Economic Perspectives and Social Acceptance of Possible Increase in the Small Scale Hydropower Plants in Finland

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ABSTRACT

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The objectives of this thesis are to study the possibilities for increasing small scale hydropower in Finland, by studying the social acceptance and economical perspectives. It contains general information about the electricity market, production and consumption, as well as information collected about social acceptance and economical perspectives related to small scale hydropower plants.

This thesis was conducted in Finland. The goals of this study are to determine why small scale hydropower in Finland is not increased already, regardless of the many potentials micro hydropower. In order to study a possible increase in small scale hydropower in Finland, social acceptance and economical possibilities were studied as well as the potential for increasing micro and small scale hydropower. The methods used to gather information regarding the economical perspective, were interviews conducted with owners, designers and experts in hydropower. Moreover, surveys were taken with neighbours of small scale hydropower plants for a social acceptance study.

This thesis clarifies that inhabitants of Finland accept small scale hydropower plants in more crowded areas, as well as micro scale hydropower on more outlying areas. About 85% of the people could accept a new hydropower plant in town, whereof 55% of them could accept it within 300m of their house. Economical perspectives show that small scale hydropower is profitable when its capacity is more than 1MW and the head is at least 5 meters. However, potential locations for small scale hydropower are rather limited. On the other hand, micro scale hydropower is less profitable, because mostly it serves as peak load power plant, but potential locations for this application are numerous.

Key words: small scale hydropower, micro scale hydropower, social acceptance, economical perspectives, potentials,

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De doelstelling van deze thesis is onderzoeken wat de mogelijkheden zijn om het aantal kleinschalige waterkrachtcentrales in Finland te verhogen. De thesis bevat algemene informatie over de elektriciteitsmarkt, - productie en - verbruik. Daarnaast werd ook informatie verzameld over sociale aanvaarding en economische perspectieven in verband met kleinschalige waterkrachtcentrales.

De thesis werd uitgevoerd in Finland. Het doel van dit onderzoek was om te ontdekken waarom het aantal kleinschalige waterkrachtcentrales nog niet is toegenomen, ongeacht het grote potentieel voor micro waterkrachtcentrales. Sociale aanvaarding en economische perspectieven werden hierin onderzocht, om te zoeken naar mogelijkheden om het aantal kleinschalige waterkrachtcentrales op te drijven. Interviews met eigenaars, designers en experts in waterkrachtcentrales werden afgenomen om informatie te verzamelen over de economische perspectieven. Daarnaast werden enquêtes afgenomen aan omwonenden van een kleinschalige waterkrachtcentrale om de sociale aanvaarding te onderzoeken.

Deze thesis verduidelijkt dat de inwoners van Finland kleinschalige waterkrachtcentrales aanvaarden, zowel in drukbevolkte gebieden (Steden), alsook micro waterkrachtcentrales in meer afgelegen gebieden (Summercottages). Ongeveer 85% van de ondervraagden kunnen een nieuwe waterkrachtcentrale aanvaarden, waarvan 55% het kan aanvaarden als het binnen de 300m van de woonst gelegen is. Economische perspectieven tonen dat kleinschalige waterkrachtcentrales winstgevend zijn, als de capaciteit groter is dan 1 MW en een hoogteverschil van minstens 5 meter, maar dat er anderzijds slechts weinig potentiële locaties beschikbaar zijn. Micro waterkrachtcentrales daarentegen hebben een groot potentieel aan locaties beschikbaar, maar zijn minder winstgevend, omdat ze meestal werken als piekcentrale.

Sleutelwoorden: kleinschalige waterkrachtcentrales, micro waterkrachtcentrales, sociale aanvaarding, economische perspectieven, potentiele locaties.

CONTENTS

1 INTRODUCTION

The demand for increasing the use of renewable energy has risen over the last few years due to environmental issues. The high emissions of greenhouse gases have led to serious changes in the climate. Higher usage of renewable energy would decrease the high emissions of greenhouse gases. The field of renewable energy includes, for example, wind power, solar power, geothermal power and hydropower. In this thesis the possible increase in small scale hydropower is studied.

The first time water flow was used as an energy source dates back centuries. The energy was utilized, for instance for grinding grain. The applied machinery for this purpose was based on simple water wheels. Over the years, machinery has been developed and become more advanced. Hydropower was the first renewable energy source which was used to generate electricity more than 100 years ago. Today hydropower has a significant impact on world scale electricity production. Approximately 20% of the total electricity production in the world is delivered from hydropower. (Flaspöhler, 2007)

In Finland approximately 15.6% of the total electricity consumption is delivered from hydropower. (Industries, 2009) The large amount of Lakes (approximately 188 000 Lakes), makes Finland one of the best countries for hydropower. The cause of this thesis is its numerous amount of potential locations that are not used. In order to find out why these potential locations are not used for hydropower, a social and economic study is conducted.

The social study is made in order to figure out if hydropower is socially accepted by inhabitants of Finland. The acceptance is important to see if the inhabitants stop the possible increase in hydropower, or if there are other underlying reasons. The economical perspectives are studied in order to see if the small scale hydropower plants pay off, and what kind of cash flow it brings. The economical aspect is important to find out if the cash flow for hydropower is a factor to stop the possible increase in hydropower.

This thesis shows an overall view of the electricity market in Finland. Production and consumption of electricity is explained, as well as the share of renewable energy. This information is important to show what effects a possible increase in small scale hydropower can give in the future. Hydropower in particular is explained with de corresponding techniques and methods to make hydropower efficient and profitable. In this thesis the methods used for the interviews and surveys are explained, as well as the results of the interviews and surveys.

2 BACKGROUND

The background describes at first how the electricity market and power grid in Finland works. Knowledge of the balance in the power grid is necessary to understand the importance of increase in small scale hydropower. Different types of producing electricity as well as the renewable energy share in Finland are discussed in order to show the extent to which hydropower is already active.

2.1. Electricity Market Finland

At first the electricity market of Finland will be described. The working is crucial to implement it in the economical aspect of the thesis. Finland's electricity market is open for competition and that means that all electricity users, including private households, are able to choose their preferred electricity supplier. This has become so after the Electricity Market Act in 1995.

The purpose of the electricity market reform was to increase the efficiency of operations and to integrate Finland's electricity market into the Nordic market. This liberalisation and integration actions increased the productivity and environmental efficiency, as the Nordic hydropower capacity can now be utilised efficiently and the market allows for trading in "green" energy. (Ministry of Employment and Economy, 2014)

In the Nordic electricity market, each country is independently responsible for its transmission grid. In Finland the distribution grid is owned by Fingrid Corporation, and a part of it is owned by the state, the other parts are owned by energy companies and financial investors. (Ministry of Employment and Economy, 2014)

In Finland you have three different types of electricity producers; large, small and medium sized energy companies. The large electricity producers are Fortum, -Pohjolan, -Voima and these are state owned companies. The medium and small electricity producers are local energy companies and operate with the Mankala-principle. Which means that they do not pay dividends, but rather provide power to their owners without seeking profit. Moreover, many of the industrial corporations are themselves energy producers, because they use process waste from the factories as fuels for the medium and small power plants. Mostly the waste fuel originate from wood processing, and therefore counts as renewable source. Small-scale electricity consumers connected to distribution networks, such as small enterprises and households, buy their electricity from retailers. There are approximately 75 retail sellers of electricity in Finland. Most of the retailers also act as local distributors, but the buyers are not bound to a local seller and can buy their electricity from any preferred supplier. (Ministry of Employment and the Economy , 2014), (OPET report, 2002)

2.2 Power Grid

The power system in Finland consists of power plants, nation-wide transmission grid, regional networks, distribution networks and electricity consumers. The power system in Finland is part of the inter-Nordic power system that serves together with Sweden, Norway and Eastern Denmark. There are direct current transmission links to Finland from Russia and Estonia for the connection to their systems which work under different principles, to the Finnish power system. Figure 1 below shows the Fingrid network.

FIGURE 1: Fingrid network (source: Fingrid presentation 2014)

Fingrid is responsible for the functioning of the Finnish electricity transmission grid. The transmission grid covers the entire Finland and is a high-voltage trunk network.
The grid consists of 400kV, 220kV, 110kV transmission lines. All kind of power plants are connected to the grid: major power plants, industrial plants and regional electricity distribution networks.

The transmission grid serves electricity producers and costumers. It makes it possible to trade between producers and costumers on a nation-wide level even across national boundaries. Most of the electricity consumed in Finland is transmitted via the nation-wide transmission grid. Fingrid is responsible for the system supervision, operation planning, balance service, grid maintenance, construction and development, and promotion of the electricity market. (Fingrid, 2014)

2.3 Fingrid

Fingrid is the national grid operator in Finland, its task is to maintain national power balance management. That means keeping the balance between consumption and production of electricity, to ensure that the Finnish electricity system is maintained and used in a technically correct manner. One of the biggest responsibilities, together with the other Nordic grid operators is the safeguarding of necessary reserves for the operation of the electricity system. (Ministry of Employment and the economy, 2014). Figure 2 below shows the Nordic Power system.

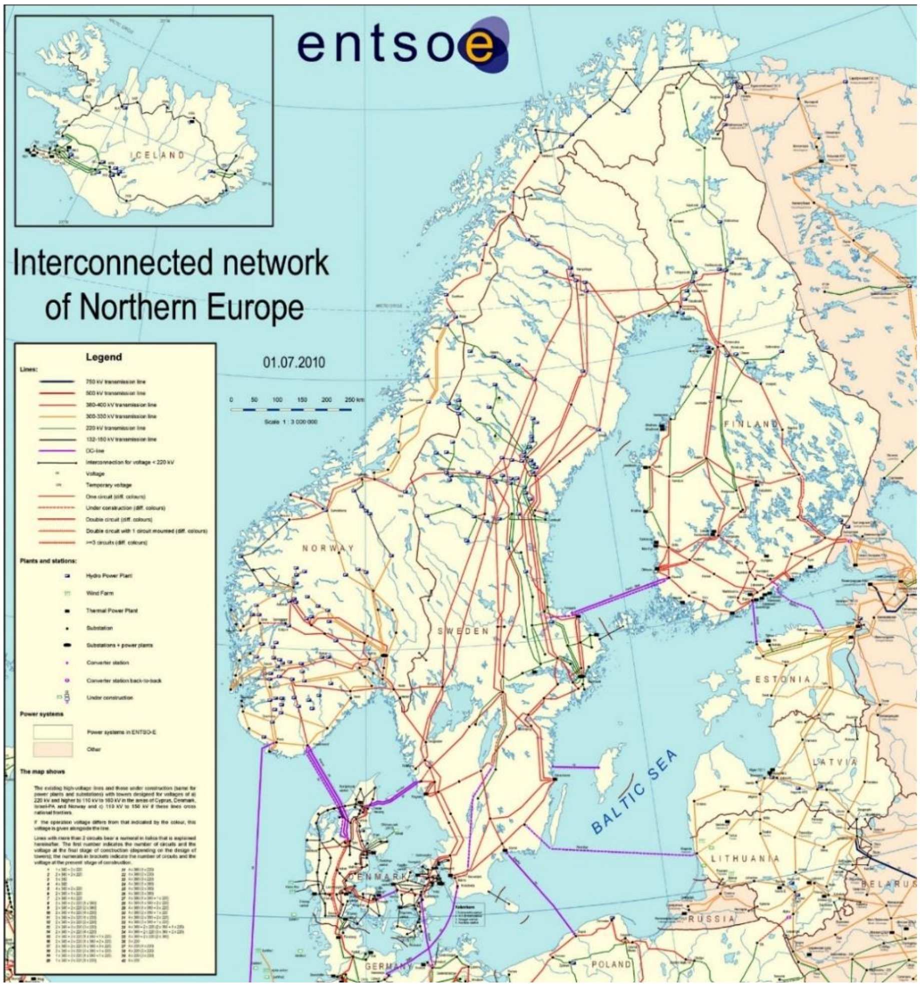

FIGURE 2: Nordic power system (source: Fingrid website)

2.3.1 Maintaining of Voltage

Maintaining of voltage is one of the tasks the Fingrid has to complete. The voltage level of the grid needs to be between the permitted ranges in all system operation situations. By focusing on the reactive power balance in the different voltage steps in the grid, it is possible to maintain the voltage. If the reactive power surplus, then the voltage increases. If the reactive power deficiency, the voltage decreases. So the voltage is kept between the acceptable limits by controlling the generation and consumption of reactive power. The control of generation and consumption is done by means of reactors and capacitors. The ratio of voltage between the various voltage steps is controlled by means of the on-load-tap-changers of the transformers. Reactive power reserves of the transmission grid are located in spinning generators, which are activated automatically if the voltage of the grid drops as result of a disturbance.

An overview of the permitted ranges of voltages are:

- 400kV network: 380 ….. 420 kV
- 220kV network: 215 ….. 245 kV
- 110kV network: 105 ….. 123 kV

During a normal operation situation the upper limit of the range must not be exceeded because of the maximum voltage of components, and electrical safety. On the other hand, the current carrying capacity of components requires a certain minimum voltage. (Fingrid, 2014)

The difference between maintaining the voltage and maintaining of power balance is located in the difference between reactive power and frequency. The difference between consumption and production is translated into the frequency of the power grid. Because Finland's electricity consumption is the sum of all the loads connected to the grid, and thus always fluctuating. The consumption also changes over longer periods, hourly, daily and seasonally. It is the responsibility of the market operators to plan and balance their production and consumption in advance. But you never know what will actually happen, and it's the task of Fingrid to keep the balance between consumption and production each hour. If the frequency drops, the consumption is higher than the production, so the frequency falls below 50HZ. If the production rises higher than the consumption the frequency exceed 50 Hz. The frequency is allowed to fluctuate between 49.9 and 50.1 Hz in normal state.

Fingrid ensures the balance between consumption and production by activating regulating bids from the balancing power market and by reserving capacity. It also acquires different reserve products that react to changes in consumption and production at different levels of time. They own their own back-up system in order to keep the network in balance. The Nordic system has obligations for maintaining reserves, it is an agreement between the Nordic transmission system operators (Finland, Sweden, Norway, and East Denmark). The reserve capacity is used for peak moments of the day (morning and evening).

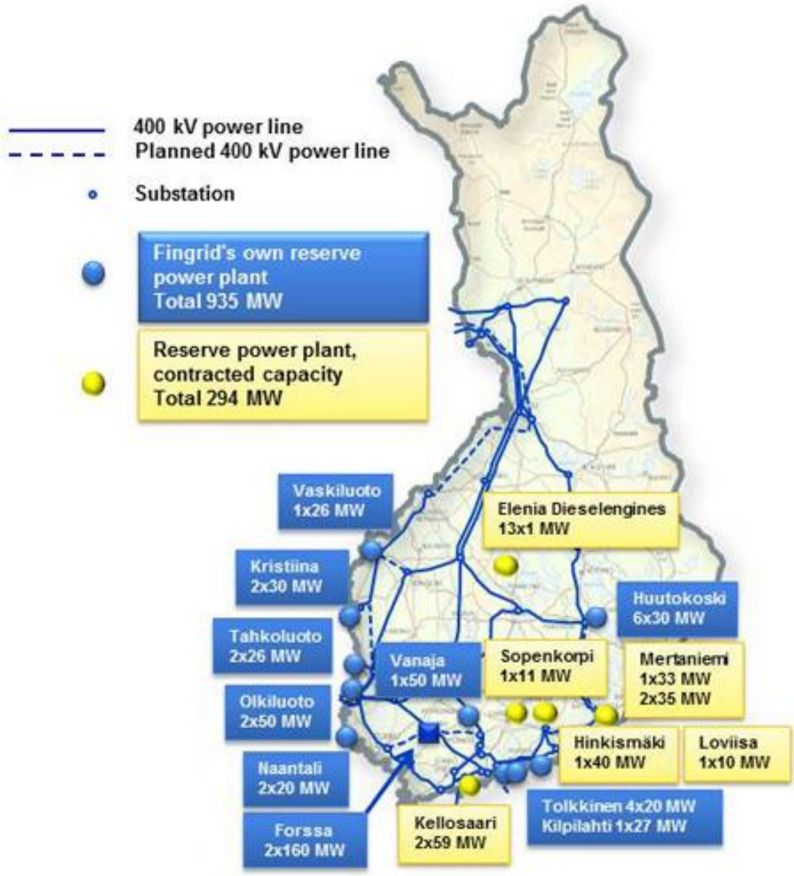

FIGURE 3: Frequency restoration reserve power plants. (source: Fingrid website)

The reserve power plants are manual frequency restoration reserve power plants. Fingrid owns and leases power plants for restoration the frequency if needed, they are not used for commercial electricity production. (Fingrid, 2014)

2.4 Electricity Market

Finland is part of the inter-Nordic power system, and so a part of the Nordic electricity wholesale market. Electricity is exchanged in the Nordic power system, approximately 70% of the electricity wholesale trade is done in the Nord Pool Spot electricity exchange. The Nord Pool Spot consists of an Elspot and Elbas electricity market. On the Elspot market, the market area's prices and regional prices are set for the next day by an auction. The prices are stated according to the purchase, sales, distributors and end users. The electricity exchange price will be used as reference price for other electricity trading. Capacity which may not have been used in the Elspot, is offered to the Elbas market, where trading finishes no later than one hour before the specific hour of operation.

The Elspot capacities for the next day are offered before the noon, and the Elbas capacities in the afternoon.

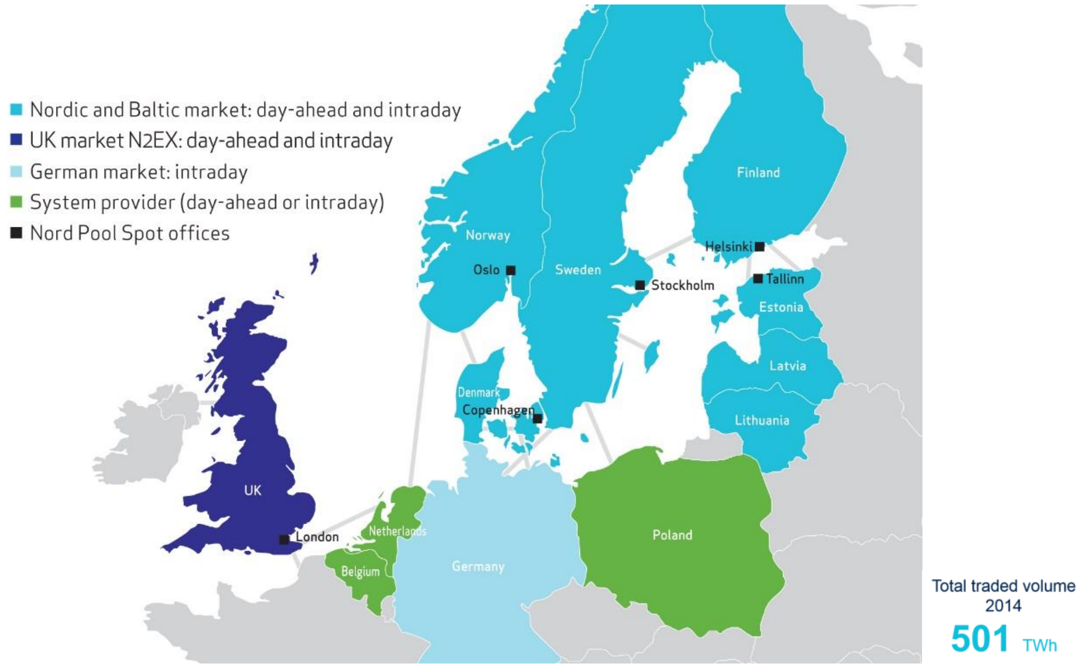

FIGURE 4: Nord Pool Spot trading market (source: Nordpoolspot, 2015)

The companies who are involved in the electricity market, are responsible for their electricity balance. They must ensure that the producer will deliver the correct amount of electricity. The transmission system operator Fingrid is responsible for the electricity balance between the countries during the usage hours of electricity trading.

The main grid transmission and distribution of electricity are natural monopolies which operation and pricing is supervised in Finland by the Energy Authority. A natural monopoly is a distinct type of monopoly that may arise when there are extremely high fixed costs of distribution, for example when large-scale infrastructure is required to ensure supply. Government often regulates those operations, to ensure that consumers get a fair deal. Typical examples for that includes cables and grids for electricity supply, pipelines for gas and water supply. (Economics Online , 2015) It is their responsibility to connect the costumers to the grid, and develop the operation of the grid without discrimination and at a reasonable price. (Fingrid, 2014)

2.4.1 Common Electricity Market

The wholesale market between neighbouring countries creates a competitive wholesale electricity market. There is a diversity of different electricity production in Nordic countries, who can be used efficiently. Norway's electricity production is in particular generated from hydroelectric power. In Denmark, approximately half of the production is thermal power based on coal and natural gas. Finland's electricity is produced on different ways, thermal power, nuclear power and hydroelectric power.
In a good water year, the Nordic market can utilise hydroelectric power to reduce expenses and carbon dioxide emissions. As opposed to a dry water year, hydroelectric power will generate less electricity in the Nordic market, so Finland and Denmark can use the thermal power to guarantee the sufficiency of electric energy.

Some advantages of the common electricity market are the common reserve capacity and a common price of electricity. The balance between production and consumption can be arranged by hydroelectric power. However every country has enough production capacity for meeting the peak demand, they are technically interdependent. For example, the largest plant in Finland is 500MW, if an emergency situation occurs you might need the Nordic countries for the reserve capacity. At the other hand, the Nordic system is also cost efficient because a significant hydropower generation capacity in Norway (97%) and Sweden (48%) drives the electricity price in Finland. Just because the price of electricity generated by hydropower is cheaper than electricity produced by any other source. (Energy and Climat Roadmap 2050, 2014)

2.5 Production of Electricity

The energy sector in Finland relies on nuclear power, coals, forest industry black liquor, wood consumption and net imports. The total energy consumption in Finland in 2014 was 1 340 123 TJ, which was on the same level as the previous year. Finnish yearly electricity consumption was between 84 and 87 TWh in 2010 – 2014. According to the latest update of the Finland's Energy and climate Strategy, and based on the European Union's climate policy, electricity consumption will increase 10% by 2020 and 20% by 2030. (Ministry of Employment and the Economy 2013).

In case electricity consumption increases in the future, more electricity production will be necessary, as well as reducing the CO_2- emissions. So the only possibility will be to generate no carbon electricity. That can be Nuclear, Hydro, Geothermal, Solar, Tidal, Wave, Wind, Biomass and waste. Table 1 below shows the energy consumption by source and the annual change with previous year (2013). The table includes energy consumption by source in Finland (both electricity and heat).

TABLE 1: Total Energy Consumption by source and CO_2-emissions in 2014 (source: Statistics Finland)

Total energy consumption by source (TJ) and CO2 emissions (Mt)

Corrected at 5 pm on 23 March 2015. The corrections are indicated in red.

