countries.

Rural people are more concerned than people living in urban area that the workforce used in installation and operational time is from their local area. From other studies reviewed in the literature review in section 4.1, it is mentioned that it is important that the workforce is from the local area. The same studies points out the importance that a local municipality or local private investors are the ones who is in charge of wind projects. This viewpoint is not considered to be important by Icelanders. The reason is probably due to the size, or lack of size, of the Icelandic community where there is not so much distinctions between regions.

A handful of respondents point out that it is important that the electricity price does not rise as result of using more expensive method in producing electricity, than hydro and geothermal are.

7.5 Final conclusion

In order to find an answer to the research question presented in chapter one, *"what is the social opinion towards wind power projects in Iceland, and which approaches and methods might be used to increase public contentment of these projects?"* A series of processes was carried out. Firstly, a thorough literature study and interviews were carried out in order to gain knowledge on the subject and other people's experience with it.

Simultaneously were two hypothetical wind farms designed as case studies, and were production values and other data created in the process used later in the study.

One of the results found in the literature studied and the conducted interviews with specialists in the field of social acceptance is that a cooperative of shareholders in wind turbines is an effective method to increase contentment of wind energy projects. Based on this, the economic feasibility of wind energy cooperative was assessed in terms of economic conditions in Iceland.

Finally two surveys, one targeted towards the Icelandic public and the other to foreigners that have, or might visit Iceland in the future was carried out in addition to number of interviews with stakeholders in Iceland in the field of tourism and municipal administration, plus to a person that already owns and operates wind turbine on his property.

The findings from these processes are that a wind farm is that a wind farm might well be realistic option in the vicinity of Svartsengi that is located in south-west corner of Iceland, while the other location in the vicinity of the town Akranes is hardly a feasible one. A cooperative of wind turbines owners could well give some profit to the shareholder in the long run, but is subjected to a great deal of uncertainties, such as development of electricity price, wind resources, discount rates and costs.

Answering the research question, then are Icelanders relatively positive towards wind power projects if certain conditions are followed, such as low visibility and not located in an unspoiled area. Compared to harnessing other energy resources is the Icelandic public more positive towards wind energy than hydro- and geothermal energy, which is considered to be the least preferable option. Foreigners and persons in the field of tourism are little bit more sceptic towards wind energy. A location close to a tourist attraction or in an unspoiled area is not preferred by them, a viewpoint that is also agreed on by some local people.

If a wind power project is situated in the vicinity of residential areas, then involving the public, affected by the project, in the planning process is a good way to gain contentment on wind power projects. To establish a joint ownership through a cooperative might also be successful.

Enlighten the public about pros and cons of wind energy. By doing so could myths regarding wind energy that are circulating and which there is no basis for, be silenced resulting in more reasonable discussion and hopefully more positivity towards wind projects.

One of the results from the literature study reviewed in chapter 4, was that people prefer to have large and few wind turbines rather many and small. This viewpoint is not agreed on by participants in this study where most people did not care on that viewpoint. That is maybe not surprising since the average Icelander don’t have any experience with living close to wind turbines. Chances are when more experience is gained in Iceland with wind turbines that the viewpoint will resemble viewpoints introduced in the literature, that bigger and fewer wind turbines are preferred.

The usage, or in some cases non usage, of land is very important to nearly all who participated in surveys and interviews. There is a strong will that wind turbines should not be placed on land or an area which has natural, historical or cultural importance. And utilize an area moderately since contentment drops accordingly size and numbers of wind turbines.

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9 Appendixes

Calculation of economic feasibility of cooperatives

Rates:

Nominal Discount Rate	[ndr]	6,00%
Inflation	[i]	3,30%
Real Discount Rate	[dr]	2,61%

Formulas:

Discount Factor	1/(1+dr)^n
Real Discount Rate	(1+ndr)/(1+i)-1

Income pr.	1 share @ Akranes. Scenario 1															
Year	2013	2014	2015	2016	2017	2018	2019	2031	2032	2033	2034	2035	2036	2037	2038	2039
n	0	1	2	3	4	5	6	18	19	20	21	22	23	24	25	26
Costs	-491,23 €	-8,66 €	-9,00 €	-7,67 €	-6,63 €	-6,83 €	-7,08 €	-6,33 €	-6,40 €	-6,47 €	-6,55 €	-6,44 €	-6,32 €	-6,20 €	-6,36 €	-6,53 €
Discount Factor	1,00	0,97	0,95	0,93	0,90	0,88	0,86	0,63	0,61	0,60	0,58	0,57	0,55	0,54	0,52	0,51
Discounted Costs	-491,23 €	-8,44 €	-8,55 €	-7,10 €	-5,98 €	-6,00 €	-6,06 €	-3,98 €	-3,92 €	-3,86 €	-3,81 €	-3,65 €	-3,49 €	-3,34 €	-3,34 €	-3,34 €
Income	0	37,33 €	42,58 €	39,40 €	36,19 €	38,78 €	41,47 €	43,35 €	44,20 €	45,07 €	45,97 €	45,61 €	45,14 €	44,63 €	44,63 €	47,75 €
Discount Factor	1,00	0,97	0,95	0,93	0,90	0,88	0,86	0,63	0,61	0,60	0,58	0,57	0,55	0,54	0,52	0,51
Discounted income	0,00 €	36,38 €	40,44 €	36,47 €	32,64 €	34,08 €	35,52 €	27,24 €	27,07 €	26,90 €	26,74 €	25,85 €	24,93 €	24,03 €	23,42 €	24,41 €
Cash Flow	-491,23 €	27,94 €	31,89 €	29,36 €	26,66 €	28,08 €	29,46 €	23,27 €	23,15 €	23,04 €	22,93 €	22,21 €	21,44 €	20,69 €	20,08 €	21,07 €
Accumulated NPV	-491,23 €	-463,29 €	-431,41 €	-402,04 €	-375,38 €	-347,30 €	-317,85 €	-12,34 €	10,81 €	33,85 €	56,78 €	78,99 €	100,43 €	121,12 €	141,20 €	162,27 €

Income pr.	1 share @ Svartsengi. Scenario 2															
Year	2013	2014	2015	2016	2017	2018	2019	2031	2032	2033	2034	2035	2036	2037	2038	2039
n	0	1	2	3	4	5	6	18	19	20	21	22	23	24	25	26
Costs	-309,97 €	-8,66 €	-7,80 €	-6,75 €	-5,93 €	-6,05 €	-6,21 €	-5,61 €	-5,66 €	-5,70 €	-5,74 €	-5,69 €	-5,63 €	-5,57 €	-5,64 €	-5,70 €
Discount Factor	1,00	0,97	0,95	0,93	0,90	0,88	0,86	0,63	0,61	0,60	0,58	0,57	0,55	0,54	0,52	0,51
Discounted Costs	-309,97 €	-8,44 €	-7,41 €	-6,25 €	-5,35 €	-5,32 €	-5,32 €	-3,53 €	-3,47 €	-3,40 €	-3,34 €	-3,22 €	-3,11 €	-3,00 €	-2,96 €	-2,91 €
Income	0	33,49 €	37,42 €	35,21 €	32,88 €	34,93 €	37,01 €	45,55 €	46,23 €	46,85 €	47,47 €	47,19 €	46,79 €	46,36 €	46,82 €	47,13 €
Discount Factor	1,00	0,97	0,95	0,93	0,90	0,88	0,86	0,63	0,61	0,60	0,58	0,57	0,55	0,54	0,52	0,51
Discounted income	0,00 €	32,64 €	35,54 €	32,58 €	29,66 €	30,70 €	31,71 €	28,63 €	28,32 €	27,96 €	27,61 €	26,75 €	25,85 €	24,96 €	24,56 €	24,10 €
Cash Flow	-309,97 €	24,20 €	27,74 €	25,83 €	23,73 €	24,66 €	25,49 €	23,01 €	22,66 €	22,26 €	21,87 €	21,06 €	20,22 €	19,39 €	18,93 €	18,40 €
Accumulated NPV	-309,97 €	-285,77 €	-258,03 €	-232,20 €	-208,47 €	-183,82 €	-158,33 €	134,59 €	157,25 €	179,51 €	201,38 €	222,44 €	242,66 €	262,05 €	280,97 €	299,37 €

Costs:
First year cost is initial investment cost.
Second year cost and onwards are O&M costs.

Income:
Purely from electricity sales.
Scenario 1: Linear progression.
Scenario 2: Submarine connection to Europe.

Calculation:
Cash flow is discounted income minus discounted costs
Accumulated NPV is previous year NPV minus current year cash flow

WindPRO version 2.8.579 Dec 2012

Project:
Blue Lagoon

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PARK - Main Result

Wake Model N.O. Jensen (RISØ/EMD)

Calculation Settings

Air density calculation mode	Individual per WTG
Result for WTG at hub altitude	1,239 kg/m³ to 1,241 kg/m³
Air density relative to standard	101,1 % to 101,3 %
Hub altitude above sea level (asl)	144,6 m to 164,6 m
Annual mean temperature at hub alt.	3,8 °C to 4,0 °C
Pressure at WTGs	984,9 hPa to 987,3 hPa