Energy source, TJ 4)	2014*	Annual change-%*	Percentage share of total energy consumption*
Oil	308,693	-3	23
Coal 1)	134,823	-11	10
Natural gas	91,678	-14	7
Nuclear energy 2)	247,174	0	18
Net imports of electricity 3)	64,690	14	5
Hydro power 3)	47,523	4	4
Wind power 3)	4 007	44	0
Peat	62,260	9	5
Wood fuels	333,198	-2	25
Others	46,077	-9	3
TOTAL ENERGY CONSUMPTION	1,340,123	-2	100
Bunkers	28,639	-11	.
CO2 emissions from energy sector	45	-6	.

1) Coal: includes hard coal, coke, blast furnace gas and coke oven gas.
2) Conversion of electricity generation into fuel units: Nuclear power: 10.91 TJ/GWh (33% total efficiency)
3) Conversion of electricity generation into fuel units: Hydro power, wind power and net imports of electricity: 3.6 TJ/GWh (100%)
4) *Preliminary

Totally 64 690 TJ electricity is imported from neighbouring countries, and an increase of 14% with last year. So a decrease of 14% is adjusted compared with last year and so 1275 163 TJ electricity is produced in Finland. In order to see the gradient of net imports and exports of Finland last 24 years, Figure 5 is showed below. (Statistics Finland, Energy , 2015)

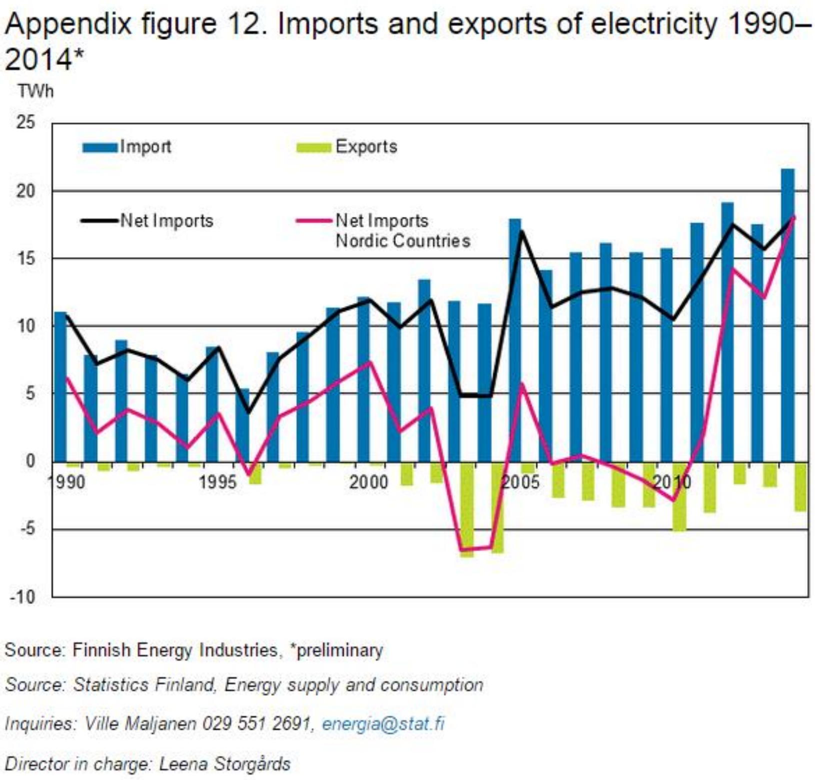

FIGURE 5: Imports and exports of electricity from 1990-2014 (source: Finnish Energy Industries)

According to Figure 5, net imports are increasing the last 5 years, net imports are coming from Nordic countries, as well as from other countries. But it is notable to see that the import of Nordic countries increases on a large scale the last years. But not only net imports are done, also exports of electricity from Finland to Nordic countries. However the share of exports is less than 25%.

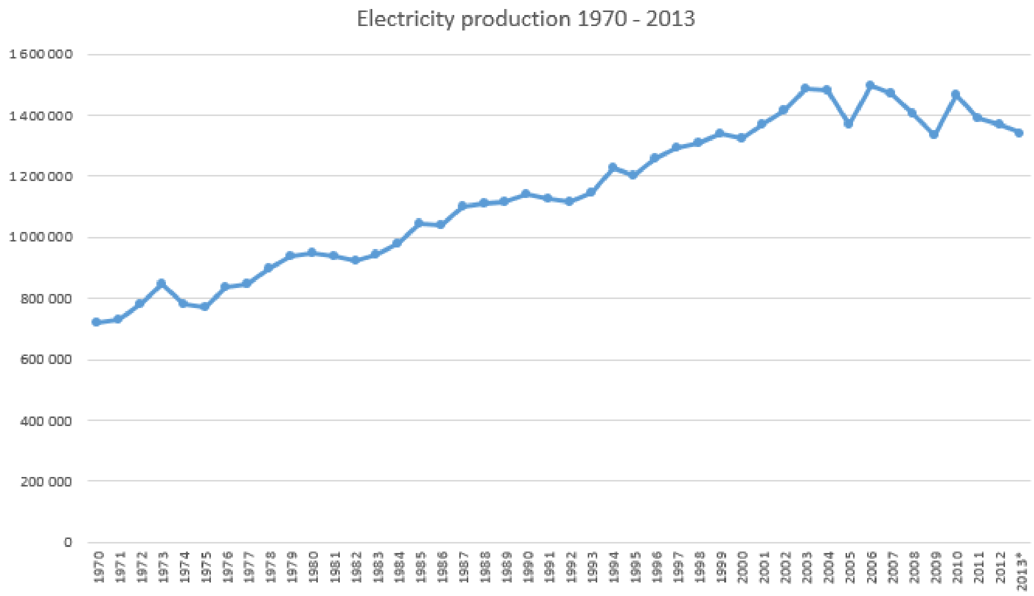

FIGURE 6: Electricity consumption from 1970 – 2013 (source: Statistics Finland)

Figure 6 shows the rise of electricity production since the 70's. In the year 2003 the production is on its highest point, and since then, electricity production is fluctuating every year. In average, electricity production is decreasing since 2003.

In order to find out why the electricity consumption decreased the last years, we can subdivide different sectors. Figure 7 below shows the electricity consumption by sector since 1980 until 2014

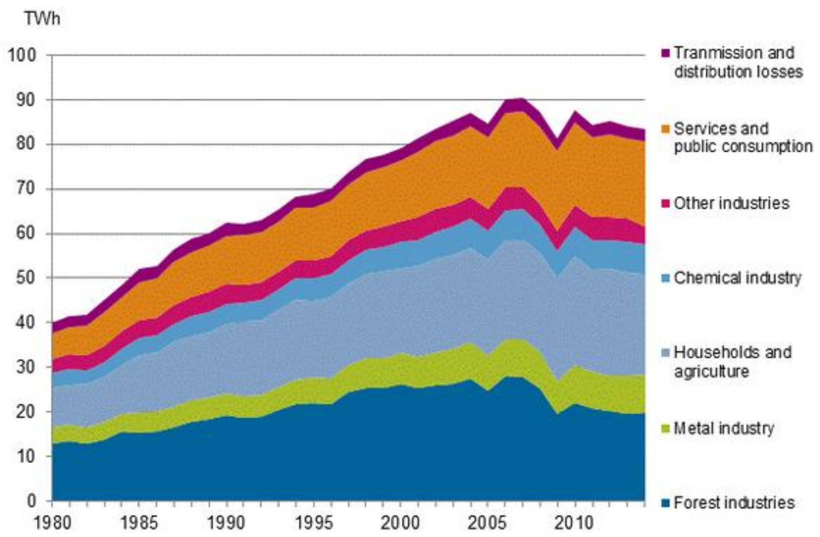

FIGURE 7: Electricity consumption by sector 1970-2013 source (statistics Finland, energy supply and consumption 2013)

Analysing Figure 7 makes clear that the electricity consumption by households and agriculture is increased the most, together with services and public consumption. Next to that, industry is making progress as well but not in large quantity. Transmission and distribution losses are fairly constant. However the transmission grid expands every year, and more electricity is transmitted yearly.

2.5.1 Production of Electricity by Source

Electricity consumption and production is increasing since the 1970's but last several years slightly decreasing. Reportedly in the future the electricity consumption will be increasing again, that means that the production of electricity needs to rise as well as some power plants are expiring, so new capacity will be needed in the future. The way of producing electricity can be done in different ways, different locations and different scales. The following Figures 8 and 9 give an overview of the energy sources in het year 2013.

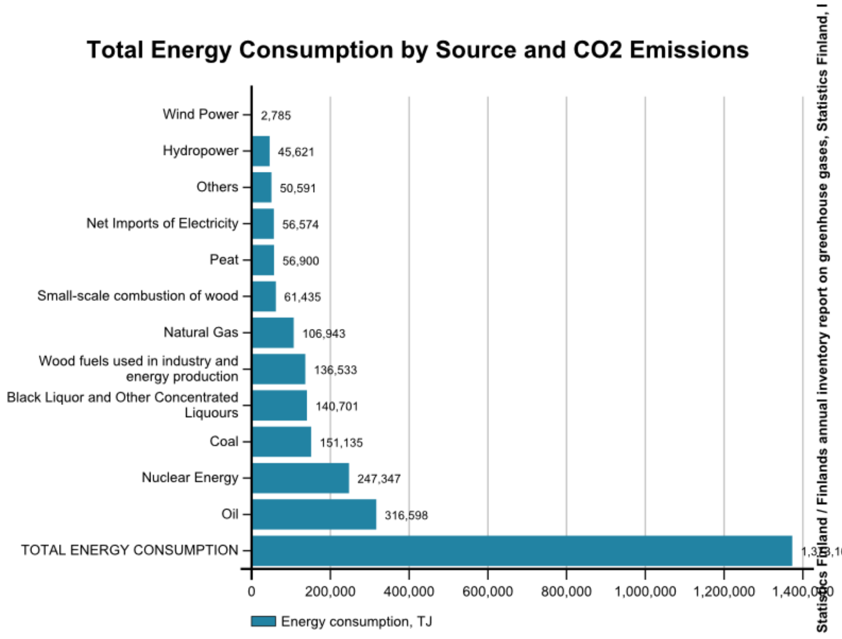

FIGURE 8: Total Energy Consumption by Source (source: Statistics Finland)

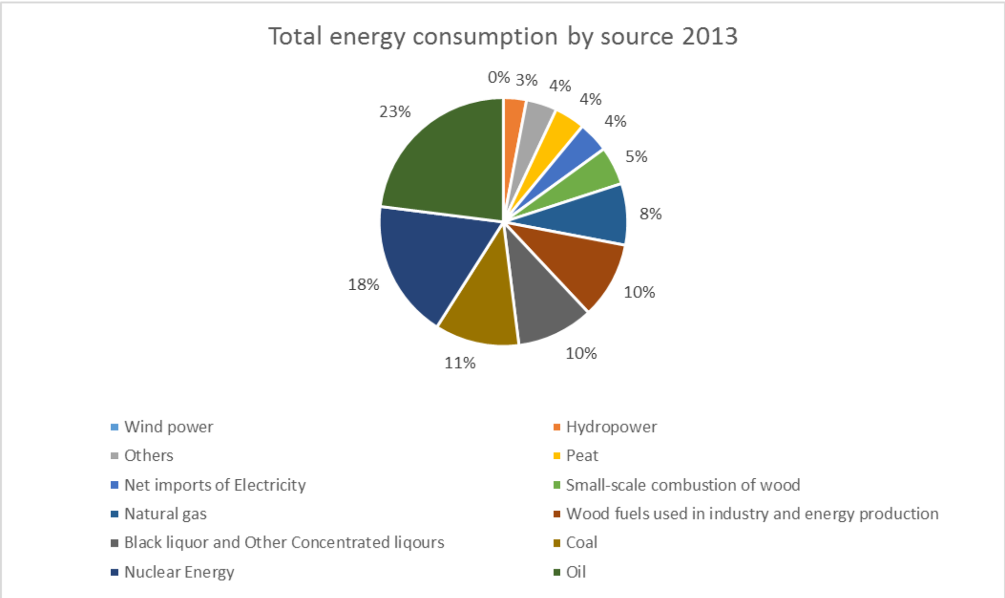

FIGURE 9: Total Energy Consumption by Source 2013 (source: Statistics Finland)

Figure 8 and 9 show the division of the production of energy by its source. As discussed the energy consist of electricity production and heating production. Oil is until now the biggest source for producing energy, it is especially used for the production of heat. Nuclear power is the second largest way of producing energy, followed by coals.

Forest industry, black liquor and wood consumption are together good for approximately 20% of the energy production. Therefore in addition to oil, the forest industry is one of the most important forms to produce energy. In order to know what the electricity consumption in particular is, Figure 10 is showed below.

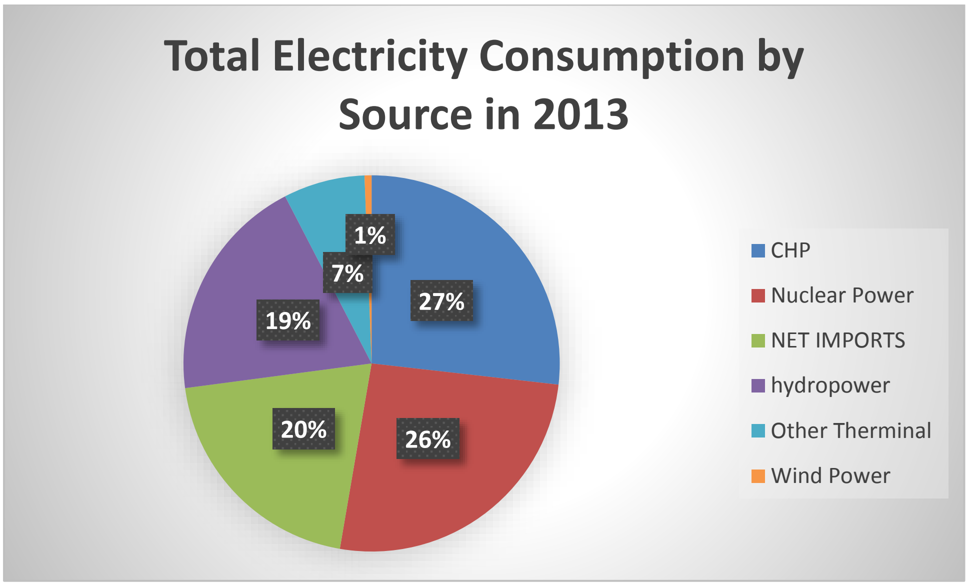

FIGURE 10: Electricity Consumption Finland (source: Finnish Energy Industries)

Figure 10 shows an overview about the electricity consumption in Finland. In previous Figures 8 and 9 an overview was showed about the energy consumption, wherein oil was the main source of energy followed by nuclear power. In the electricity production however, the sources are different, the main source for producing electricity is Nuclear, followed by CHP power and net imports. The Figures show that almost all the oil is used for producing heat and only a very little part for producing electricity (0,3%).

In order to get a view of the renewable energy share, a definition of renewable energy is needed. "Renewable energy: any energy resource that is naturally regenerated over a short time scale and derived directly from the sun (such as thermal, photochemical, and photoelectric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy). Renewable energy does not include energy resources derived from fossil fuels, waste products from fossil sources, or waste products from inorganic sources." (TREIA, 2015)

In case we study the energy consumption in Finland, the forest industry black liquor and wood consumption is considered to be a renewable energy source, because black liquor is made from the waste product from the kraft process when digesting pulpwood into paper pulp. Wood consumption is renewable because, the bulk of the stem is utilised in industrial processes as raw material and the major part of the remainder is used to generate electricity. (The Center for Paper Business and Industry Studies, 2007)

Small scale combustion of wood is a renewable energy source, because it is considered to be CO_2- neutral. Trees absorbing CO_2 which is present in the air, during the life time. When burning the wood the CO_2 is released in the atmosphere again, but no more than which is absorbed. For that reason it is considered to be a renewable energy source.

Hydropower and wind energy is naturally regenerated, over a short time scale and derived indirectly from the sun.

Counting the renewable energy sources together, in Energy Consumption shows a share of 28% renewable energy in Finland in year 2013. (Statistics Finland, Energy , 2015)

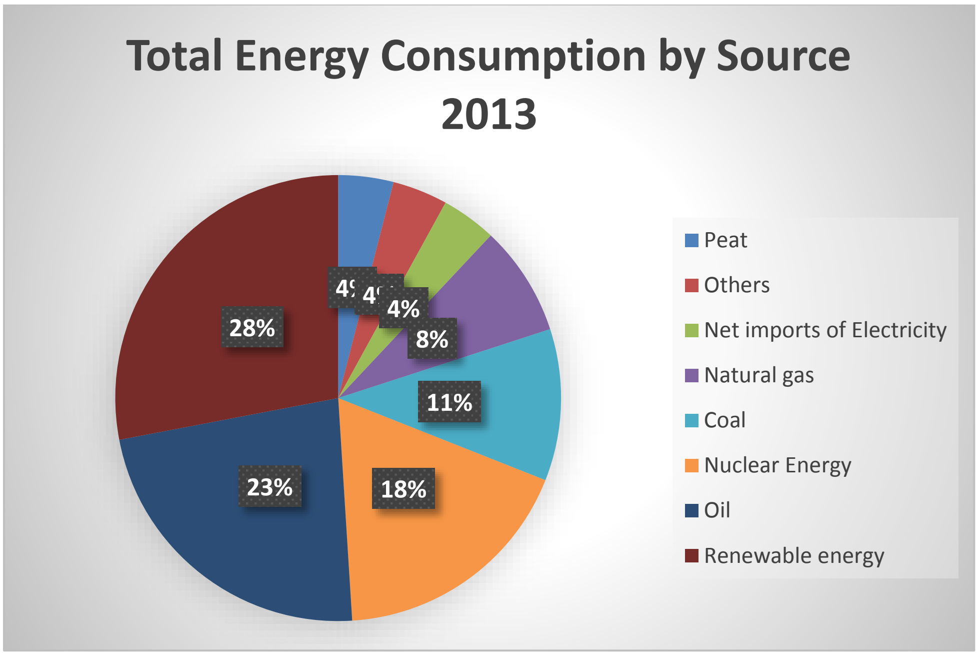

FIGURE 11: Total Energy Consumption by Source (source: Statistics Finland)

In case we study the electricity consumption in Finland, hydropower, wind power and solar power are considered to be renewable energy sources. However the share of solar power is negligible for this graph. In Figure 12 the share of renewable energy for electricity consumption is showed.

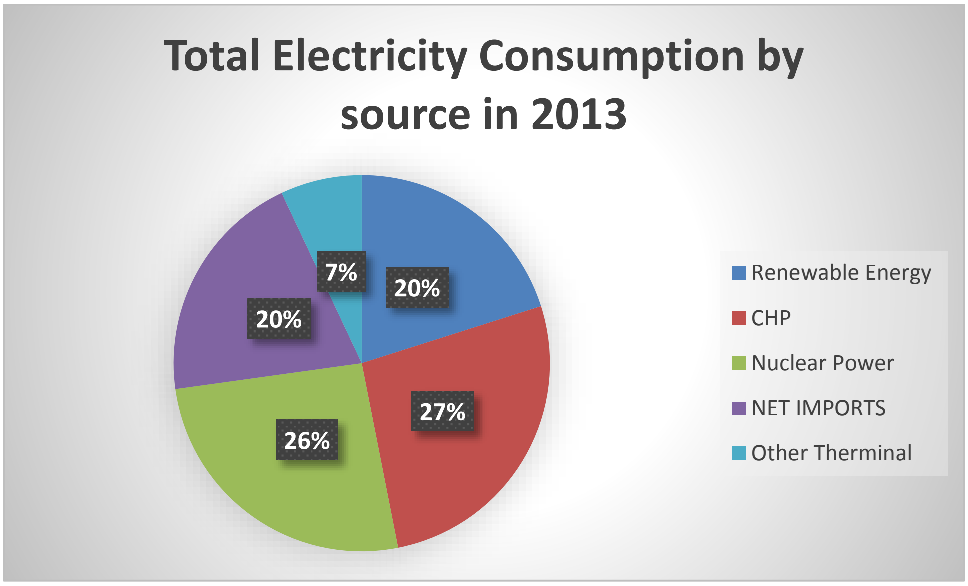

FIGURE 12: Total Electricity Consumption by Source in 2013 (source: Finnish Energy Industries)

Figure 12 makes clear that the share of renewable energy in electricity consumption depends on the share of hydropower. Wind power is rising every year, but until now it still has only one percent share. The renewable energy share for electricity consumption was 20% in Finland in year 2013.

2.5.2 Production of Electricity by Scale and Purpose.

Different scales and types of electricity production are necessary in order to keep the balance between production and consumption. Therefore it is important to know which power plants serve as basic load power plant, peak load power plant and reserve power plant, as well as the scale of the power plants.

Basic load plants are used for producing the basic production of electricity. A basic plant is needed, because a basic of electricity is always used. Most companies use Nuclear power as basic load plants. Because nuclear power plants cannot be started or stopped very quickly. It takes days to week before the process extinguishes.

Nuclear energy is almost always a large scale power plant. An example of the production by a nuclear power plant, is showed in Figure 13 below. The example showed below is a nuclear power plant owned by Fortum, and shows the monthly electricity production of loviisa unit two. Clearly to see is the constant and regularly electricity production, what proves that it serves as basic load power plant. (Fortum, Fuels , 2014)

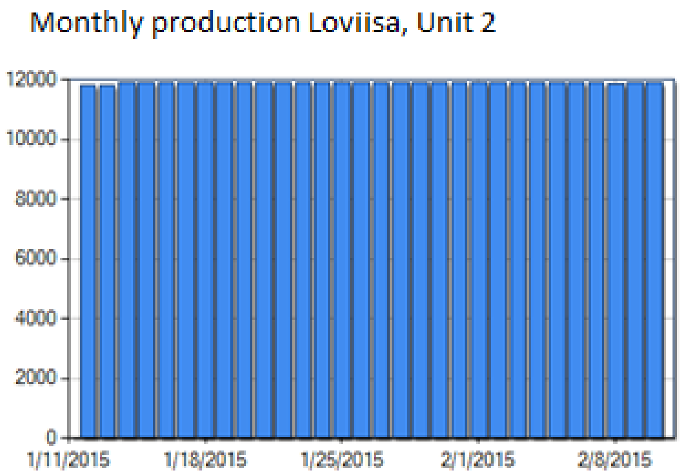

FIGURE 13: Monthly Production Loviisa, Nuclear Power Plant (source: Fortum)

Other examples of basic load power plants are combined power and heat production (CHP). It combines the heat and power production and has a significant role in the energy production in Finland. Different fuels and a flexible manner can be used in CHP power.

Peak load plants are used when the consumption of electricity is very high, called peak moments during the day. If the production of electricity by a basic load power plant is not covered anymore, peak power plants need to be started. Peak power plants can be large scaled, as well as small scaled. The used peak load plants can be condensing power and coals. A condensing power plant generates electricity using mostly coal, natural gas or oil as fuel source. As in a heat plant, water is heated and turned into steam to rotate a turbine, which rotates the generator.

Another example of peak power plants can be mini/micro scale hydropower plants. These plants can be automatically started and stopped in peak moments.

Reserve load power plants are used to generate electricity in a short interval of time. When a power plant shuts down, the reserve load power plant is started. Most power systems are so designed that, under normal conditions, the operating reserve is always at least the capacity of the largest generator plus a fraction of the peak load. A condensing power plant can be used for that, as well as thermal power plants working on coals or oil.

The scale of power plants depends on the amount of megawatts they produce, and so how large they are in size. The scale depends on the purpose of the power plant. If the plant is used for reserve load, it needs to cover the biggest power plant as well as a fraction of the peak load, so these are mostly large scale power plants. If the power plant is used as peak load plant, a smaller size with smaller electricity production is allowed, but it needs to cover the demand of electricity. In order to give a good overview about the basic and peak power plants Figure 14 is showed below.

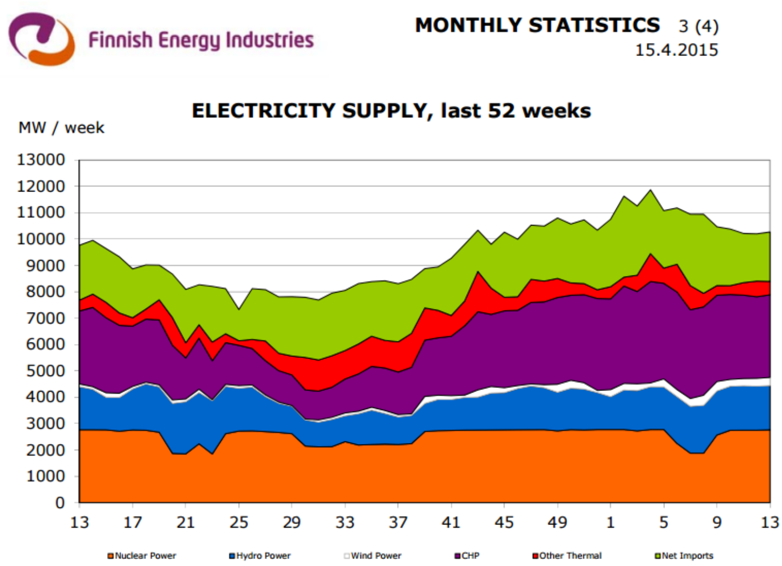

FIGURE 14: Electricity Supply, last 52 weeks in Finland (source: Finnish Energy Industries)

Analysing Figure 14 shows that nuclear power serves as basic load power plant. It has approximately the same electricity production every year.

Hydropower electricity production is changing during the year, because of several reasons. One of the reasons is because hydropower is used as flexible electricity source, and that because it is easy to run up and down. In winter months the electricity production is approximately the same, in summer months (week 29-39) the electricity production is less. There are several reasons for that, firstly the summer is a dry season with less water flow. The second reason is that the need for electricity during the summer is less than the other seasons, because electricity and heating needs are lower. Since electricity is regularly used for heating in Finland. Also industrial processes that are kept in maintenance during the year, stop in the summer holidays (Johanna Kirkinnen, personal communication, 11 May 2015). The opposite is given for the spring period, when the snow is melting and so a wet period is dawned with a lot of water flow and electricity production. Although hydropower serves as basic power plant as well.

Combined heat and power plants produce more heat and power during the winter months, because the heat demand is much bigger then. The opposite is given for the summer months when almost no heat is required.

The shortage of electricity production by hydropower and CHP-power is picked up by other thermal electricity production. The other thermal power plants serve here as peak power plants. As well as the shortage of electricity during the year is picked up by net imports. (Finnish Energy Industries, 2015)

2.6 Renewable Energy in Finland

In the previous chapter, the share of renewable energy in Finland was explained. In the current chapter the different types of renewable energy will be discussed. A study about renewable energy in Finland is done, with help of major suppliers of electricity.
The biggest suppliers of Finland are Fortum, Vattenfal, Teollisuuden Voima Oy, and for Tampere in particular Sähkölaitos is the biggest supplier.
The different renewable energy sources are: Wind power, Solar energy, Solar thermal, Hydropower, Geothermal heat pumps, Aero thermal heat pump, Wood energy, and Biogas energy.

2.7 Hydropower

Hydropower uses water to power machinery or make electricity. Water constantly moves through a perpetual global cycle, evaporating from lakes and oceans, forming clouds, precipitation as rain or snow, then flowing back down to the ocean. The energy of the water cycle, which is driven by the sun, can be trapped to produce electricity or for mechanical tasks like grinding grain. Because the water cycle is an endless, constantly recharging system, hydropower is considered to be a renewable energy source. Figure 15 below shows the perpetual global water cycle.

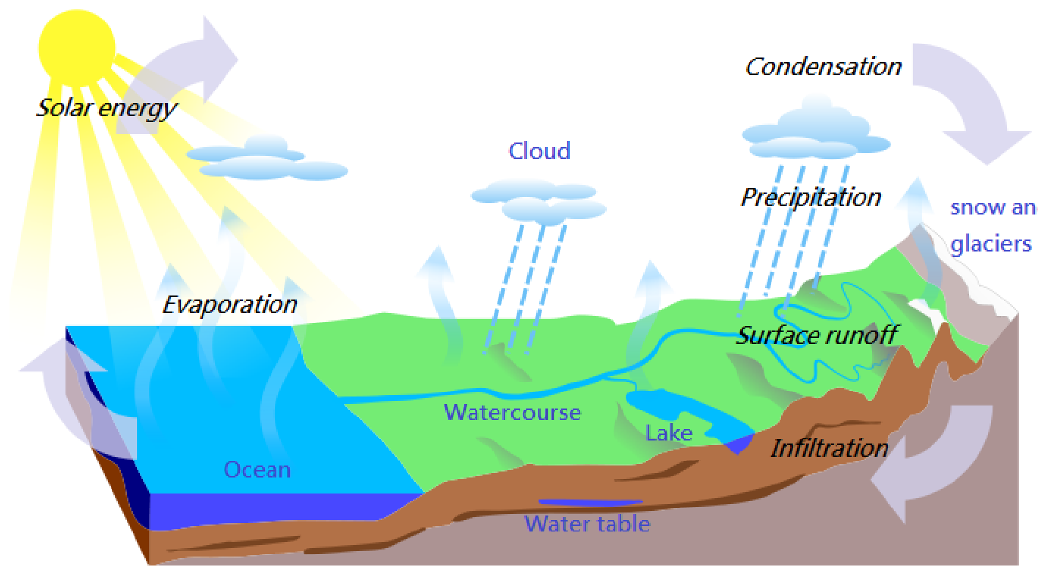

FIGURE 15: the perpetual global water cycle

When flowing water is captured and turned into electricity, it is called hydroelectric power or hydropower. There are several types of hydroelectric facilities: they are all powered by the kinetic energy of flowing water as it moves downstream. Turbines and generators convert the energy into electricity, which is then fed into the electrical grid to be used in homes, businesses, and by industry. (Department of Energy , 2014)

Hydropower plants can be constructed on different ways, with different features. There are three types of hydropower facilities; impoundment, diversion (so called run-off-river) and pumped storage.

2.7.1 Impoundment Hydropower Plant

One of the most common types of hydropower plants is an impoundment facility. An impoundment facility is typically for a large hydropower system. A dam is constructed to act as reservoir of water sources and has the ability to continuously supply the water in undulating manner. The intake of the water is near the bottom of the dam wall. The water released from the reservoir flows from the upper level to the lower level and so gives the water a certain water flow. The water flow contains a lot of kinetic energy, the kinetic energy is used to drive the turbine, and changes the kinetic energy into mechanical energy. The generator that makes electricity is driven by the turbine. The water can be released on different quantities, depending on the electricity demand or reservoir level. Figure 16 shows an overview of the impoundment hydropower plant construction. (Department of Energy , 2014)

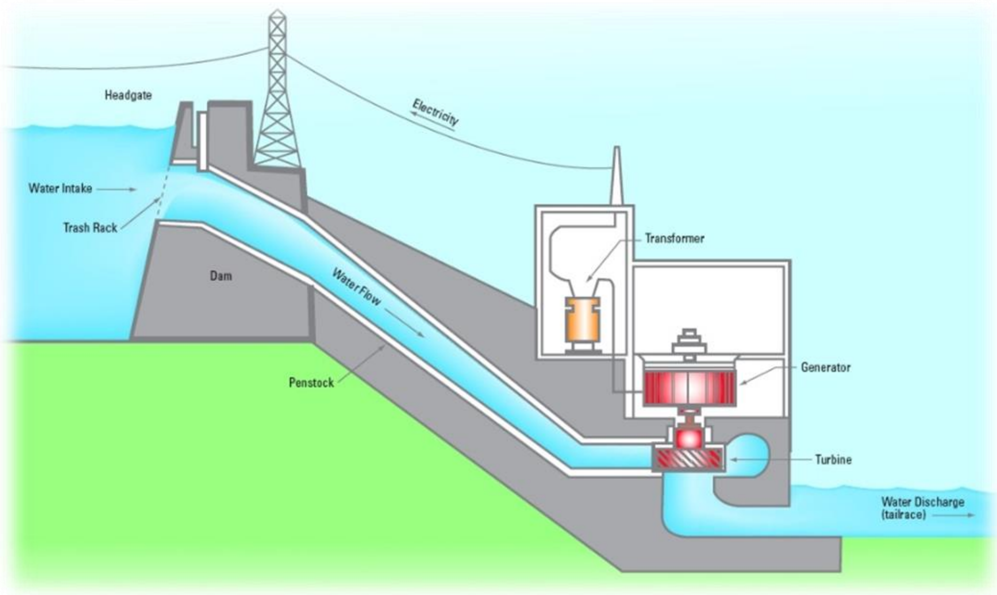

FIGURE 16: Impoundment Hydropower Plant Construction (source: Borzen)

2.7.2 Diversion Hydropower Plant

A diversion hydropower plant, also called as "run-off-river" uses a different method to convert the kinetic energy from water into mechanical energy. The diversion hydropower plant is the most used method in Finland.

The “run-off-river” type is constructed to glide a part of the water from the river into the turbine without changing the natural flow of the river. However, a disadvantage appears, the water source can vary according to the season. For that reason the diversion hydro-power construction is used for small scale, mini scale and micro scale. Figure 17 shows an overview of the diversion hydropower plant construction. (Department of Energy , 2014)

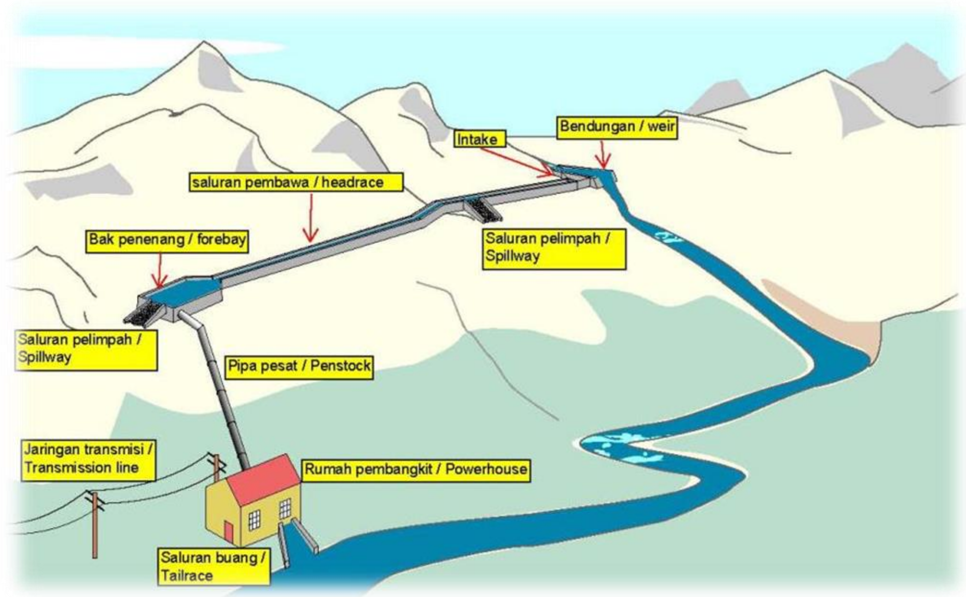

FIGURE 17: Diversion Hydropower Plant Construction (source: imgarcade)

2.7.3 Pumped Storage

Pumped hydroelectric storage facilities store energy in form of water in an upper reservoir, pumped from another reservoir at a lower level. During periods of higher electricity demands, power is generated by releasing the stored water from the upper reservoir to the lower reservoir. The water that flows through the turbine works at the same way of a normal hydropower station. During periods of low demand, (which is usually during nights or weekends, when electricity is also lower cost), the upper reservoir is recharged by using low-cost electricity from the grid to pump the water back to the upper reservoir. Reversible pump-turbine/motor-generator assemblies can act as both pumps and turbines. These plants are typically highly efficient and can prove very beneficial in terms of balancing load within the overall power system. Because of the production and consumption of electricity. Figure 18 shows an overview of the pumped hydroelectric storage plant construction. (Energy Storage Association , 2012)

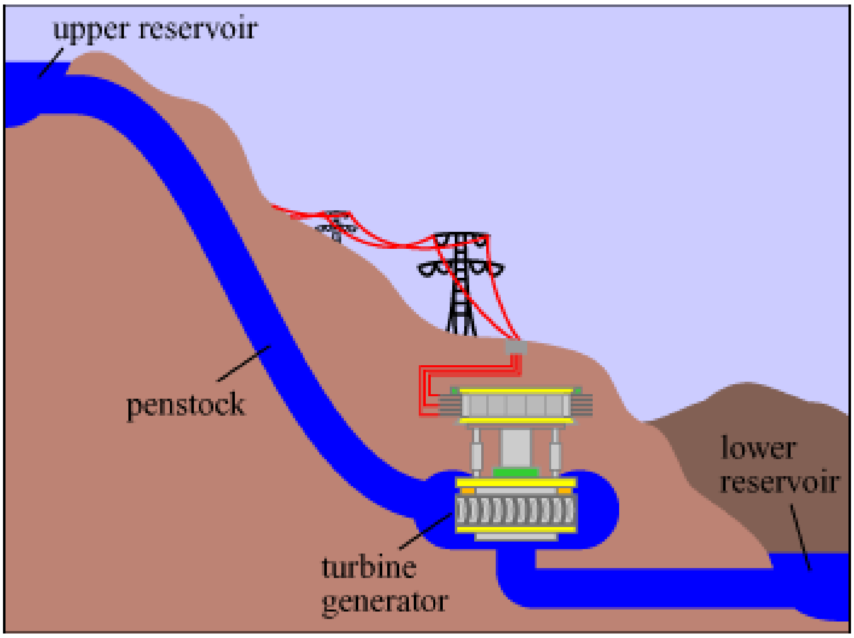

FIGURE 18: The structure of a pumped storage power station (source: Energy Generation and Storage Using Water)

2.8 Small Scale Hydropower

Small scale hydropower in Finland is defined as a hydropower plant with a capacity between 1MW and 10MW. Most small scale hydropower plants in Finland are built according to the run-off-river construction.

2.8.1 History Small Scale Hydropower

The history of small scale hydropower is given, because nowadays it has an important role in the possible increase of small and micro scale hydropower in Finland.

People have been using water to preform work for thousands of years. The Greeks used water wheels for grinding wheat into flour more than 2 000 years ago. Besides grinding flour, the power of the water was used to saw wood and power textile mills and manufacturing plants.

For more than a century, the technology for using falling water to create hydroelectricity has existed. The evolution of the modern hydropower turbine began in the mid-1700s when a French hydraulic engineer, Bernard Forest de Bélidor wrote Architecture Hydraulique. In this four volume work, he described using a vertical-axis versus a horizontal-axis machine. For Finland, Tikkurila was one of the first persons that got in touch with the power of water, he lived in the village of Dickursby (Tikkurila) in the helsinge parish, near the city of Helsinki. The first water mill on the Tikkurilankoski rapids of the river Keravanjoki was built in 1757, and an oil press was established alongside the water mill in 1862. Dickursby Oljeslageri, owned by Lieutenant Colonel Anders Lorentz Munsterhjelm, utilised fax and hemp seeds in its production. Later on wood industry occurred with sawmills driven by water turbines. (Department of Energy , 2014)

During the 1700s and 1800s, water turbine development continued. In 1880, a brush Arclight dynamo driven by a water turbine was used to provide theatre and storefront lighting in Grand Rapids. In 1881, a brush dynamo connected to a turbine in a flour mill provided street lighting in Niagara Falls, New York. These two projects used direct-current technology. The breakthrough came when the electric generator was connected to the turbine, which resulted in the world’s first hydroelectric plant, located in Appleton, Wisconsin in 1882.

Finland’s growing needs for electric power, ensured that the hydropower technology continuously improved in order to increase the domestic generating capacity, which in early 1986 had reached 10,700 Megawatts. In the late 1980s, hydroelectric plants supplied approximately 41% of the total electric power. Finland’s main domestic energy sources were hydroelectric power, peat, and wood. By the late 1980s, the country’s large hydroelectric potential had been thoroughly used, except possibly for the rivers protected by environmental legislation. However, hydroelectric production could still be increased by renovating existing installations and by building additional plants at secondary sites. (The Library of Congress Country Studies; CIA World Factbook, 2004)

In years 1500s horizontal-axis waterwheel mills began to move and in that time the first water timber set up. In 1850 century, around 4000 water mills were around. Until now old sawmills, that were operative at approximately the 1800s are still visible. These locations are the potentials to increase the micro scale hydropower in Finland. (The Library of Congress Country Studies; CIA World Factbook, 2004)

2.8.2 Small Scale Hydropower in Finland

Hydropower's share of electricity production in Finland has varied in recent years within the range of 10-15%, depending on precipitation levels and other hydrological conditions. Hydropower is Finland's second most widely exploited renewable energy source, after bioenergy. Different scales of hydropower plants are used in Finland, Large scale (>10MW), small scale (1-10MW), mini scale (0.1-1MW) and micro scale (10-100kW). The most significant areas of hydropower development in Finland are on the Kemijoki River in northern Finland and in the Oulujoki River basin in central Finland. In particular, the Oulujoki and its tributary the Emäjoki have become in effect, a series of lake from the numerous small and medium-size hydropower facilities that have been constructed there. However most of the hydropower plants in Finland are small scale. About 60% of Finland's rivers have been developed for hydropower plants, and about 20% are protected against development. In Figure 19 below, a graphic about the production of hydropower in Finland is showed. (Energy overview of Republic of Finland , 2002)

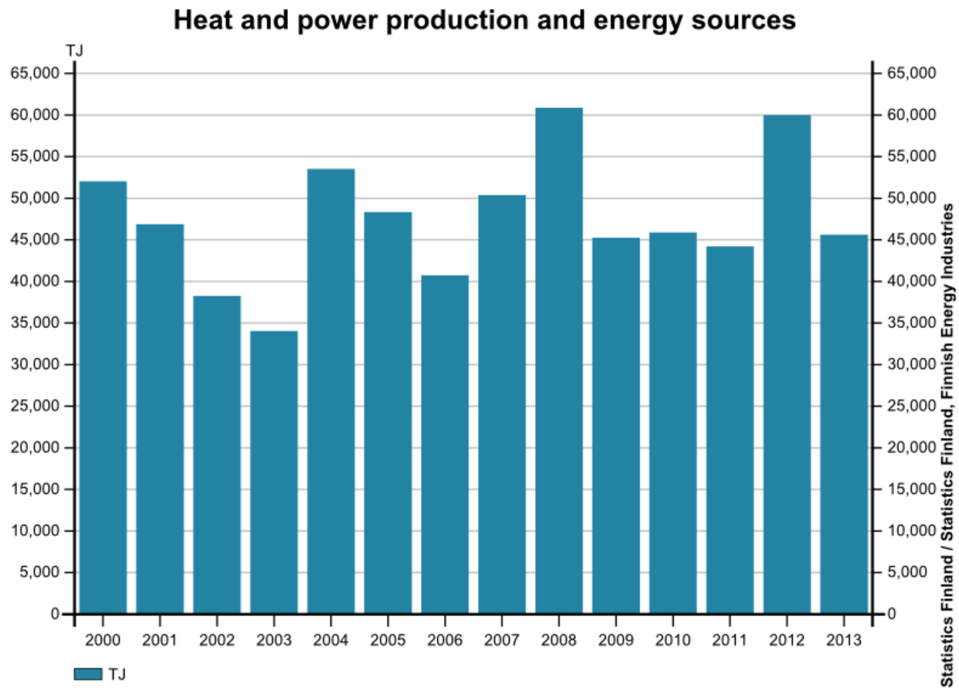

FIGURE 19: Power Production derived from Hydropower in Finland (source: Statistics Finland)

2.8.3 Other Renewable Energy Sources in Finland

Wind Power

Wind power capacity in Finland was at the end of 2013 approximately 447MW. The wind power production in 2013 was about 771GWh which represents 0, 9% of the Finnish electricity consumption. At date 06.09.2013 the Finnish government published 11 013MW of wind turbine projects in Finland. The share of offshore projects planned is 2 974MW.