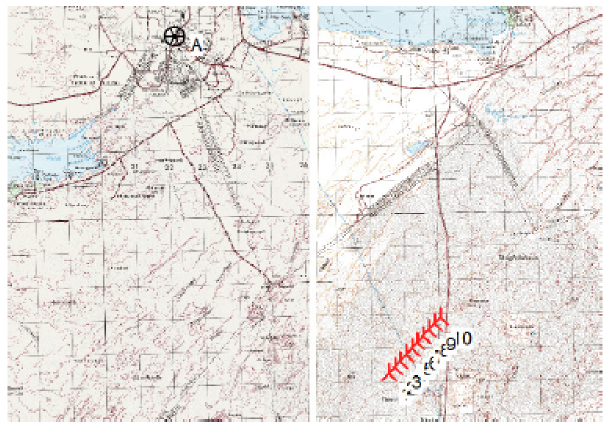
Wake Model Parameters
Wake Decay Constant 0,075 Open farmland

Wake calculation settings

Angle [°] start	end	step	Wind speed [m/s] start	end	step
0,5	360,0	1,0	0,5	30,5	1,0

Wind statistics IS Keflug - 57,00 m.wws

WAsP version WAsP 6-9 RVEA0011.dll 1, 0, 0, 13



Scale 1:200.000
New WTG Site Data

Key results for height 50,0 m above ground level

Terrain UTM (north)-WGS84 Zone: 27

	East	North	Name of wind distribution	Type	Wind energy [kWh/m²]	Mean wind speed [m/s]	Equivalent roughness
A	422.285	7.095.166	Site data AEP-WAsP	WAsP (WAsP 6-9 RVEA0011.dll 1, 0, 0, 13)	8.139	9,3	1,7

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	Result-10,0% [MWh]	GROSS (no loss) Free WTGs [MWh/y]	Park efficiency [%]	Specific results¤) Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	129.044,9	116.140,4	137.137,6	94,1	44,2	11.614,0	3.871	11,0

¤) Based on Result-10,0%

Calculated Annual Energy for each of 10 new WTGs with total 30,0 MW rated power

	Terrain	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh]	Result-10,0% [MWh]	Park Efficiency [%]	Mean wind speed [m/s]
1	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	13.072,4	11.765	94,97	11,07
2	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	12.828,3	11.545	93,67	11,02
3	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	12.714,0	11.443	93,25	10,96
4	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	12.672,0	11.405	93,09	10,95
5	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	12.683,4	11.415	93,11	10,97
6	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	12.801,5	11.521	93,23	11,06
7	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	12.810,8	11.530	93,42	11,05
8	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	12.923,4	11.631	93,86	11,09
9	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	13.095,8	11.786	94,83	11,13
10	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	13.443,3	12.099	97,52	11,11

WTG siting

UTM (north)-WGS84 Zone: 27

	East	North	Z [m]	Row data/Description
1 New	428.432	7.085.005	60,0	42,2°, 250,0 m
2 New	428.604	7.085.186	60,0	
3 New	428.776	7.085.367	60,0	
4 New	428.949	7.085.548	61,2	

To be continued on next page...

Akranes site Park Calculation from WindPRO

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Akranes

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PARK - Main Result

Calculation: Park calc local data

Wake Model N.O. Jensen (RISØ/EMD)

Calculation Settings

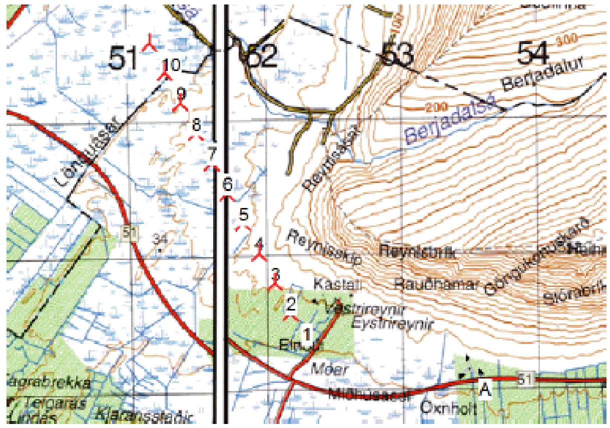
Air density calculation mode	Individual per WTG
Result for WTG at hub altitude	1,245 kg/m³ to 1,249 kg/m³
Air density relative to standard	101,6 % to 102,0 %
Hub altitude above sea level (asl)	103,6 m to 137,6 m
Annual mean temperature at hub alt.	4,1 °C to 4,4 °C
Pressure at WTGs	991,1 hPa to 995,3 hPa

Wake Model Parameters

Wake Decay Constant 0,075 Open farmland

Wake calculation settings

Angle [°] start	end	step	Wind speed [m/s] start	end	step
0,5	360,0	1,0	0,5	30,5	1,0