Figures 20, 21 and 22 below show the overview of the electricity produced by wind power, starting with year 1997. As well as the locations of wind turbines in Finland and the size of the wind turbines. (VTT, 2013)

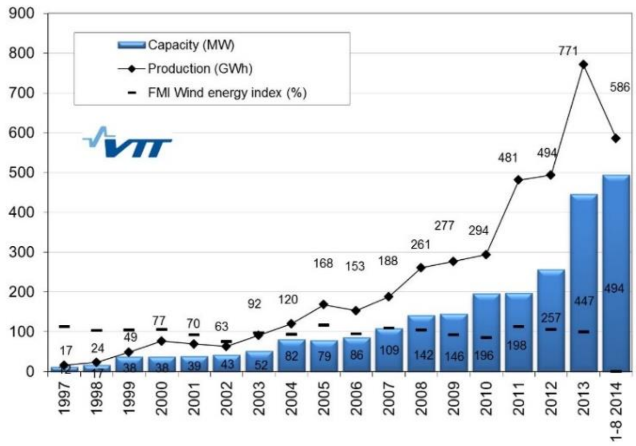

FIGURE 20: Production and Capacity of Wind Power in Finland (source: VTT)

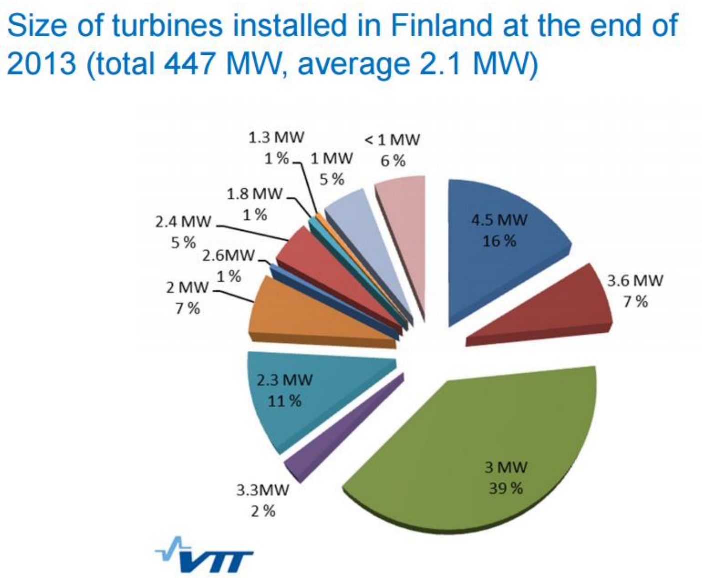

FIGURE 21: Locations of Wind Power Plants in Finland at the end of 2013 (source: Wind Energy Statistics Finland)

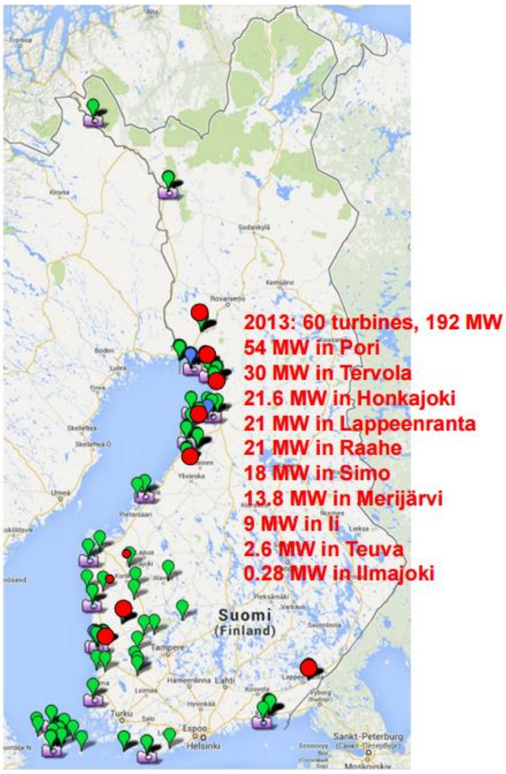

FIGURE 22: Size of Wind Turbines Installed in Finland at the end of 2013 (source: VTT)

Solar Power

Solar technologies can be roughly divided into solar photovoltaics (PV), solar thermal (ST) and concentrating solar power (CSP). Photovoltaics and concentrating solar power is used for electricity production and solar thermal systems for heat production. Solar photovoltaics uses solar cells to convert energy from the sun into a flow of electrons. Solar thermal uses a technology to change solar energy into thermal energy. Concentrated solar power uses direct sunlight, concentrates is several time, to reach higher energy densities and so higher temperatures. The heat is used to generate steam or gas. (The Finnish Solar Cluster, 2012)

Currently solar energy is a relatively small market in Finland but there are many visible signs of increasing interest towards solar technologies and solar energy. There are already some Finnish companies offering their products and services for the global solar market. Although solar energy is not yet such a big phenomenon in Finland as what it has become in other European countries, but positive signs of solar power are emerging. During the last few years Finland has seen its first larger-scale solar installations. One of the Finnish companies who offers solar panels on the market is Fortum, they offer small micro scale solar panels for costumers. The panels are sold as service where they install a customised package for micro production of electricity for private consumers. The panels have a range from 1.5kW to 4.5kW. Figure 23 below shows an overview of electricity production since 1990 by solar thermal and photovoltaics in Finland.

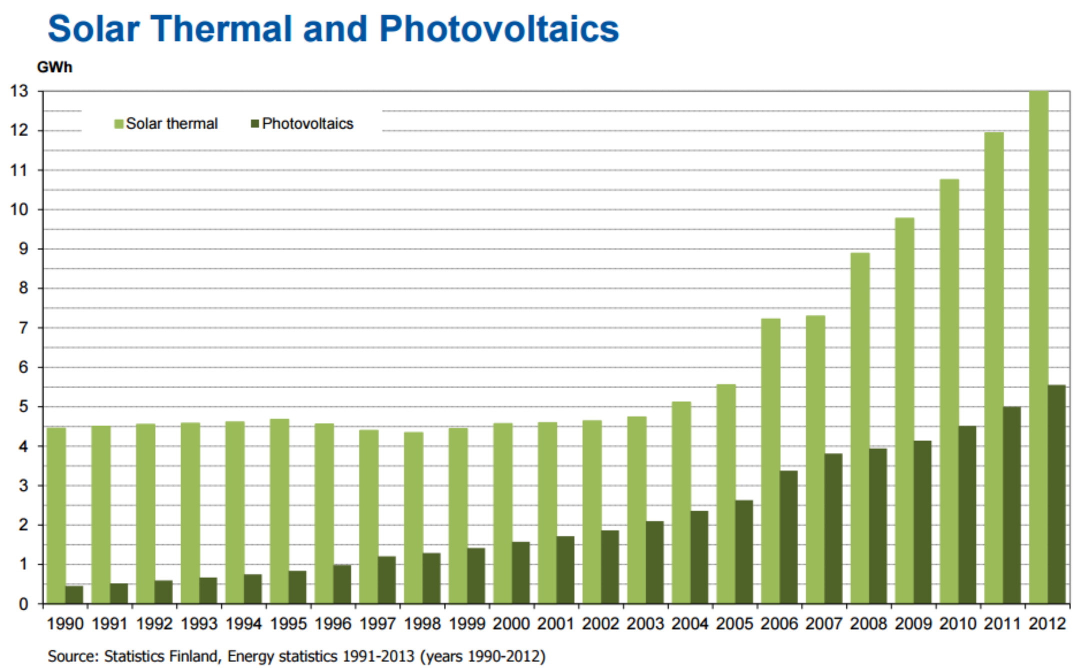

FIGURE 23: Electricity Production by Solar and Photovoltaics from 1990 - 2012 (source: Statistics Finland)

Geothermal power

The use of geothermal energy in Finland is limited to the utilization of ground heat with heat pumps. This for the reason of the geological conditions in Finland which is a part of the Fennoscandian (or Baltic) shield. The lithosphere is very thick in Finland (150-200km), and heat flow is below the continental average (< 65mWm-2). Geothermal energy is not used in Finland for electricity production and there are no direct applications of geothermal energy either. This situation is due to the Precambrian geology with thick crust and lithosphere, resulting in low geothermal gradient values. Due to the cool thermal regime of bedrock, the only type of geothermal energy used in Finland is ground heat with the aid of heat pumps installed either in vertically in boreholes, or horizontally in Quaternary sediments as well as lakes and rivers. The ground heat is considered here as geothermal energy, although it is a combination of deep geothermal energy and solar energy stored in the near-surface layers of the earth. Although, there are about 10 000 heat pumps utilizing the ground-stored heat either in bedrock, quaternary sediments or water-sources (lakes). Heat pumps seem to provide a feasible alternative for space heating in small family houses or country farms. Figure 24 below shows an overview of the electricity and heat produced by heat pumps, since 1990 in Finland. (Geothermical energy in Finland , 2000)

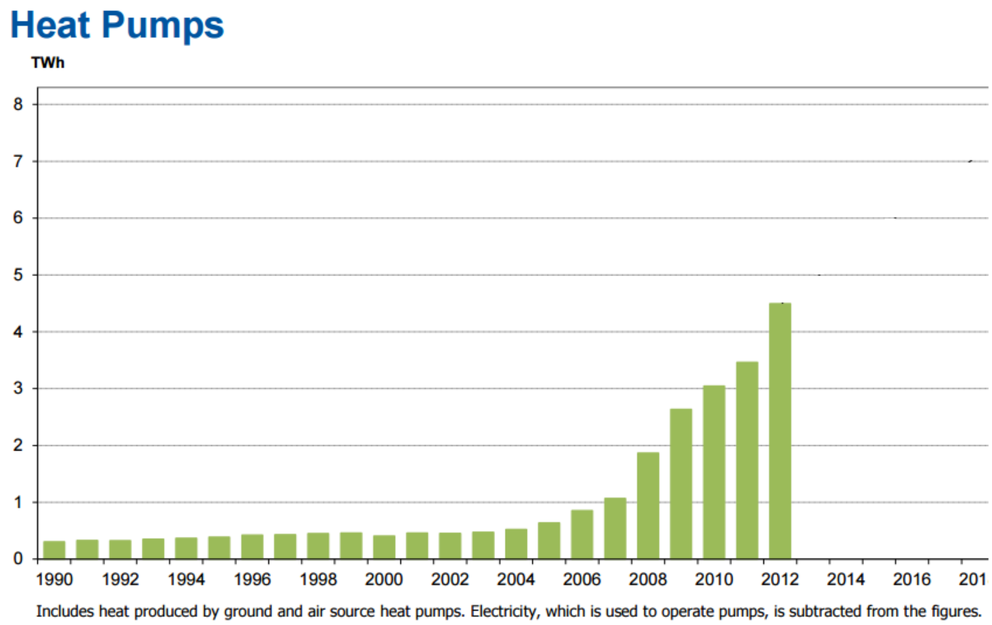

FIGURE 24: Electricity Production by Heat Pumps (source: Statistics Finland)

Bio Fuels

When we focus the attention on biofuels, several types of biofuels can be used in the electricity and heat production, for example biomass, waste derived fuels, bio oil.
Biomass is a CO_2-neutral way to produce electricity, heat and traffic fuels. Biomass is used in a lot of the forested Nordic regions where fuel is available cost-efficiently. Two types of biomass can be used, namely solid biomass and liquid biofuels. The biofuels include wood chips and other wood-based fuels, plant-and animal-based oils and fats.

Waste derived fuels can be used to replace fossil fuels and at the same time, reduce the amount of waste ending up in landfills. Industry's wood-and plastic-based waste as well as municipal waste are burned. Strict limits have been set for flue-gas emissions from waste incineration, and the ash must be handled properly as well.

Bio-oil raw materials include forest residues and other wood-based biomass, and thus it is a renewable energy. Bio-oil replaces heavy fuel oil. And in the future, the bio-oil can be used as a raw material for various bio chemicals or traffic fuels. The use of bio-oil in energy production reduces greenhouse emissions by more than 70% compared to fossil fuels. Figure 25 below shows an overview of the electricity produces by wood fuels since 2000. (Fortum, Fuels , 2014)

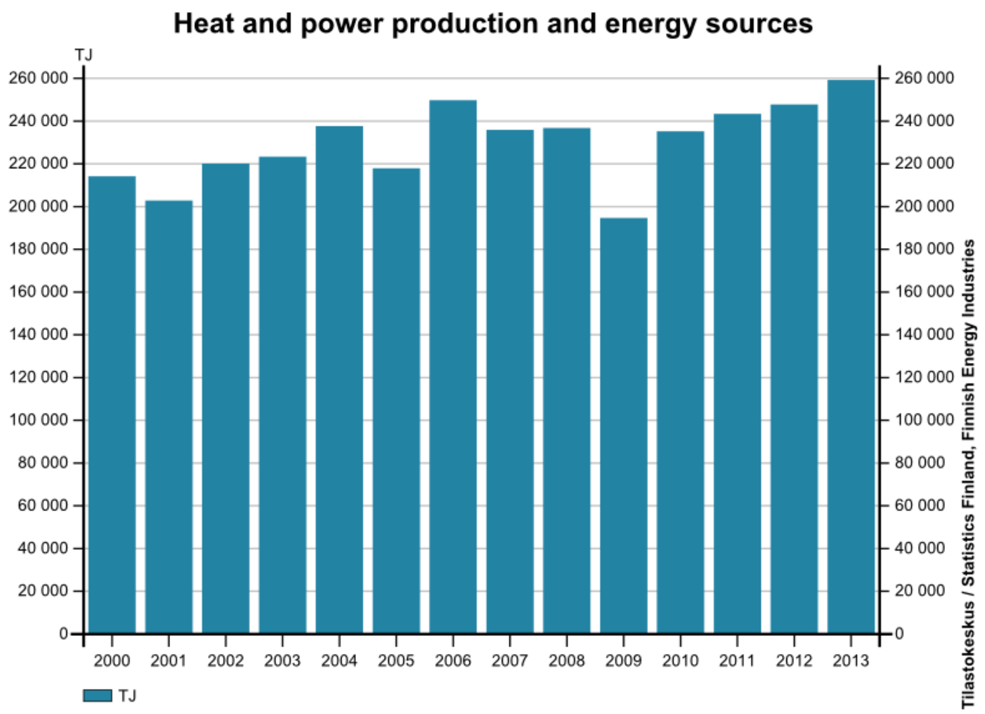

FIGURE 25: Electricity Production by Wood Fuels from 2000 – 2013 (source Statistics Finland)

3 METHODS

In this chapter the methods used for the study of social acceptance, and economical perspectives will be explained. Correct methods and proper structure is needed to bring the study to a successful conclusion.

3.1 Economical Perspectives Method

Economical perspectives of hydropower plants in Finland are investigated in order to search for the possibilities to increase small and micro scale hydropower plants in Finland. A lot of difficulties were encountered when doing the economical investment of small scale or micro scale hydropower in Finland. Analyses and data about production and cash flow was not obtained by companies. Companies do not want to expose their information for the sake of competition. In order to get information about investment, thesis and papers are read online. Appendix 1: Small Hydro Investment Costs (price/installed kW), shows an overview of the price per kW in function of the head.

3.2 Social Acceptance Method

In order to get a correct view of the social situation about hydropower plants in Finland, interview methods and survey techniques are applied. In order to make a social study, information from Finnish population is needed. Collecting the data can be done on different ways with different methods. In this thesis a distinction is made between the neighbours and builders, designers or owners of small/micro hydropower plants. The methods used to interview people in this thesis are: interview method to interrogate builders/designers or owner of small/micro scale hydropower plants and a survey is made to interrogate neighbours of small/micro scale hydropower plants. In the section below, the used interview methods and survey techniques will be thoroughly explained.
Firstly an overview of the discussed methods is showed in Table 2 below.

TABLE 2: Overview discussed Interview methods

Made for owners, builders, designers of hydropower plants	Interview Methods	Post It Interview Method
		Rich Picture Interview Method
		STAR Interview Method
	Interview Type	Standardised Interview Type
		Half Standardised Interview Type
		Open Interview Type
Made for Neighbours of Small scale Hydropower Plants	Interrogation type	Survey

3.2.1 Interview Methods

An interview is one of the most common ways to collect qualitative information. Obvious is that, if there is no large-scale survey research that takes place, Questions need to be asked to respondents, and that is what happens in an interview.
Information can be collected in different ways, Reports or digital sources can be read, but also questions can be asked, or so called interviewing. Interviewing is actually happening constantly in a conversation by asking questions to each other. Focused questions are asked within a real interview and that is the main difference. The object and purpose of an interview is recorded in advance. The interview is particularly known for the media: radio and television programs. Interviews are particularly useful for getting the story behind a participant's experiences. The interviewer can pursue in-depth information around the topic. However it is less logical than it looks like, because interviews are often time consuming to perform, they provide large quantities of unstructured data and can lead to complicated problems in the analysis and reporting.

The qualitative research interview seeks to cover both a factual and a meaning level, through it is usually more difficult to interview on a meaning level (Kvale 1996). The main task in interviewing is to understand the meaning of what the interviewees say. (interview as a method of for qualitative research , 2002)

The interview method and place of the interview has to be thought thoroughly by the interviewer. There are many different methods, a few examples are: Post it interview method, STAR interview method, Rich picture method,.. A combination of the STAR-method and Rich picture method is preferred in this thesis. The interview is preferred to be taken at the workspace, because the working materials people use to do their work, will be close at hand. Documents and products will be able to be shown. An explanation of the different methods is given below.

Post It Interview Method

While the interview takes place with the interviewee, three times is asked to summarize and write down the keywords on sticky notes. At the end of the interview, the interviewee is asked to sort the sticky notes, so a good representation of the interview is given. The result of the interview is a plan of keywords that are associated with each other by the interviewee. The increase of the validity of the interview is the main advantage of the method. It ensures that the interviewee, even during the interview, reflects on what has been discussed. The interviewee checked if it were his or her own decisions and summarizes. (de professionele dialoog , 1998)

Rich Picture Interview Method

The rich picture is generally constructed by interviewing people. Because information can be lost by the complexity of the problem, and a difficult message is often greatly simplified conveyed. A solution for that problem is the rich picture, a rich picture is made while doing an interview. The rich picture shows the interviewer clearly how the interviewee sees the situation. The opposite is also true that the interviewee easily can see how the interviewer sees the situation, and adjust it to how the interviewee sees it. The main advantage of a rich picture is that a complex situation can be displayed clearly for everyone. (Methods & Tools: the rich picture , 1998)

STAR Interview Method

The STAR stands for Situation Task Action Result. It is a universally recognised communication technique designed to enable you, to provide a meaningful and complete answer to questions. At the same time, it has the advantage of being simple enough to be applied easily. It is divided into several steps.

Step one is about Situation or Task, the interviewee is asked to describe the situation where difficulties about a difficult person had to be dealt with, explain how that person was met.

Step two is about Action, now that the interviewee described a situation, it can be asked how he/she dealt with the problem of the obstacle. Explain what you did, how you did it and why you did it.

Step three is about Result, explain what happened eventually and how it all ended. Also describe what you accomplished and what you learnt in that situation.
The main advantage of a star interview is the insight that you get of how the interviewee deals with problems he encountered. (Interview Skills Consulting , 2015)

3.2.2 Used Interview Method

The STAR interview method is used in this interview, because problems who have dealt with are told, and solutions are shown. So a positive side of the situation can be shown, and solutions for specific situations can be given. Bringing up problems and the related solutions can be helpful for preventing them in the future.

The Rich Picture method is combined with the STAR method. Before making the interview questions, a rich picture was made. The rich picture shows a link between the owners of hydropower plants, the neighbours, the law, as well as which difficulties or problems that can occur between the links. An overview of the situation is showed on the rich picture, and so finding the questions that need to be asked in order to get the information, is easier. The Rich Picture used in this thesis is shown in Figure 26 below.

With experiences learned along the way, conversations can be very difficult and a lot of information can be lost if the language skills are not on the same level.
People living around a micro hydropower plant, or owners of micro hydropower plants do not always speak English, and if it is spoken, it is basic knowledge. For that reason the interview is made in English as well as translated in Finnish in order to make it easier for the interviewee. Understanding the questions is the most critical part of the entire interview. Answering questions is easier when the questions are clear, regardless of answering the questions in English.

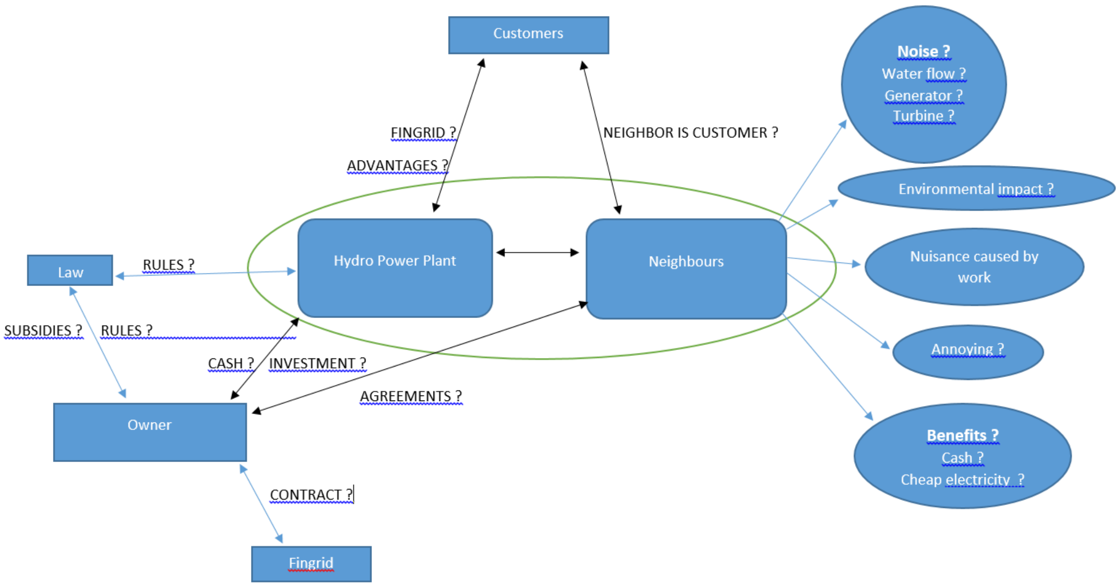

FIGURE 26: Rich Picture Sketch.

3.2.3 Interview Types

Except for the interview methods there are also interview types. The different types of interviewing are about how the questionings are asked. Three different types of interviews are possible.

Standardized Interview Type

One of the methods is the standardized interview, also called survey. The interviewer asks questions to the interviewee, but the possible answers are already made in advance, so the interviewee needs to choose one of the already existing answers.

Half Standardized Interview Type

The second type is the half standardized interview. The interviewer has written some subjects on paper he wants to talk about, and made some questions around it. Now the interviewee can answer the questions about the subject in his own words, but the subject of the interview cannot be chosen.

Open Interview Type

The third type of interview is the open interview. The interviewer has a subject in minds as well as a first question. Once the first question is asked, the interviewee can talk freely about any subject he wants. It is the responsibility of the interviewer to lead the conversation, and to make sure he knows everything he needs at the end of the conversation.

3.2.4 Used Interview Type

The interview method used in the study of micro/small scale hydropower is the half standardized interview. The questions, as well as the subject of the interview are in mind of the interviewer, and the interviewee can answer freely how he/she feels about the question or subject. This interview type matches to the chosen interview method (STAR interview Method). While the interviewer ask questions, the interviewee can answer them freely meanwhile the interviewer can write the answer down. (Carrièretijger, 2015)

3.2.5 Used Interview

The structure of the interview is based on the STAR interview method, this in combination with the half standardized interview. The questions are built up on the basics of the Rich Picture method.

In order to get an idea how hydropower plants are designed and what kind of efforts the designers or builders do to make sure the power plant get social accepted, an interview was made. In Combination with the interview, a survey was made, to try and find out if there is a link between what people think about the hydropower plants, and what efforts the designers or builders do to let the people agree with the current situation. The interview is divided in four parts.

The first part is about the relationship between the power plant and the neighbours. The second part is the design, the third part is about the economical aspect and the last part is about the social acceptance.

The questions in the first part are related to the relationship between the power plant and the neighbours. The importance of these questions is to see in how far there is a connection or communication between both of them, and who ensures it. By asking these questions, the relationship between the owner of the hydropower plant and the neighbours is clarified.

The second part questions are about the design. Questions about design are asked to figure out what part of the hydropower plant gets the most attention and why. Some of these questions are related to noise, others are related to the environmental impact and about the view of the power plant.

The questions in the third part are about the economical aspect. The economical aspect of the hydropower plant is realized by asking the question if electricity made by hydropower is more expensive than electricity made by another source, for example nuclear, coals, biomass and so on. Different interviews are taken with different owners of power plants, as well as small scale as micro scale. A second part question is asked in case the answer on the first question is yes. Why is it cheaper? These questions give a view of the ratio between investment and profit of a hydropower plant.

The fourth and last part is about the social acceptance. The questions are about the complaints of neighbours, which ones they receive, and what are they about? As well as do neighbours have advantages of the hydropower plant, or which efforts are made by the owner or government in order to make sure the hydropower plant gets accepted by the neighbours. The complete interview is giving in appendix 3 and 4 in English and Finnish.

3.2.6 Used Survey

In addition to the interview a survey is made. In this study it is very important to measure the social acceptance, and in order to get the opinion of the local populations, a survey is made about small scale and micro scale hydropower plants. Collecting the data and analysing afterwards is necessary in order to get a correct understanding of the social acceptance situation in Finland.

Selecting the public for the survey is important to get reliable information. In order to do that, the location for taking the survey is decisive. The survey is taken in Tampere, because there are four hydropower plants in the Tammerkoski River which is going right through the city of Tampere.

The two uppermost plants, Finlayson and Tampella are parallel, across each other, and they control the flow of Tammerkoski as the water of Lake Näsijärvi flows directly in to them. A bit lower in the river at Satakunnankatu, there is the biggest hydropower plant named Keskikoski, what means Middle River in English. The last hydropower plant is called Alakoski and is located at Kehräsaari (Riku Merikoski, personal communication, 1 April 2015).

The survey has been taken at the Tampella area, because apartment blocks are located right next to the two uppermost small scale hydropower plants of the Tammeroski river, Finlayson and Tampella. To be more specific, most of the surveys were taken at the apartment block with address Kanavaraitti 10, Tampere. In order to get reliable information from neighbours who live just a few meters from the hydropower plant, as well as they are overlooking at the power plant.

Finlayson and Tampella hydropower plants are already there since the year 1861, so people are already used to the hydropower plants for many years, and we need to take that into account, when making the analyses (The city of Tampere , 2013).

In order to increase the reliability of the survey, as many as possible surveys were taken, and in this thesis the number of 40 surveys was set, as well as different categories of ages were tried to reach. The different categories of ages are important to see if there is a different mentality between younger or older generation. The survey is divided in four parts.

The first part is a general part to know some information about the person involved. That contains questions about where they live, work as well as if there is a connection between the surveyed person and the hydropower plants.

The second part of the survey is meant to figure out what energy is preferred, as well as the way of thinking about the impact of hydropower plants on the environment and in what sense it is good and helps to reduce CO_2 emissions. The sequel to these questions is if the government should invest more in hydropower, and if the people want more information about it.

The third part is about the social acceptance of the hydropower plant. Questions are asked about annoyance caused by the hydropower plant, in particular about the noise caused by the plant. Also general questions about the hydropower plant and its role in the cityscape, as well as the attraction for visitors are asked. These questions are mentioned to figure out in which way the power plant is accepted by the inhabitants. The acceptance is expressed by the proudness of the power plants in the city. This proudness is outdated in the way publicizing is allowed.

To go deeper in the acceptance more questions are asked, and the level of acceptance is polled. Could you accept a new hydropower plant in your town? Could you accept a new hydropower plant in your town if it is within 300m of your house? These questions are meant to show in which level of acceptance the surveyed person is located. The reason for asking those two questions immediately after each other is to figure out if the Not In My BackYard theory is applied. The NIMBY theory means that people want to use services but they are not willing to encounter disturbance of it.
The NIMBY theory is a very famous theory for the renewable energy market, and one of the main problems on world scale for inhibiting the progress of renewable energy.

The fourth part of the survey is about the economical aspect related to the plants. Are you willing to pay more for electricity made by natural sources? (Green power) and why? The answer on that question shows an indication of the importance of green power for inhabitants of Tampere. A next question is prepared if the answer of the first question is no.

Are you willing to pay more for electricity made by natural sources, if that gives your country independence in the future? The reason for asking those two questions immediately after each other is to figure out to what extend they are prepared to pay more for green power and what reason can motivate them. Full survey is located in the appendix 2.

3.2.7 Link between Survey and Interview

Like indicated in the previous chapter, there is a link between the survey and the interview. This because the interview is taken to builders, owners or designers of hydropower plants, and the survey shows the opinion of inhabitants in Tampere.

The interview, as well as the survey is divided in four parts and each one has questions about the social acceptance, economical perspectives and connection between the neighbours and owner of the plant.

In order to link the interview with the survey, questions about the same subject, need to be asked, but in different ways. For example questions about noise, caused by the plant, need to be asked to neighbours, and for the interview, questions about the way of reducing noise need to be asked. Similar reactions between the builders, designers, owners and surveyed inhabitants should become apparent. In the result chapter, links can be shown and the way of working and designing can then be encouraged or discouraged.

3.3 Technical Methods

To improve the efficiency of small or micro scale hydropower, different techniques are used depending on the place and its surroundings. In this chapter, the different techniques are explained, as well as what techniques should be used for which specific location and environment.

3.3.1 Technical Aspects of Small and Micro Scale Hydropower

The technological progress in hydropower plants has been improved. However the power plants look the same from the outside, as a few decades ago. New technologies are in use and improved efficiency is obtained. The evolution of the technology made it possible to automate the hydropower plants. As well as the structure of building has improved and so, they are more energy efficient. (Pienvesivoimayhdistys 2009.)

In general, small scale hydropower have two important parameters to generate electricity: the amount of discharge Q (water flow) and the head of the water ΔZ. The ability is calculated by next equation: P = ρ·Q·g·ΔZ ·η With ρ = Specific weight of water ≅ 1000 [kg/m3] Q = Maximal discharge [m3 /s] g = Gravitational acceleration [m/s2] ΔZ = Gross head [m], $\eta\text{tot} = \text{Total efficiency} = \eta\text{c} + \eta\text{t} + \eta\text{e} + \eta\text{f}$, ηc = Penstock efficiency ≥ 90 %, ηt = Turbine efficiency 89% ≤ ηt ≤ 94% [-] ηe = Generator efficiency ≥ 92%, ηf = Transformer efficiency ≥ 97%.The efficiencies indicated above are the present state of optimally-designed hydropower extraction schemes. The yearly power production can then be calculated by multiplying the electrical power output Pe with the hours of operation. Equation 1 shows an overview of the equation. (Larikka, 2012)

EQUATION 1: Calculating the ability of hydropower (source: larikka, 2012)

$$P_e = \rho \cdot Q \cdot g \cdot \Delta Z \cdot \eta_{tot}$$

With $\rho = Specific\ weight\ of\ water \cong 1000\ in$ [kg/m³]

$Q = Maximal\ discharge\ in\ [m^3/s]$

$g = Gravitational\ acceleration\ in\ [m/s^2]$

$\Delta Z = Gross\ head\ in\ [m]$

$\eta\text{tot} = \text{Total efficiency} = \eta\text{c} + \eta\text{t} + \eta\text{e} + \eta\text{f}$

$\eta\text{c} = \text{Penstock efficiency} \geq 90\%$

$\eta\text{t} = \text{Turbine efficiency } 89\% \leq \eta\text{t} \leq 92\%$

$\eta\text{e} = \text{Generator efficiency} \geq 92\%$

$\eta\text{f} = \text{Transformer efficiency} \geq 97\%$

3.3.2 Efficiency of Small and Micro Scale Hydropower

In order to have a hydropower plant with a good efficiency, which is important for the cash flow, the correct selection of the turbine is necessary. There are two main types of hydro turbines: impulse and reaction. The type of hydropower turbine selected for a project is based on the height of standing water so called “head”, the flow of the water and volume of the water. Other deciding factors include how deep the turbine must be set, the efficiency and the cost.

3.3.3 Impulse Turbine

An impulse turbine uses the speed of water flow, and so contains kinetic energy, to drive the turbine. This happens under atmospheric pressure. The water flow hits the buckets on the turbine, and so the turbine starts spinning. There is no suction on the backside of the turbine, water flows out of the bucket when it hits the water in the river. Generally an impulse turbine is suitable for high head, and low water flow applications. (Department of Energy , 2014)

Pelton Turbine

The working principle of a Pelton turbine is very simple, when a high speed water jet injects water through the buckets of the Pelton wheel, it induces an impulsive force. This force makes the turbine rotate. One of the most important parameters of Pelton turbine design, is the number of buckets on the disk. When too much buckets are on the disk, a part of the water from the jet will be lost. When lowering the number of buckets, the complete water jet might be lost. So there is an appropriate number of buckets, which will make sure that no water is lost. The water jet is always open, and so under atmospheric pressure, as well as for inlet as outlet. The velocity of water will have a drop from the inlet and the exit of the bucket. This kinetic energy drop is the maximum energy the bucket can absorb, and so all the energy is transported (Learn Engineering , 2013). Figure 27 below shows the working principles of the Pelton turbine.

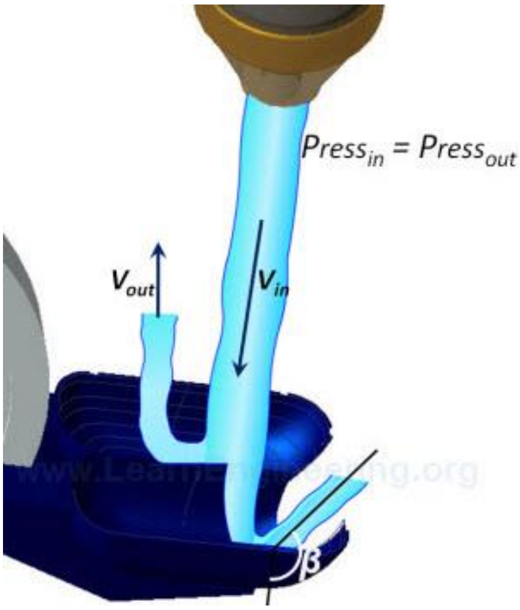

FIGURE 27: Working Principle of a Pelton Turbine (source: Learn Engineering)

Cross Flow Turbine

A crossflow turbine gets its name from the way the water flows through, or more specifically 'across' the rotor. The water flows over and under the inlet guide-vane, which directs the water flow to ensure it hits the rotor at the correct angle for maximum efficiency. Water flows not only on the upper blades, but also through the centre and back across the lower blades of the turbine, and so produces more torque. A major advantage of a crossflow turbine is their wide operating flow range with a high efficiency across the whole range.

- Head height: H = 3 … 200m
- Flow: Q = 0,03 … 13 m^3/s
- Capacity: N = 10 … 3500 kW

This is made possible by two inlet guide-vanes, 1/3 of the intake width and the second 2/3 of the width. In short that means that even in lower flow periods (by dry season) an inlet guide-van can be closed so only 1/3 guide vane is open, and thus only 1/3 of the rotor is used. The same method can be used when high water flow rates (by wet season) are available both guide-vanes can work together. Realistic efficiency rate is 82% for a high quality crossflow turbine. The efficiency curve is shown in Figure 28, therefore a crossflow turbine is mostly used for small scale or micro scale hydropower plants (Renewables First , 2015). The cross flow turbine is a new coming and emerging technology which is used more and more in hydropower in Finland. Figure 29 below shows the working principle.

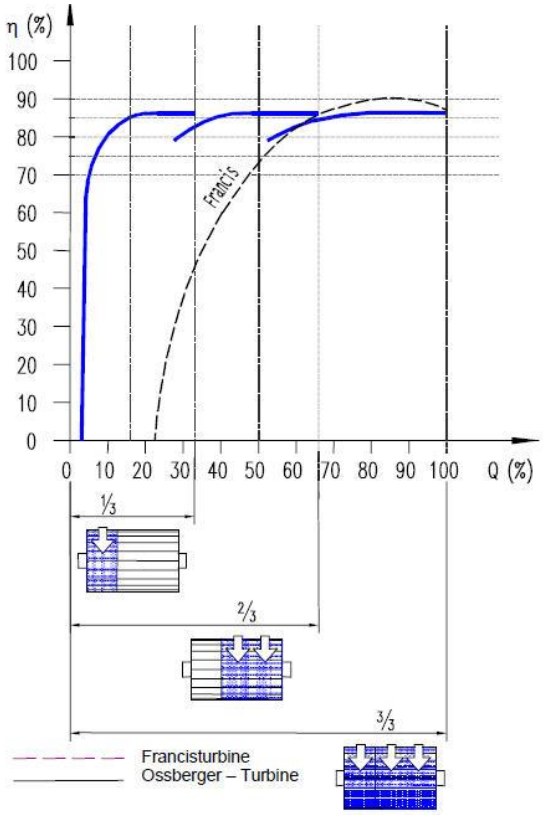

FIGURE 28: Efficiency characteristics of Ossberger crossflow compared to Francis turbine (source: Water21)

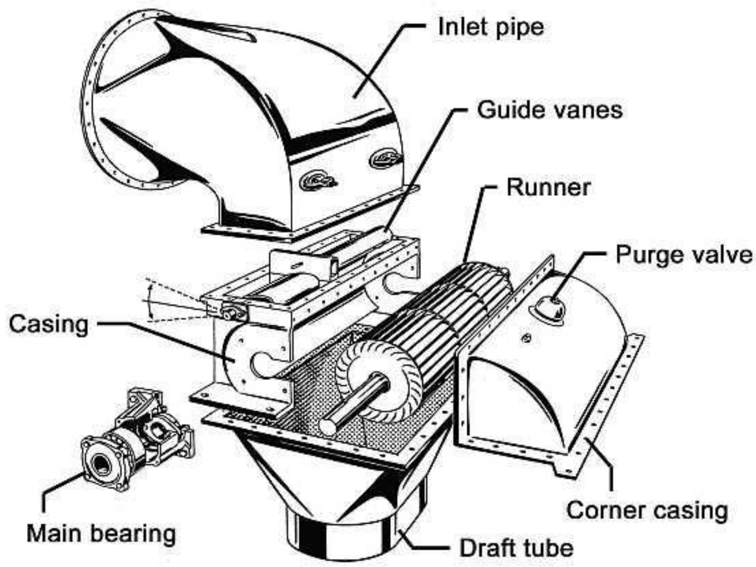

FIGURE 29: Parts of the Cross Flow Turbine. (source: freeflow hydro)

3.3.4 Reaction Turbine

A reaction turbine develops power from the combined action of pressure and water flow. The runner is placed directly in the water and entirely surrounded by water. The water stream is flowing over the blades, rather than striking each individually. Reaction turbines are generally used for sites with lower head and higher flows, compared with the impulse turbines.

Propeller

A propeller turbine generally has a runner with three to six blades in which the water contracts all the blades constantly. The same system is used to drive a boat. The pressure through each blade is constantly. The pitch angel of the blades can be adjustable. There are different types of turbines, and the most important ones are the bulb turbine and the Kaplan turbine. The Efficiency of the Kaplan turbine is showed in Figure 30 below. (Department of Energy , 2014)

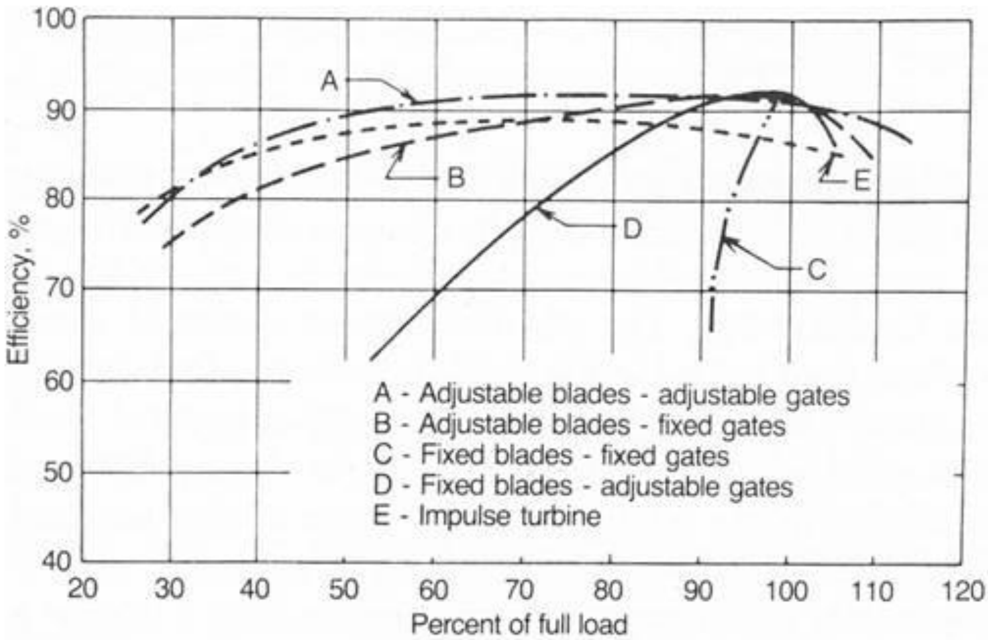

FIGURE 30: Efficiency Propeller Turbine (source: Department of Energy)

Francis Turbine

Francis turbines are the most preferred hydraulic turbines. They are the most reliable workhorse of hydroelectric power stations. It contributes approximately 60% of the global hydropower capacity, mainly because it can work efficiently under a wide range of operation conditions.

- Head = 45 – 400 m
- Flow rate = 10-700m³/s

The head and flow rate are the most vital input parameters that influence the performance of a hydraulic turbine. But seasonal variations can change these parameters. The Francis turbine can deliver a high efficiency even if there is a huge variation in these flow parameters. See Figure 31 below.

The runner of the Francis turbine is the heart of the system. The water enters radially, and leaves axially. During the course of flow, water glides over the blades. The shape of the blade cross-selection is of thin air foils. That means that water flows over it, and low pressure is created on one side, and high pressure on the other side. This results in a lift force. Figure 31 below shows the efficiency of the Francis Turbine, Figure 32 below shows the Explanation of Lift and Impulse. (Learn Engineering , 2013). The Francis turbine used to be the most commonly used turbine in small scale hydropower in Finland.

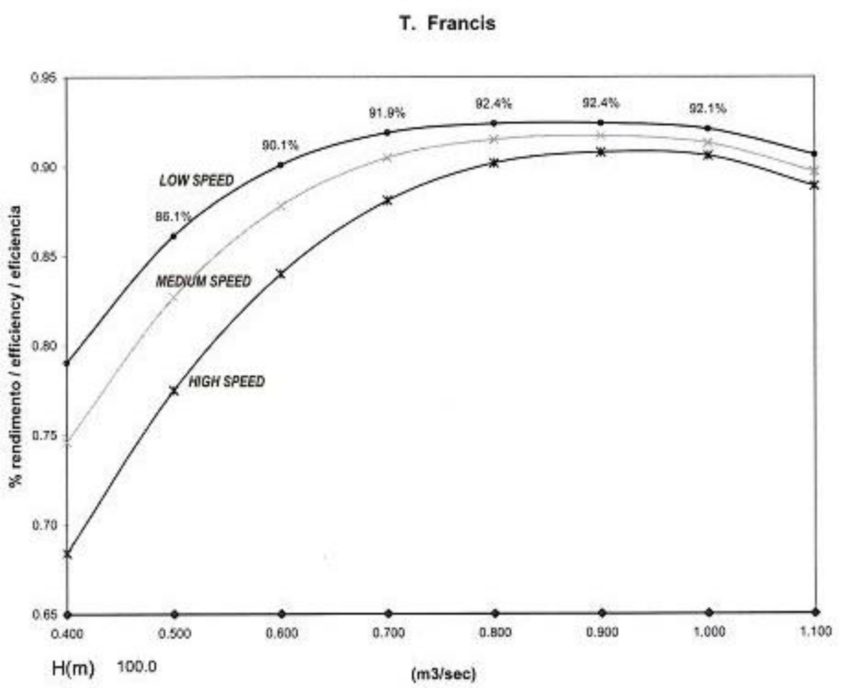

FIGURE 31: Efficiency of Francis Turbine (source: Learn Engineering)

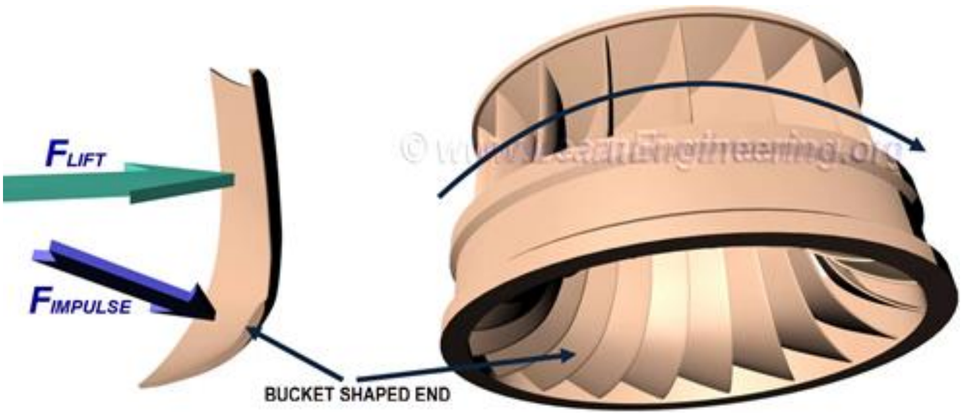

FIGURE 32: Explanation of Lift and Impulse on Francis Turbine (source: Learn Engineering)

3.3.5 Environmental Impact

Most hydropower plants in Finland are small scale, and so the construction of the plant is mostly from the diversion type (so called run-off-river). Related to the Social Acceptance study, the environmental impact needs to be discussed.

The run-off-river projects are considered to be ‘green energy’ with a little environmental impact, because they do not require damming like large hydro projects. There are no greenhouse gas emissions, and run-off-river projects run from a renewable inexhaustible source.