Scale 1:50.000

New WTG   Meteorological Data

Key results for height 84,0 m above ground level

Terrain UTM (north)-Hjorsey 1955 Zone: 27

	East	North	Name of wind distribution	Height [m]	Type	Wind energy [kWh/m²]	Mean wind speed [m/s]
A	453.459	7.132.350	Akranes Ice met mast	84,6	MEASURE	5.452	7,6

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	Result-10,0% [MWh]	GROSS (no loss) Free WTGs [MWh/y]	Park efficiency [%]	Specific results¤) Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	84.369,3	75.932,3	85.139,6	99,1	28,9	7.593,2	2.531	7,6

¤) Based on Result-10,0%

Calculated Annual Energy for each of 10 new WTGs with total 30,0 MW rated power

	Terrain	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh]	Result-10,0% [MWh]	Park Efficiency [%]	Mean wind speed [m/s]
1	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	8.457,4	7.612	99,37	7,63
2	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	8.425,5	7.583	99,05	7,63
3	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	8.418,7	7.577	98,99	7,63
4	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	8.422,6	7.580	98,97	7,63
5	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	8.424,2	7.582	98,96	7,63
6	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	8.426,1	7.583	98,97	7,63
7	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	8.429,8	7.587	98,98	7,63
8	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	8.434,3	7.591	99,00	7,63
9	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	8.444,1	7.600	99,09	7,63
10	A	Yes	ENERCON	E-82 E3-3.000	3.000	82,0	84,6	EMD	Level 0 - calculated - Rev 2.0 - 11/2009	8.486,6	7.638	99,57	7,63

WTG siting

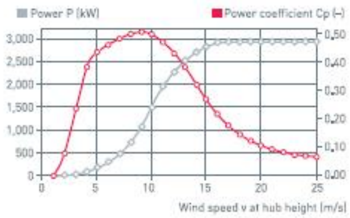
UTM (north)-Hjorsey 1955 Zone: 27

	East	North	Z [m]	Row data/Description
1 New	452.156	7.132.782	41,9	-27,3°, 250,0 m
2 New	452.044	7.133.006	49,9	
3 New	451.933	7.133.230	53,0	
4 New	451.821	7.133.454	42,7	
5 New	451.710	7.133.677	38,9	

To be continued on next page...

E-82 Enercon product overview

Calculated power curve



Wind (m/s)	Power P (kW)	Power-coefficient Cp (–)
1	0,0	0,00
2	3,0	0,12
3	25,0	0,29
4	82,0	0,40
5	174,0	0,43
6	321,0	0,46
7	532,0	0,48
8	815,0	0,49
9	1,180,0	0,50
10	1,580,0	0,49
11	1,900,0	0,44
12	2,200,0	0,39
13	2,480,0	0,35
14	2,700,0	0,30
15	2,850,0	0,26
16	2,950,0	0,22
17	3,020,0	0,19
18	3,020,0	0,16
19	3,020,0	0,14
20	3,020,0	0,12
21	3,020,0	0,10
22	3,020,0	0,09
23	3,020,0	0,08
24	3,020,0	0,07
25	3,020,0	0,06

$\rho = 1,225\ kg/m^3$

Technical specifications E-82 E3

Rated power:	**3,000 kW**
Rotor diameter:	**82 m**
Hub height in meter:	**78 / 85 / 98 / 108 / 138**
Wind zone (DIBt):	**–**
Wind class (IEC):	**IEC/EN IA und IEC/EN IIA**
WEC concept:	Gearless, variable speed Single blade adjustment

Rotor

Type:	Upwind rotor with active pitch control
Rotational direction:	Clockwise
No. of blades:	3
Swept area:	5,281 m²
Blade material:	GRP (epoxy resin); Built-in lightning protection
Rotational speed:	Variable, 6 – 18 rpm
Pitch control:	ENERCON single blade pitch system; one independent pitch system per rotor blade with allocated emergency supply

Drive train with generator

Hub:	Rigid
Main bearing:	Double row tapered/cylindrical roller bearings
Generator:	ENERCON direct-drive annular generator
Grid feed:	ENERCON inverter
Brake systems:	– 3 independent pitch control systems with emergency power supply – Rotor brake – Rotor lock
Yaw system:	Active via yaw gear, load-dependent damping
Cut-out wind speed:	28 – 34 m/s (with ENERCON storm control*)
Remote monitoring:	ENERCON SCADA

* For more information on the ENERCON storm control feature, please see the last page.

E-82
3,000 kW

1 Main carrier
2 Yaw drive
3 Annular generator
4 Blade adapter
5 Rotor hub
6 Rotor blade