However there are disadvantages as well on the environmental impact. The effects of the natural habitat is the biggest concern with run-off-river projects. Reduction of the natural water flow can change the quality of the habitat for fish and other organisms, such as temperature of the water, depth and vegetation. (RENU LATA, 2013)

In order to keep the natural habitats and the habitats for fish, some actions need to be taken. Nowadays in Finland a fish way, also known as fish ladders or fish passes is required for every renovation or new hydropower plant. The fish way is a structured way on or around the dam, to give fish the opportunity to migrate. Each dam on a river, that is targeted for a fish way construction, represents a unique situation. There are many aspects that need to be considered within the design of the fish way. Specifications, diversity and size of the fish way varies from site to site. Seven types of fish ways can be used: pool-type, denil, lock, trap and transport, rock ramp, bypass and eel. The different types will not be explained in this thesis, because specialized companies are required to make the study, because it depends on too many factors and it is not allowed for the owner to do it himself.

In Finland specialized companies come on site, to make a study of the fish way, calculations in order to be conform on the norms of the law. In order to get the approval of the Finnish government to renovate a micro or small scale hydropower project, the environmental impact needs to be discussed with the accompanying measures. In appendix 5 and 6 a construction plan for a fish way is showed. This plan is obtained by a micro scale hydropower plant that is under construction for renovation.

4 RESULTS

In the results chapter, the results of the studies will be showed, in particular for the Economic perspectives, Social Acceptance and Technical aspects. The results are made on the basics of the collected information from neighbours, designers, owners, builders, companies, papers and theses in Finnish, as well as in English.

4.1 Results Economic Perspective

The results of economical perspectives are made by analysing papers, theses and information received by companies which own the hydropower plants.

4.1.1 Potential Hydropower in Finland

The available information indicates that there are more than 200 hydropower plants in Finland, having a total power production of almost 13 TWh, in an average precipitation year. After 1970, six hydropower plants have been shut down. These had a total power capacity of 5 MW and a production volume of 27 GWh. Results of a survey shows that Finland has a hydropower potential, corresponding to an annual production volume of 9 715 GWh.

Most of Finland's rivers are relatively short in length and are often very shallow. The longest river in Finland is the Kemijoki, which begins in the Northeast of Finland near the border with Russia and flows toward the Southwest to the Gulf of Bothnia. Other major rivers include the Muonio, which begins in far Northwest Finland and flows Southward to the Gulf of Bothnia (forming part of Finland's border with Sweden) and the Oulujoki, which begins in central Finland and flows Westward to the Gulf of Bothnia. The most significant areas of hydropower development in Finland are in the Kemijoki River in northern Finland, in the Oulujoki River basin in central Finland and in Vuoksijoki which flows between the lake Saimaa and the lake Ladoga in Russia. From the 200 hydropower plants in Finland, most of these are small scale – only eight are large scale and have generating capacities of at least 100 MW with none more than 200 MW. The eight largest of Finland's hydroelectric power plants are shown in Table 3 below. (Twenties Tansmitting Wind , 2012)

Table 3: Hydroelectric Power Plants in Finland (100MW and greater) (source: World Small Hydropower Development Report)

Power Plant	River	Capacity (MW)
Imatra	Vuoksijoki	170
Petäjäskoski	Kemijoki	135
Taivalkoski	Kemijoki	133
Pyhäkoski	Oulujoki	122
Rouhiala	Vuoksijoki	120
Pirttikoski	Kemijoki	110
Isohaara	Kemijoki	106
Seitakorva	Kemijoki	100

4.1.2 Potential Small Scale Hydropower in Finland

In 2010, Finland had 152 small hydropower plants divided into 73 plants with 1-10 MW and 79 plants with less than 1 MW. The total installed capacity was 302 MW (generating 1,314 GWh per year). In addition to these plants, there are approximately 40-50 plants with a capacity of less than 50 kW (micro-hydro), operated without connection to the national grid. Figure 33 shows the small hydropower capacities in Finland.

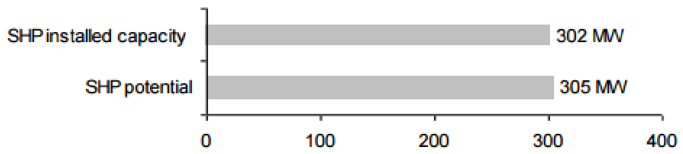

FIGURE 33: Small Scale Hydropower Capacity and potential in Finland (source: World Small Hydropower Report)

By 2020, the aim is to have 160 plants with a total installed capacity of 305 MW (generating 1,330 GWh). However, the small hydropower sector has lately been facing a difficult growth environment, where the economic support has been withdrawn. Considering this change in support, the estimation of extra small hydropower potential has recently decreased by up to 90%, from 1,200 GWh in 2005 to around 210 GWh in 2010. Refurbishment plans are being made mainly to upgrade larger plants of the sector in the range of 1 MW to 10 MW. This work was supported by the decision made in 2010 to raise the upper limit for the energy investment support from 1 MW to 10 MW. (World Small Hydropower Devolopment Report , 2013)

Small scale hydropower plants in Finland can be ranked in different ways, profitable power plants are counting for 130MW and produce up to 671GWh. Less profitable hydropower plants are counting for 73 MW and produce up to 156 GWh, and non-profitable hydropower plants are counting for 34 MW and produce up to 156 GWh. Protected small scale hydropower potential share of 177 MW/ 830 Gwh (Small Hydropower Survey 2005, 5). The most profitable hydropower locations in Finland have already been provided with hydropower plants or protected against new hydropower projects. The profitability of increasing hydropower by building it, varies greatly by the size category and type of the project. The most achievable project types are power increases in small scale hydropower. Although it can be concluded that the current small scale hydropower sector is a weakened situation, particularly as a result of the protected oversized potential.

Ari Aalto, Co-Chairman of the Workshop, Head of AF Hydro (Finland), presented a report on the energy policy of Finland and the role of small hydropower industry in that country. It was noted that the economically efficient potential for construction of new hydropower plants in Finland is almost exhausted, so attention is directed to the reconstruction of small hydropower plants, as well as construction of small hydropower plants at operating non-energy hydro installations. (Basrec workshop on small scale hydropower plants, 2013)

The most achievable project types are power increases in micro scale hydropower plants by redesigning and upgrading the equipment of the main machinery at the power plants. As well as riverbed clearing and heighten the dam for upstream water level. However, there is a lack of interest for projects to increase micro scale hydropower plants.

The opportunities to increase new hydropower production capacity are also limited, because of the season, environmental protections. And these reason may also limit the increasing capacity.

4.1.3 Investment in Small Scale Hydropower in Finland

Hydropower is a capital-intensive technology, with a lot of time spent for development and construction, a lot of planning, design and civil engineering works are required. There are two major cost components for hydropower projects: the civil works for the hydropower plant construction, including any infrastructure development required to access the site and the project developments costs. The project developments cost is the cost related to the electro-mechanical equipment.

Project development costs include planning and the feasibility of environmental impact analysis, licensing, fish and biodiversity, historical and archaeological mitigation and water quality monitoring and mitigation. Civil works costs can be categorised as: Dam and reservoir construction, tunnelling and canal construction, powerhouse construction, site access infrastructure and grid connection. If the transmission networks are far away from the transmission grid, construction of transmission lines can be a significantly part of the total cost.

Electro mechanical equipment for the project includes the turbines, generators, transformers, cabling and control systems that are required. These costs are significantly less than the civil engineering costs which are affected by the size of the plant. The price per kW is especially determined by the local site alterations, design choice, cost of local labour and materials, these factors determine the total investment cost for the hydropower plant. It is clear that the total investment cost for hydropower can vary significantly, especially because of the civil engineering costs. Therefore in some cases the investment price can be larger than for other renewable technologies.

Analyses made by the International Renewable Energy Agency shows following results: the total costs for large-scale hydropower projects typically range from a low cost of approximately € 1000/kW to around € 3500/kW. However it is not unusual to find projects with costs outside this range. For instance, when a hydropower plant is installed at an

existing dam that was built for other purposes (flood control, water provision,..), it may have a lower cost than € 500/kW. On the other hand, projects at remote sites, without customized surrounding for infrastructure, and which are located far away from the transmission grid, can cost significantly more than € 3500/kW.
The cost of hydropower varies within countries and between countries depending on the resource available, cost structure of the local economy, etc., which explains the wide cost range of hydropower plants.

Small scale hydropower projects have investment costs that are slightly higher and thus are expected to have higher average costs. This is particularly true for plants with capacities of less than one MW, electromechanical costs can be very high and dominate the total costs. However the investment cost per kW tends to be lower if the plant has higher head and installed capacity. According to Figure 34 and 35, next conclusions can be made: the price of small scale hydropower in the European Union is the largest of all, price of large scale is comparable with the rest of the world. The price per kW degreases and is conversely with the head that increases. (Renewable energy technologies: costs analysis series , 2012)

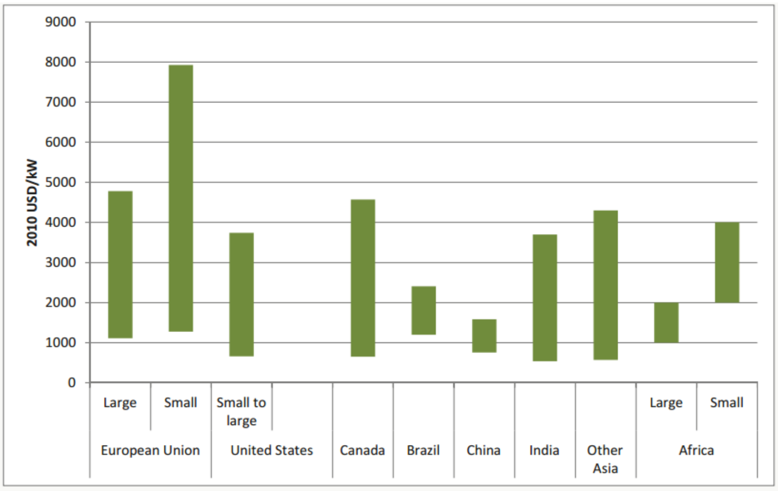

FIGURE 34: Price per kW Large and Small Scale Hydropower, compare study on world scale. (Source: Renewable Energy Technologies Cost Analysis)

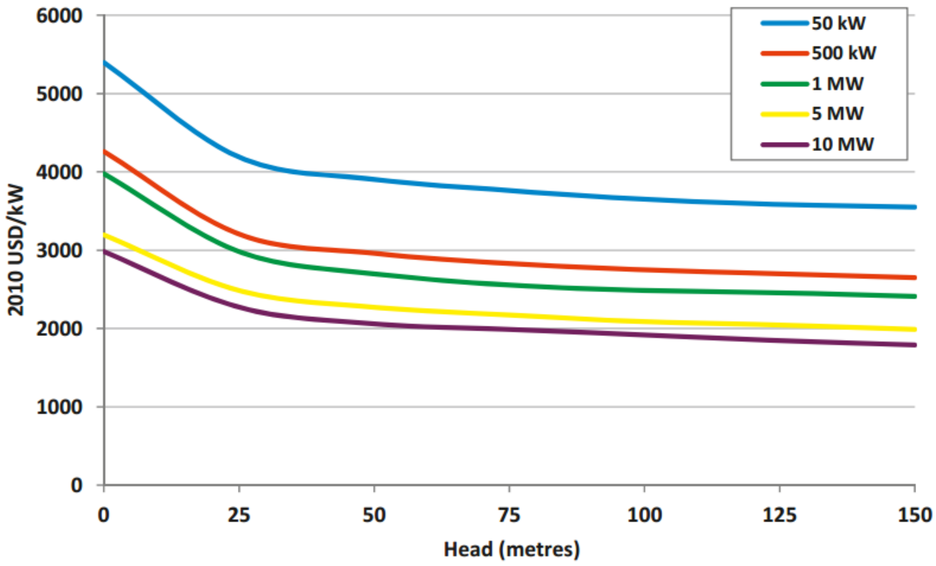

FIGURE 35: Price per kW of Small Scale Hydropower Plants in General (source: Renewable Energy Technologies Cost Analysis)

According to a study, large scale hydropower plants have an economic lifetime of at least 40 years, and 80 years lifetime is used as upper bound. For small scale hydropower plants, the typical lifetime is about 40 years, but in some cases it can be less. The advantage of hydropower is that electromechanical equipment have a durability of 30 years or more and it takes 50 years before the penstocks need to be replaced. Figure 36 below shows the cost breakdown for small scale hydro projects in developing countries.

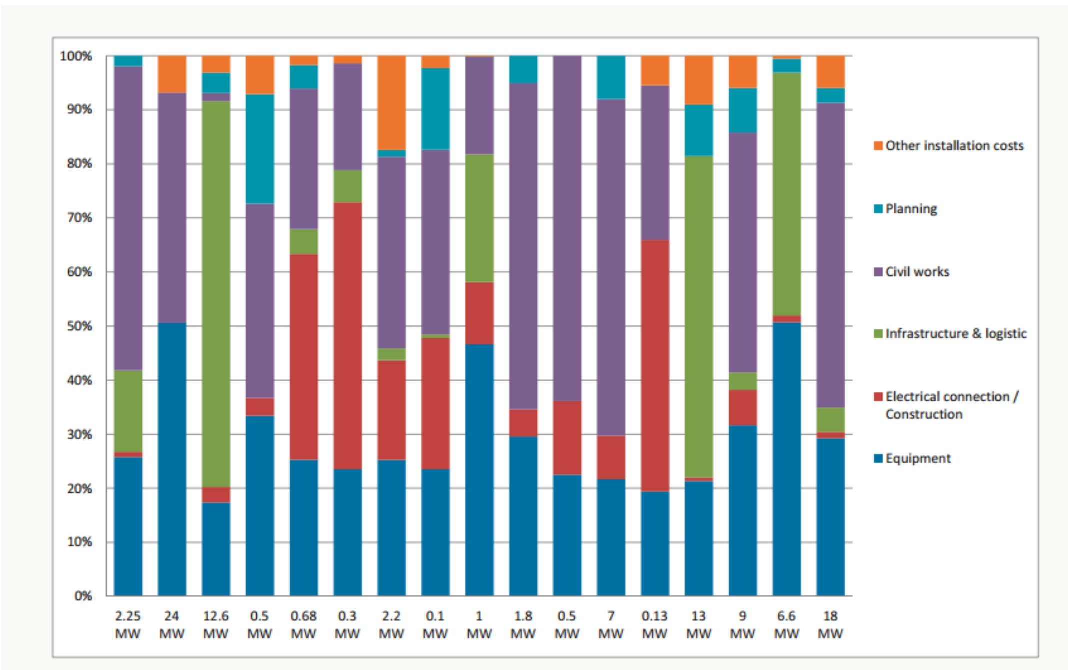

FIGURE 36: Cost Breakdown for Small Hydro Projects in Developing Countries (source: Irena/GIZ)

Price of Electromechanical equipment

A range of studies have analysed the cost of the electromechanical equipment for hydropower plants as a function of total plant size and head. The following formula describes the relationship between costs, the power and head of a small scale hydropower scheme (Ogayar and Vidal, 2009)

$$\text{Cost (per kW)} = \alpha P1 - \beta H\beta 1$$

Where P is the power in kW of the turbines, H is the head in meters, α is a constant, and β and β1 are co-efficients for power and head. (Renewable energy technologies: costs analysis series , 2012)

Price of Civil Engineering

Civil costs for large hydropower projects dominate the capital costs of the project. The costs of civil works are influenced by many factors, and depend on the site, the scale of development and the technological solutions that needs to be made. Around three-quarters of the total investment costs of hydropower project are driven by site-specific elements that impact the civil engineering, design and costs (Ecofys, etal. 2011).

Price of Maintenance and Operating

Once hydropower plants are operating, they usually require little maintenance and operation costs. If a series of plants are installed along the same river, a centralised control can reduce the costs. Most operating and maintenance costs are quoted as a percentage of the investment cost per kW per year. Typical values range from 1% up to 4%. The International Energy Agency assume that 2,2% is correct for large hydropower and 2,2 up to 3% is used for smaller projects, with a global average of approximately 2,5% (IEA, 2010c).

4.1.4 Cost of Electricity Made by Hydropower

Hydropower is a proven, predicable and reliable technology and can also be low-cost. It has a relatively high initial investment, but has the longest lifetime of any generation plant, including replacement parts, and a low operation and maintenance cost. As discussed before, the investment costs highly dependent on the location and conditions of the site. So the cost of electricity for hydropower has a wide range, depending on the project, but generally it can be very competitive. The critical parts required to calculate the electricity price of hydropower are: installed capital cost, capacity factor, economic life, operating and maintaining cost and the cost of capital.

Another very complicated factor is the design of the hydropower plant, because it can perform very differently. For example the capacity can be low to ensure a high average capacity, but the consequence is that the plant cannot be used to meet peak demand loads. The opposite for power plants which are designed for high capacities to meet peak demands. The alternative is to combine those two, the plant could have relatively high capacity and low capacity factors, if it is designed to help to meet peak demands and provide reserve power. The decision about which strategy must be used for any given hydropower plant, is highly dependent on the local market, grid and structure of power generation. Hydropower plants made for capture peak power prices, can have a large impact on the economics of a project.

A study of the International Energy Agency, shows that small hydropower in Europe, where most large scale projects already have been constructed, reveals a wide range, depending on the local resource and cost structure. The average cost for European countries ranges from €0,04 to €0,18/kWh. (Ecofys, et al., 2011), (Renewable energy technologies: costs analysis series , 2012)

4.1.5 Payback Time of Small Scale Hydropower

According to Aari Alto, Senior Advisor of ÅF-consult oy, next conclusions can be made in case of Finland’s small scale hydropower. Because each case is individual and different, a general solution is difficult to make. But it has turned out that in general a small scale hydropower plant of less than 500 kW is feasible only in special cases and power plants bigger than 1MW are normally feasible if the head is at least 5 meters.

The payback time is highly dependent on the site, flow and especially available head. Typical payback time in Finnish small hydro plants from 0,5 MW to 10 MW is long. It takes 20 to 40 years depending on the hydrological, geological and hydraulic circumstances, automation degree and other structure of the plant. Financing is also a possible state investment support (normally 20%) and so on. A general solution can be made; the bigger the power plant capacity, the more profitable is the project. In Finland typical small hydro plant project costs are split 50/50 between civil costs/electro-mechanical machinery (turbine-generator set + electrification and automation) and development costs vary in 10 to 15% range (Aari Alto, personal communication, 25 march 2015).

According to Riku Merikoski, Portfolio Manager of Tampereen Sähkölaitos Oy, next conclusions can be made for small scale hydropower plants in Tampere (Finland).
In Tampere four small scale hydropower plants are located on the river between Lake Näsijärvi and Lake Pyhäjärvi. These power plants serve as basic load plants and try to produce as much electricity as possible.

The two uppermost plants, Finlayson and Tampella are placed in parallel. This means that they can both run or be stopped independently of the other plants. They control the flow of Tameroski as the water of Lake Näsijävi flows directly in to them. Tampella hydropower plant has a capacity of 3,3 MW and the yearly production is about 13 000 MWh. Finlayson hydropower plant has a capacity of 4,4 MW and a yearly production about 16 000 MWh. A bit lower in the river, at Satakunnankatu, there is the biggest hydropower plant called Keskikoski, what means Middle River in English. The power plant has a capacity of 8,7 MW and produces yearly about 32 000 MWh. This plant gets its water through the upper plants, so it can only run if at least one of the upper plants is running. The last hydropower plant on the river is Alakoski, at kehräsaari, it has a capacity of 4,6 MW and produces about 15 000 MWh each year.

The production values vary a lot, depending on the rainfall. A scrutiny shows that in a wet year, with a lot of rainfall, the production value can go up to 50%. If looked at a dry season, production value can be at least one third less than the data showed above. All the plants at Tammerkoski have more than one turbine, so they can also produce less than the maximum effect at any given time. Therefore, there are actually much more operating hours than getting by counting from the effects and yearly production numbers. These power plants run about 4 000 to 6 000 hours each year, depending on the rain and availability. In order to maximize the power production, the power plants are more often used in daytime, than at night.

Regulations set by the authorities have to be followed, the regulations set rules about the the level of Lake Näsijärvi, that may not be too high or too low (Riku Merikoski, personal communication, 1 April 2015). Appendix 7 shows an overview of the water level set by the authorities.

4.2 Results Social Acceptance

The results of the social acceptance are made by analysing the information received from the basics of the surveys and interviews taken during the thesis period.

4.2.1 Results Interview

In order to have an idea how designers and builders have a different approach for building the power plant, it was necessary to interview people from different working areas. The interview is taken from four people who are working with hydro power plants all day. Jaakko Mattila has his own hydropower plant, as well as he is working and designing hydropower plants. Kaarlo Koivisto is working on the design and restauration of hydropower plants. Olli Hallikainen has his own hydropower plant and it is under construction to renovate it right now. Riku Merikoski is working for the company Sahkolaitos and is responsible for the hydropower department.

The same questions are asked to different people who are all working with hydropower plants. We have searched different types of hydropower plants. Small scale hydropower plants (1MW – 10MW) and micro scale hydropower plants (< 1MW).
The surroundings of the plants, are different according to the scale of the plant. Micro scale hydropower plants are mostly located in a quite area, and the neighbours are having a summer house there and live at least a few tens of meters away from the plant.

The surroundings of the small scale hydropower plants can be very different. Small scale hydropower is located on bigger rivers, and these are mostly going through a village or city. So people are more faced with it. As well as they can live closer to a hydropower plant than with micro scale hydropower plants.

The analyse shows that neighbours are informed when a renovation happens. The procedure for a new hydropower plant is different. But no new hydropower plants are built since 1930's. The way neighbours are informed is however different and depends on the owner and the scale.

Informing the neighbours on small scale projects always happens by the government, as well as by the owner of the power plant. It is required to state the information for who is interested. On small scale hydropower projects a website is made, and information is available for who is interested. Updating the website happens frequently.
Informing neighbours on micro scale hydropower projects happens by the government. It is the own choice from the owner of the plant if he informs them or not. No webmail is needed and information about the project is not publicly available.

Disagree the hydropower project is possible and can be done in different ways. Writing a complaint on an official document and send it to the government is the procedure to do it. However the complaint needs to have good arguments in order to be handled. An example of a dignified argument can be if the builder of the plant does not follow, the by government presented, construction rules. A specific example can be if the fish way is not built or locked during operation times. In case of disagree and if strong arguments can be showed, the next step is to bring it to court.

Questions about the design of the hydropower plant give the following results. The questions about the design are asked in order to get an overview about what part of the plant they concentrate the most on.

The noise of the water flow is not an issue. The water flow is always there, it does not make much noise both for micro and small scale hydropower, so reducing the noise of water flow is not being done. In order to reduce the noise of the turbine, a small chamber (house) is built around the turbine. The chamber is isolated and noise is reduced, so no noise is heard from the outside. The same strategy is used to reduce the noise of the generator. The generator is also located in the isolated chamber. If the noise is not reduced enough, isolation is affixed to the generator.

In order to give the hydropower plant a good look, a lot of time is spent on the design. However there is a difference between small scale and micro scale hydropower plants. Because small scale hydropower plants are located on bigger rivers and so mostly in the city, hiding or giving a good look to the hydropower plant is very important in order to get socially accepted. Small scale hydropower plants in the city are tried to be hidden. For example the small scale hydropower plants in the city of Tampere are tried to be hidden into existing buildings, but historical rules have to be followed what makes it difficult and so a lot of time is spend on the design. Also lots of time is spent on the design of micro hydropower. But because micro hydropower plants are located more remote a different strategy is used. The most important of renovating a micro hydropower plant, is to renovate it in its original condition. Most renovations happen at old sawmills, and bring back the character and the historical charm of the mill is the most important thing in order to get social accepted.

The efficiency of the hydropower plant is important for the cash flow, so maximum efficiency is tried to achieve. However not much space and rules of historical surroundings, together with environmental rules, make sure that the efficiency is limited. Very low electricity prices also make it unprofitable to invest a lot to small efficiency upgrades.

Environmental impact is one of the most important things when building or renovating a hydropower plant, therefore a lot of time is spend on that part. Approval for the renovation/building must be obtained and the orders of the authority must be followed in the field of environmental. Nowadays to get an approval for renovating or building a hydropower plant, it needs to contain a fish way. A specialized company will built the fish way. In case there is no possibility to build a fish way, the fish has to be guided away from the hydropower plant, so reaching the power plant is not possible. This part of the hydropower plant is also very important to get socially accepted, because neighbours attach much importance to it.

Further studies to the acceptance of hydropower plants showed that the complaints received by neighbours are about the water level. Despite of the fact that it has nothing to do with the hydropower plant, because the plant does not have any impact on the water level. Again there is a difference between small scale and micro scale. In case of micro scale the water level depends on the rainfall. In wet months the water level rises because of many rain. The micro scale hydropower plants have more water flow, and so let more water pass through the plant. In case of small scale hydropower plants the water level can be slightly controlled. But the owner of the plant needs to regulate the water level like the authorities instruct them. Acting against the rules, set by the authorities, cannot be done.

The owner of a hydropower plant has the advantage of buying electricity at a cheaper price, but not the neighbours. In order to keep the neighbours happy a few compromises can be made with small scale hydropower plants. For example one of the compromises the owner of the hydropower plant in Tampere made is keeping the water level of the Lake Näsijävi at a higher level by not using all the allowed capacity. The water level is kept considerably higher than the lower level in winter time, because making it go too low (by letting to much water through the power plants) would annoy people. That ensures that the water level in the lakes are more constant than it would naturally be. It also keeps the water level fairly constant during the summer which is good for water-related hobbies.

One of the main advantages of storage the water in the lakes upstream of the cities is to prevent floods. For example in Tampere, water is stored in Lake Näsijärvi, and so prevents floods downstream in the Kokemäenjoki River, as the cities of Huittinen and Pori would face severe flooding much more often than if the storage of the water was not possible. Also regarding the actual daily operation of the power plants, production patterns can be changed by request if there is an event in or at the river which requires stopping the water flow. An example for that is the minimalizing of water flow in the river during rowing competition.

Questions about the price of hydropower, show that it is much cheaper to generate electricity from small scale as micro scale hydropower plants than any other energy source. No raw materials are needed, because a natural water flow is continue, always present, and furthermore free of charge. The costs of the employees are much lower, because the hydropower plants can be started and stopped fully automatically. So only the maintenance needs staff and some rent need to be paid to the owner of the land, so the costs are extremely low.

However looking at the payback time, there is a difference between small scale and micro scale hydropower plants. In case of renovating/building a micro hydropower plants, the investment is smaller than a small scale hydropower plant. Most of the time, the dam is already made and the investment for renovating turbine and generator is rather small. The most expensive part is building the fish way or fish guide. However the payback time is much larger than with small scale because the hydropower plant produces less electricity. In case of small scale hydropower the investment is much bigger, but still not bigger than building a different power plant. So the payback time of small scale hydropower is much faster.

4.2.2 Results Survey

At first an overall conclusion of the results will be given, without taking the age into account. After the first overall conclusion, the different categories of ages and their conclusion will be discussed. The survey was taken by 40 people who live close or next to a hydropower plant.

Overall Conclusion

In the overall conclusion, all the asked questions and their results will be discussed.
In the first part general questions are asked to know some information about the relationship between the hydropower plant and the neighbours as well as the preferred type of energy. The results of the first two questions are showed in Figure 37 and 38 below.

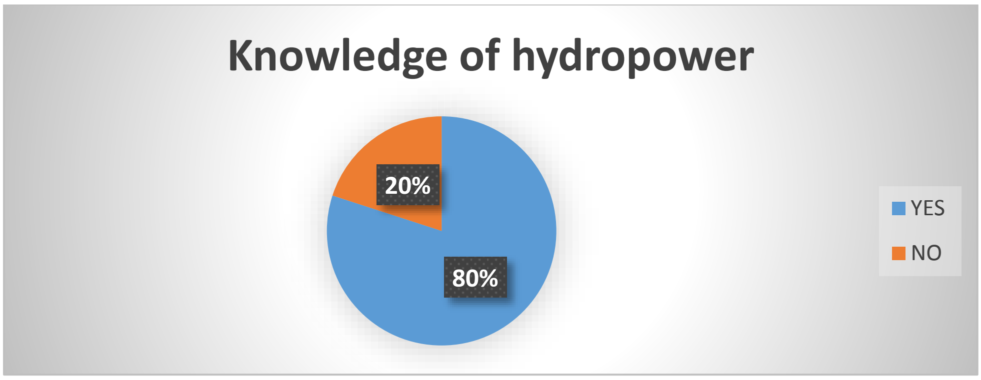

FIGURE 37: Results Survey: Knowledge of the Owner of the Hydropower plants in Tampere

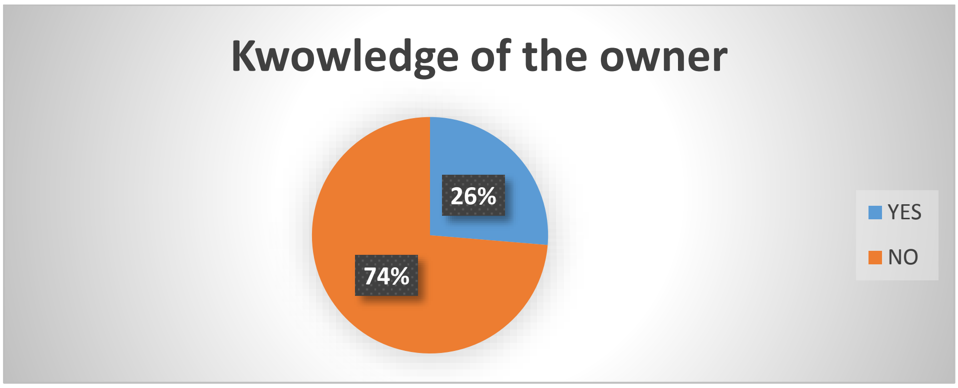

FIGURE 38: Results Survey: Knowledge of Hydropower plants in Tampere

The results of Figure 37 and 38 show that 80% of the surveyed people had knowledge of the hydropower plants, however only 26% knew the owner of the plant.

The second part of the survey is meant to figure out what energy is preferred, as well as the way of thinking about the impact of hydropower plants on the environment and in what sense it is good and helps to reduce CO_2 emissions. The results of the question asked about the second part is showed in Figure 39 and 40 below.

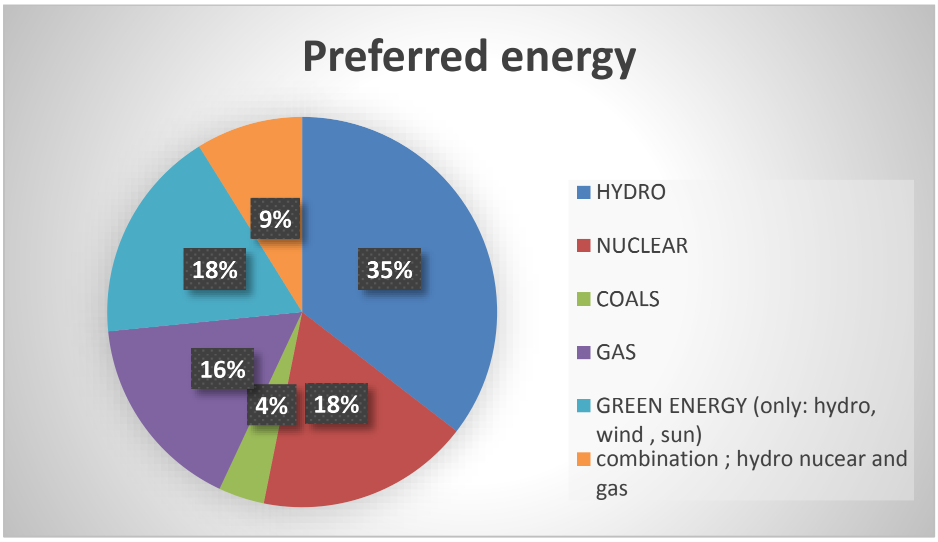

FIGURE 39: Results Survey: Preferred Energy

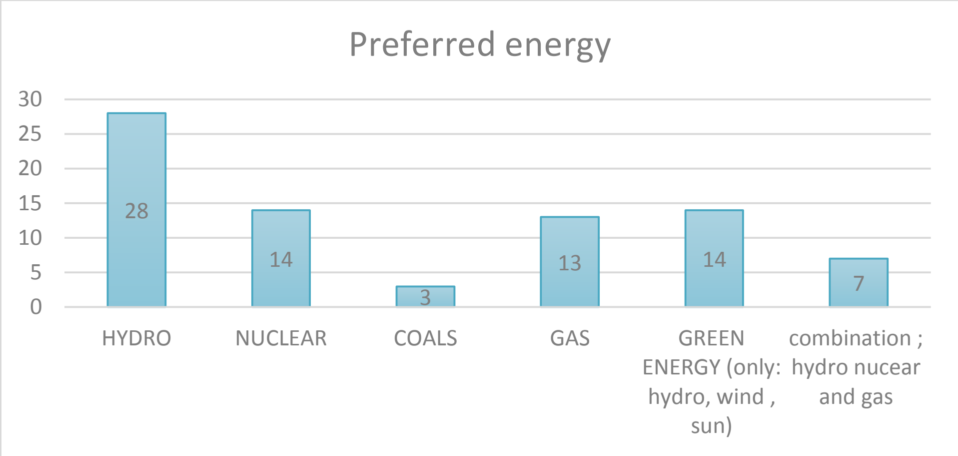

FIGURE 40: Results Survey: Preferred energy

The results of Figure 39 and 40 show that 35%, (good for 28 persons) prefer Hydropower, 18%, (good for 14 persons) prefer Nuclear, 16% gas, (good for 13 persons) and 18% Green energy (only wind, solar or hydro). An overall conclusion of this question can be that coals are not beloved by the people. Green thinking is proven by the preference of Green power or Hydropower. However people are conscious of the need for a mixture between Nuclear, Hydro and Gas.

The next question is asked in order to figure out why people prefer Green power and Hydropower, the question is related to CO_2-emissions of hydropower. Figure 41 shows the results.

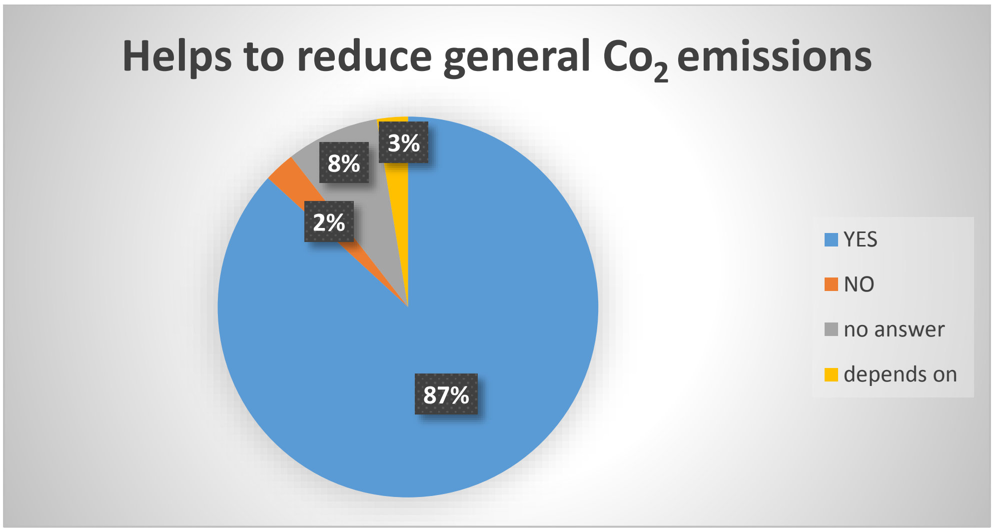

FIGURE 41: Results Survey: Can Hydropower help to reduce the general C02-emissions?

The results of Figure 41 shows us that 87% of the people are convinced that more hydro-power plants will help to reduce the general CO_2-emissions in the world. That explains why hydropower is preferred in the previous question.

The questions in the third part is about the social acceptance of the hydropower plant. The next questions are about the nuisance caused by the hydropower plant that people experience by living next to it. A hydropower plant has a certain level of noise while producing electricity, the turbine and generator are responsible for that noise, but also the water flow can be annoying. The results of these questions are showed in Figure 42, 43 and 44 below.

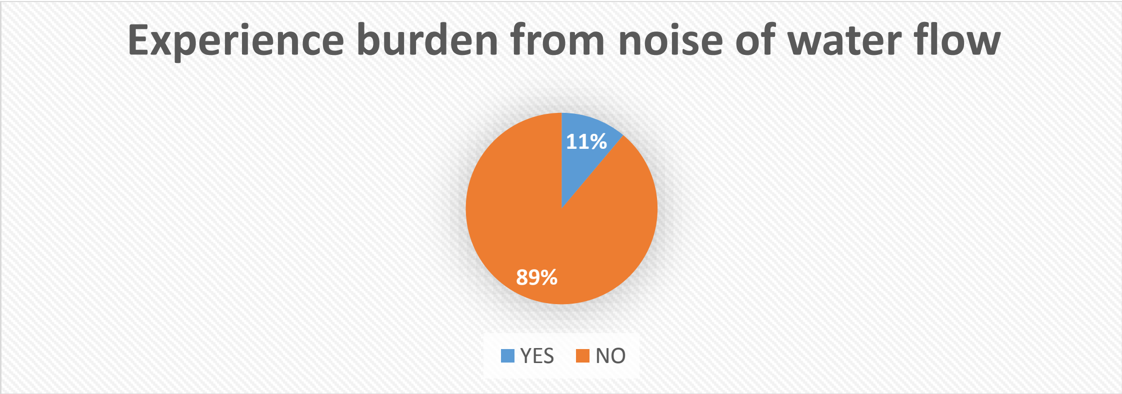

FIGURE 42: Results Survey: Burden from Noise at Night

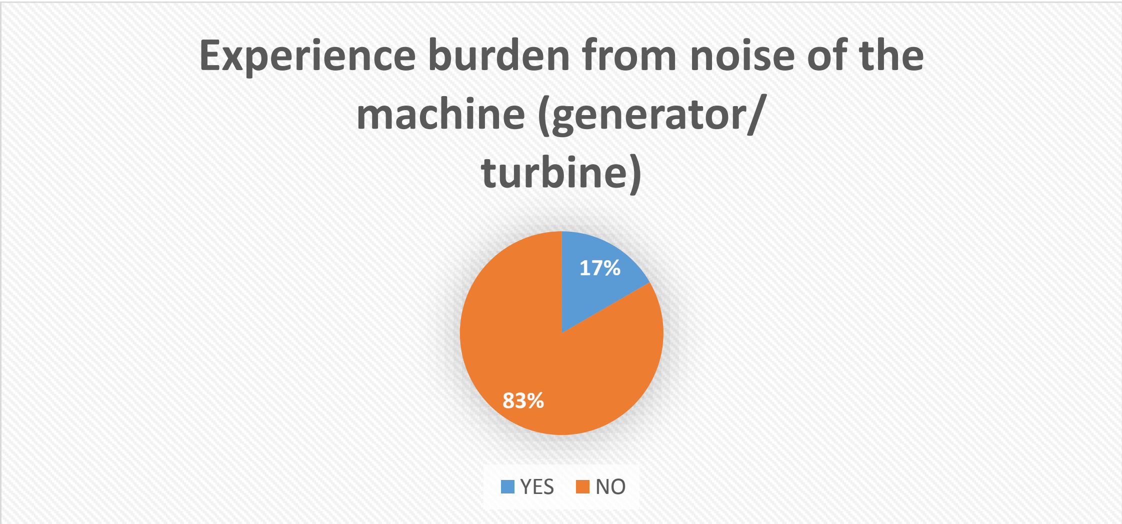

FIGURE 43: Results Survey: Burden from noise of the machine

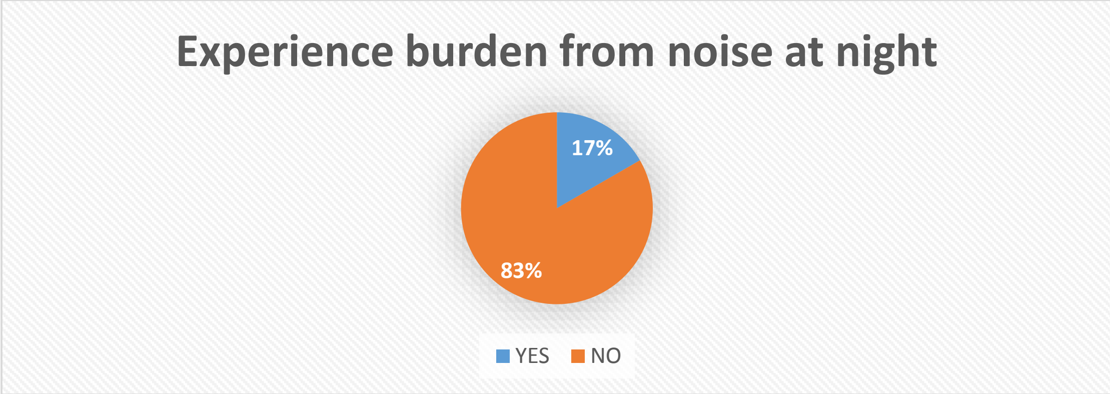

FIGURE 44: Results Survey: Burden from Noise of Water Flow

The results of the nuisance caused by noise of the hydropower plant shows an astonishing result. 90% of the people told that the noise caused by the water flow does not bother them. Approximately the same amounts of people 83% have said that the noise caused by the turbine or generator does not bother them either. As discussed in the results of the interview, designers and builders of hydropower plants endeavour to reduce the noise of the generator and the turbine. Following on the questions about noise, the social acceptance level is polled with results showed in the Figures 45 and 46 below.

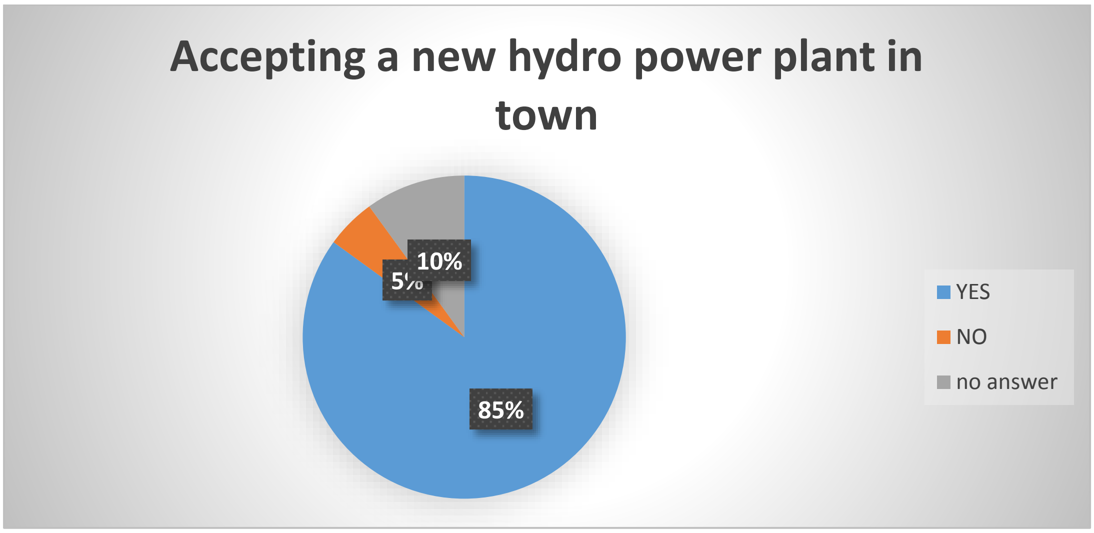

FIGURE 45: Results Survey: Accepting a New Hydropower Plant in Town

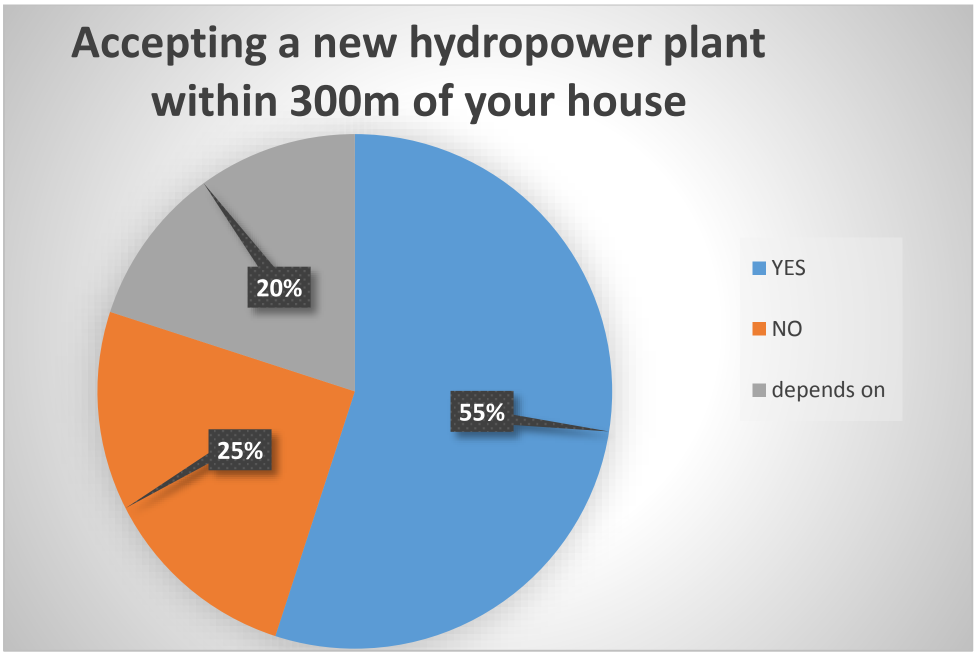

FIGURE 46: Results Survey: Accepting a New Hydropower Plant within 300m of your house

Figure 45 above shows that 84% of the people directly said yes to the question if they could accept a new hydropower plant in the town. The acceptance of hydropower in Tampere is proven by these results. But going deeper into this question will show if the Not in My BackYard theory is applied in Finland.

In Figure 46 we see that suddenly only 55% of the original 85% agree with the hydropower plant close by their house, this responds to 12 people who changed their mind from yes I could accept a hydropower plant in my town, to no I could not accept it if it is within 300m of my house. 25% of the people from original 5% said that it depends on many factors (such as noise, environmental impact, construction, and so on.) As well as the people who have given the answer no, increased from 10% to 20%. This makes us conclude that the Not In My BackYard theory is also used in Finland. However not to forget that still 55% of the people could agree a hydropower plant close by their house. The rest of the people are doubting about it, what means that with more information given, people would answer more easily and clearly. This is a breakthrough in the results of social acceptance. We can conclude that according to the surveys taken in Tampere people would agree a hydropower plant in their backyard, if useful information is given about the project. If the information is not given, the NIMBY theory will be used by the inhabitants.

The fourth part of the survey is about the economical aspect related to the plants. General questions are asked about the willingness to pay more for green power, and the reason why is tried to figure out. Figure 47 and 48 show the results of the asked questions.

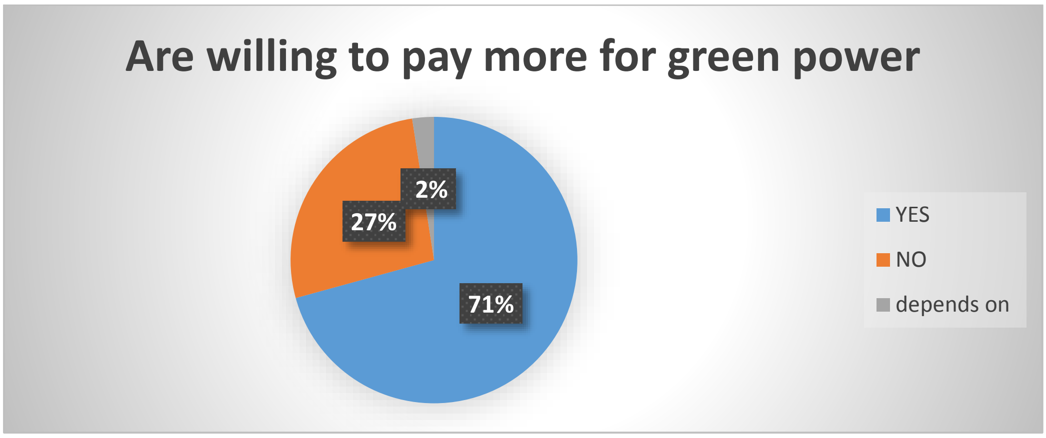

Figure 47: Results Survey: Are you willing to Pay More for Green Power?

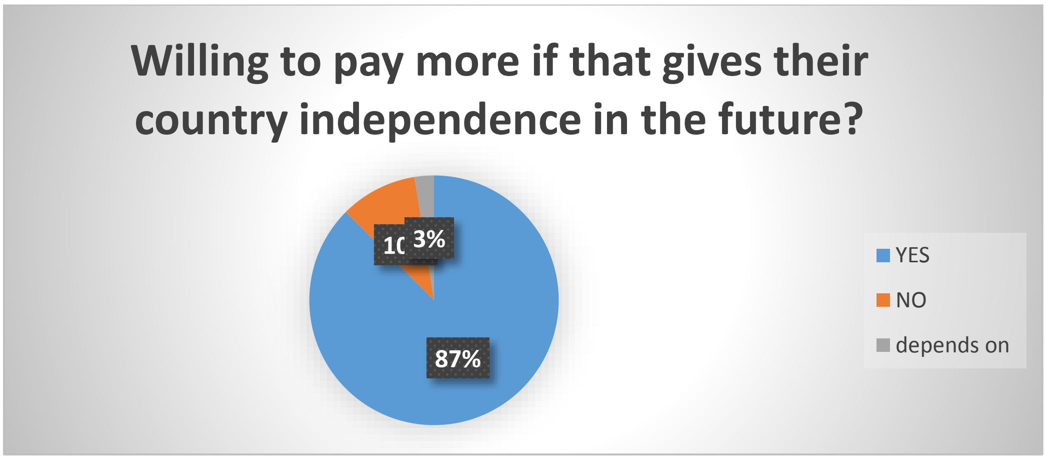

Figure 48: Results Survey: Willing to Pay More for Green Power if that gives Independence in the Future?

Figure 47 above show that 71% of the people directly said yes to the question if they are willing to pay more for green power. Only 27% said no to that question. The second part of the question is made to give the people a reason why they should pay more for green power. The results showed in Figure 48 are astonishing and the original 71% became 87%. This means that the people are willing to pay more for green power, especially if that gives their country independence in the future.

Conclusion Related to the Age

An analyse is made related to the answers and age of the inhabitants in Tampere. Herewith we want to figure out if there is a difference in the mentality between older and younger generation. The categories of ages are divided in parts of 10 years, starting with <21 years old until >60 years old.

In the analyses related to the age, following results are shown up.
A conclusion can be made that almost everybody from all age categories has knowledge of the existence of hydropower plants in Tampere. However nobody from the age less than 30 knows who the owner of the plant is, the people who do know who the owner is, are in the age category of 30 – 40 years, as well as some older people from 40 + and 50+. This makes us conclude that the youth knows that hydropower plants are installed in Tampere, but do not know the owner of the plant.

In the age category of <21 these things stood up: Gas and Hydropower are the preferred energy types. Notable in that age category is that people are prepared to pay more for green power, as well as they could accept a new hydropower plant in their town and within 300m of their house. The NIMBY theory is not used in that age category. The people are not sure if the hydropower plants in Tampere are an added value for the city, but mentioning it in the tourist information should be a good thing.

In the age category of 21 to 30 years, these things stood up: the preferred energy is a mix between nuclear, gas and hydropower. Perhaps a more objective opinion and more knowledge of the needs for different energies is there the cause. Environmental impact however is a sensitive subject, people have more doubts and concerns are about the eco-system in the river. Building a fish way is necessary in order to convince people from that age category. Half of the people think that the government should not invest more in hydropower, and concentrate on other renewable energies. Related to the price of green power, almost everybody is prepared to pay more, however some people are already doubting and saying no, but if it gives the country independence, they are changing their mind. Most people could accept a new hydropower plant in town, but the NIMBY theory is used by some people (30%).

In the age category of 30 to 40 years, these things stood up: Very outstanding is the preference of energy in that category of people. They prefer green power. Hydro, gas, wind, solar. Some of them also nuclear. But every one answered with at least one green energy source. That means that people are aware for the need to new alternatives. The people think that hydropower is good for the environment, as well as it can help to reduce the general CO_2-emissions. Notable is that 30% in the age between 30 and 40 does not want to pay more for green power, however 75% changed their mind if it gives independence in the future. The NIMBY theory is applied by 30% of the surveyed people.

In the age category of 40 to 50 years, these things stood up: the preferred energy is a mix of hydro, gas and nuclear. Most of the surveyed people from that age are not willing to pay more for green power, but some of them change their mind if that gives independence in the future.

In the age category of 50 to 60 years, these things stood up: Energy made by coals is not preferred, Nuclear, Hydro and Gas is accepted. They are not willing to pay more for green power. As well as they are not willing to have a new hydropower plant in town, certainly if that is too close by their homes.

In the age category of > 60 years, these things stood up: very surprisingly to see that also in that age category, people don't want to work with coals, they prefer a mix of hydro, nuclear and gas, as well as green power, and paying more for green power is accepted as well. Related to the noise of the power plant, most of the people have some kind of annoyance by the hydropower plant, but it is rather in small order. They could accept a new hydropower plant in town, also when it is within 300m of their house, so the NIMBY theory is not applied by that age category.

4.2.3 Results Technical Part

According to the technical methods study, the type of installation, turbine and generator depends on the location where the site is situated.

The cross flow turbine is an emerging technology that is used more and more in Finland's hydropower plants. Because of the huge potential of micro scale hydropower with its additional consequences of different water level during the year, a cross flow turbine can be used, and efficiency is at its maximum during the whole year.

The Francis turbine is the most used turbine in Finland for small scale hydropower, because it can work efficiently under a wide range of operation conditions. As well as the Francis turbine can deliver a high efficiency, even if there is a huge variation in these flow parameters. In Finland these parameters do change with the changing of seasons, that makes a Francis turbine the best option for small scale hydropower.

5 DISCUSSION

The question of future development of Finnish energy sector receives a lot of attention and its prognosis is updated every year. The European climate action submits targets that must be achieved by every member of the European Union. The 2020 renewable energy targets contents that Greenhouse gas emissions must be reduced by 2020 with 20% compared to 1990, the share of renewable energy must be 20% of the final energy consumption by 2020 and the energy efficiency must improve to 20% by 2020 to decrease the total energy consumption.

A new framework for climate and energy policies is created by the European climate action and it contains reducing greenhouse gas emissions by at least 40%, increasing the share of renewable energy to at least 27% and increasing energy efficiency by at least 27%.

The obligation by European framework is that increasing renewable energy, and continue investments are required. In case of Finland, renewable energy is rising more and more, and the investments in new technologies are large. Wind power is one of the upcoming technologies and a lot of projects are planned to increase the share of wind power in Finland. However the share of hydropower must be increased as well, and that can be done with small investments, because of its huge potential places. Increasing hydropower in Finland can be done on different ways, by updating existing hydropower plants, by restore old sawmills or by using the potential locations to build new hydropower plants.

All over the country, there are numerous potential locations especially for micro hydropower plants. According to Jaakko Matilla it is not even necessary to build completely new hydropower plants. In the period 1900-1940 more than 1300 hydropower plants were built in Finland with an average capacity of approximately 60kW. 400 of these hydropower plants are in good condition and can work again with a small investment. Together they should have a capacity of 24MW. The other 900 hydropower plants will need more investment and work, but they have a capacity of 54MW together. So all together a capacity of 78MW is available for micro hydropower plants. Assuming that these 1300 micro hydropower plants are brought back in use and work at an efficiency of 70%, which is realistic, approximately 7000 households would be provided with electricity if we assume that the electricity consumption in households (in 2012) was 66.7 MWh.

The social study is made to study if the possible increase in micro hydropower could be socially accepted by the neighbours of the plant. The social study showed that inhabitants of Finland have accepted hydropower in their country. However building new hydropower plants close to their house causes more doubts. The study shows that most people agree with a hydropower plant in town, and close by their house. However, to make sure the Not In My BackYard theory is applied by the neighbours, information about the plant and the working procedures needs to be available. The study also shows that the neighbours are very excited if an old sawmill or old hydropower plant will be restored and the authentic character is retained. The environmental impact however is an important issue for the neighbours, so information about the environmental impact and the used strategies is required to help the social acceptance. Nowadays a fish way is installed in almost every micro scale hydropower plant according to the Finnish water licence of the hydropower plant.

The economical study is made to investigate if micro hydropower is profitable, as well as the willingness of inhabitants of Finland to pay more for green power. The study shows that the investment and the costs for maintaining a hydropower plant is lower than any other energy source, one of the reason is the constant water flow that is always present and free of charge. Micro scale hydropower has an even lower investment cost, and many materials such as; generator and electric equipment are recycled from industrial factories. Despite it produces less electricity and serves more as peak load power plant, the payback time is shorter because of the use of recycled materials.

The studies also show that inhabitants of Finland are willing to pay more for green power, and especially if that gives their country independence in the future. The fact that Finland could be independent in terms of electricity, by paying more for green power, is a very interesting fact. It clarifies that independence in the future could be used for promoting the increase of hydropower in Finland.

5.1 Authors Opinion

According to the read information, -theses and personal contact with owners, designers, builders and neighbours of hydropower plants, next personal conclusion can be made. It is clearly that there are a lot of potential locations for micro hydropower plants. However the potential locations for small scale hydropower plants are rather small. In order to increase the share of hydropower in Finland, small scale hydropower can be updated, or micro scale hydropower plants can be restored.

Hydropower plants in Finland are definitely accepted and increasing hydropower plants on micro scale should be possible. People are willing to accept new hydropower plants if enough information is given. An important issue is the environmental impact, so specific information about that should be provided as well. With experiences learned along the way people are happy to have a restored hydropower plant in their neighbourhood, because it has a value for them.

A general conclusion could be that inhabitants of Finland have the good mentality in order to make an increase in hydropower possible. As well as the willingness to invest in green power and pay for this. So if the hydropower in Finland does not increase, it would not be because the inhabitants of Finland are against it. Perhaps more because of political reasons, or the complicated law about hydropower, which is the case right now.

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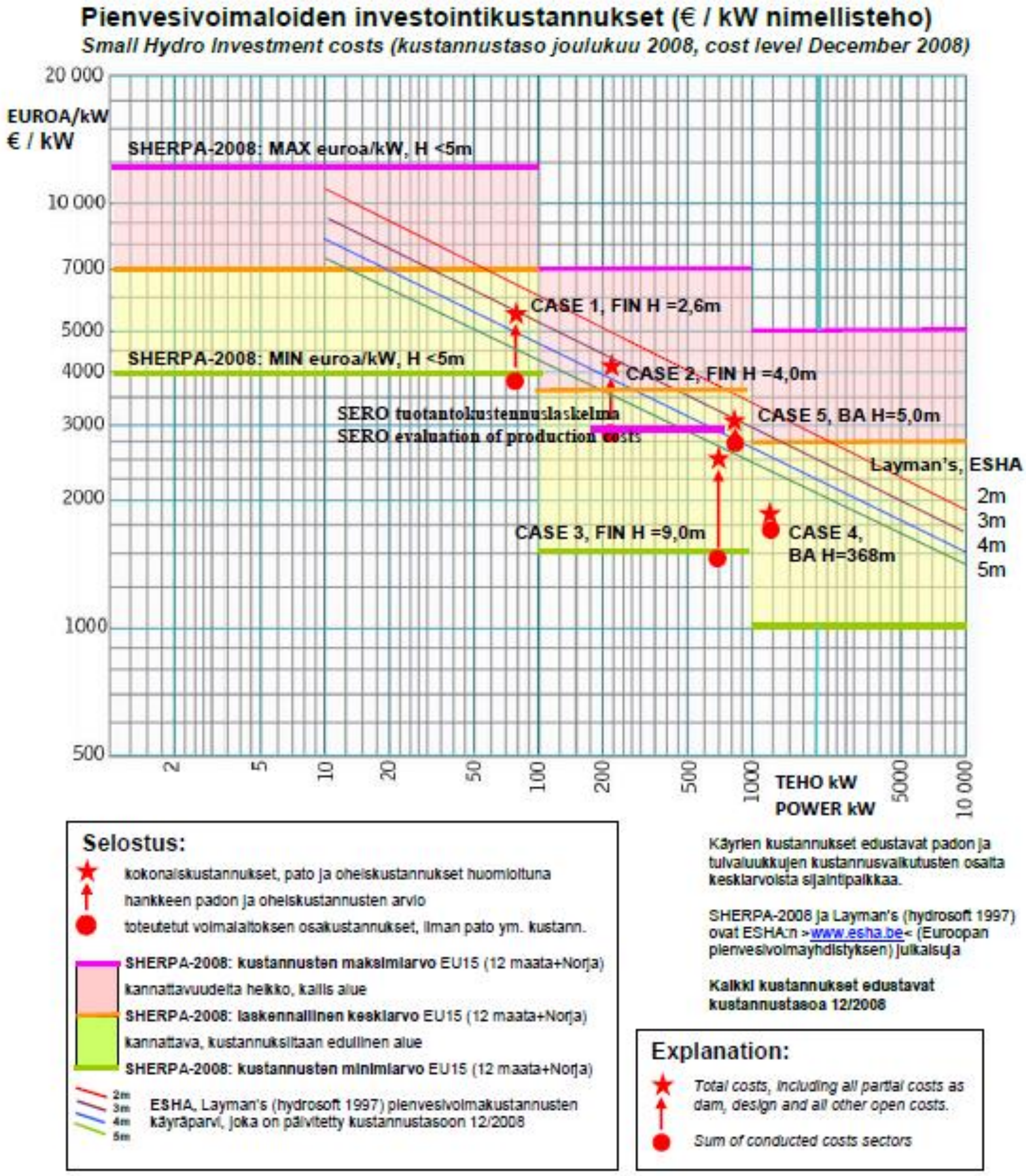
APPENDICES

Appendix 1. Small Hydro Investment Costs (price/installed kW).

Pienvesivoima-alan investointikustannusten selvitys — Raporti 15.8.2009

kustannukset, joita syntyisi, mikäli kysymys olisi kokonaan uusrakentamishankkeesta. Kustannusnomogrammi julkaistaan myös Motivan rahoittamassa pienvesivoimayhdistyksen pienvesivoimalaoppaassa.



Kuva *Figure* 1

Raportissa käsitellään myös kustannusten ositus 10 eri kustannusosaan (6 peruskustannusta ja 4 lisäkustannusta). *10 cost-sectors, 6 basic costs and 4 add on costs are introduced in the report.*

Appendix 2. Survey to neighbours of small and micro scale hydropower plants in Tampere.

1	**Do you live here in Tampere?**	yes	no
2	**Do you work here?**	yes	no
	in case of no : go to 4		
3	**Do you have your own company here?**	yes	no
4	**Do you know we also use water to make electricity here?**	yes	no
	in case of no : go to 5	yes	no
4	**Do you know who owns the plant?**	yes	no
5	**What kind of energy do you prefer? Nuclear energy, hydropower, coals or natural gas?**		
6	**Do you think electricity made by water is good for the environment?**	yes	no
7	**Do you think hydropower plants can help to reduce the general co2 emission in the world?**	yes	no
8	**Do you think the government should invest more in electricity made by water?**	yes	no
9	**Do you think the government should give you more information about the hydropower plants?**	yes	no
10	**Can you give me on a scale from 0 to 5 what irritates you about the hydropower plant? (0 = no irritation, 5 = maximum irritation)**		
	a) The noise of water flow?		
	b) The noise of the machine?		
	c) Noise at night?		
	d) Is there anything else you are not happy with?		
10	**Are you willing to pay more for electricity made by natural sources? (green power) (Why?)**	yes	no
11	**Are you willing to pay more for electricity made by natural sources, if that gives your country independence in the future?**	yes	no
12	**Could you accept a new hydropower plant in your town?**	yes	no
13	**Could you accept a new hydropower plant within 300m from your house?**	yes	no
14	**Do you think the hydropower plant is an added value for the city?**	yes	no
15	**Do you think the city should make the hydropower plant more attractive to visitors or tourist for the city?**	yes	no
16	**Do you think that the city should mention this hydropower plant in the tourist information?**	yes	no
	male / female	M	F
	age		

Appendix 3. Interview to neighbours/designer and owners of small and micro scale hydropower plants in English.

RELATIONSHIP BETWEEN POWER PLANT AND NEIGHBOUR

1	**Are neighbours informed about a new (or renovation) of a hydropower plant close to their house?** If no : go to question 3	Yes

2	**Who informs them about this and how?** Please answer here

4	**Do they have a chance to disagree with this?** If no : go to question 5	Yes

5	**How can they disagree with this?** Please answer here

DESIGN

5	**On which part of the power plant do you concentrate most? Rank from 0 to 5. (0 = least important, 5 = most important)**	
	Noise of the water flow?	2
	Noise of the turbine?	1
	Noise of the generator?	3
	View of the hydropower plant?	0
	Efficiency of the hydropower plant?	5
	Environmental impact of the hydropower plant?	4

6	**How do you try to reduce the noise of the water flow?** Please answer here

7	**How do you try to reduce the noise of the turbine?** Please answer here

8	**How do you try to reduce the noise of the generator?** Please answer here

9	**How do you try to hide the power plant or give it a good look?** Please answer here	

10	**What do you do to reduce the environmental impact?** Please answer here	

ECONOMICAL

11	**Is it more expensive to generate electricity with a hydropower plant, than electricity made by gas, coals, or nuclear power?** If no : go to question 13	Yes

12	**Why is the price higher?** Please answer here	

SOCIAL ACCEPTENCE

13	**Did you receive any kind of complaints (especially from neighbours?) concerning the active hydropower plant?** If no : go to question 15	Yes

14	**What kind of complaints did you receive?** Please answer here	

15	**What kind of efforts/compromises are you doing to ensure the hydropower plant will be socially accepted?** Please answer here	

17	**What is the advantage for the neighbours of a hydropower plant?** Please answer here	

Appendix 4. Interview to neighbours/designer and owners of small and micro scale hydropower plants in Finnish.

VESIVOIMALAN JA LÄHIASUKKAAN VÄLINEN SUHDE

1	**Ilmoitetaanko lähinaapurustolle, kun heidän talon lähelle rakennetaan uusi vesivoimala tai vanhaa kunnostetaan?** Jos ei, siirry kysymykseen 3	Yes

2	**Kuka ilmoittaa tästä heille ja miten?** Vastaa tähän

4	**Onko lähiasukkaalla mahdollisuus vastustaa muutoksia?** Jos ei, siirry kysymykseen 5	Yes

5	**Kuinka he voivat vastustaa muutoksia?** Vastaa tähän

SUUNNITTELU

5	**Mihin seuraavista vesivoimalan ominaisuuksista keskitytte eniten? Arvioi asteikolla 0-5 (0 = vähiten tärkeä, 5 = tärkein)**	
	Veden aiheuttama meteli?	2
	Turbiinin aiheuttama meteli?	1
	Generaattorin aiheuttama meteli?	3
	Vesivoimalan ulkoasu?	0
	Vesivoimalan tehokkuus?	5
	Vesivoimalan vaikutus ympäristöön?	4

6	**Kuinka pyritte vähentämään veden virtauksen aiheuttamaa meteliä?** Vastaa tähän

7	**Kuinka pyritte vähentämään turbiinin aiheuttamaa meteliä?** Vastaa tähän

8	**Kuinka pyritte vähentämään generaattorin aiheuttamaa meteliä?** Vastaa tähän

9	**Kuinka pyritte piillottamaan vesivoimalan tai parantamaan sen ulkoasua?** Vastaa tähän

10	**Millä keinoin vähennätte vesivoimalan aiheuttamia ympäristöhaittoja?** Vastaa tähän

TALOUDELLISUUS

11	**Onko sähkön tuottaminen vesivoimalassa kalliimpaa, kuin kaasu-, hiili- tai ydinvoimalassa?** Jos ei, siirry kysymykseen 13	Yes

12	**Miksi se on kalliimpaa?** Vastaa tähän

SOSIAALINEN HYVÄKSYTTÄVYYS

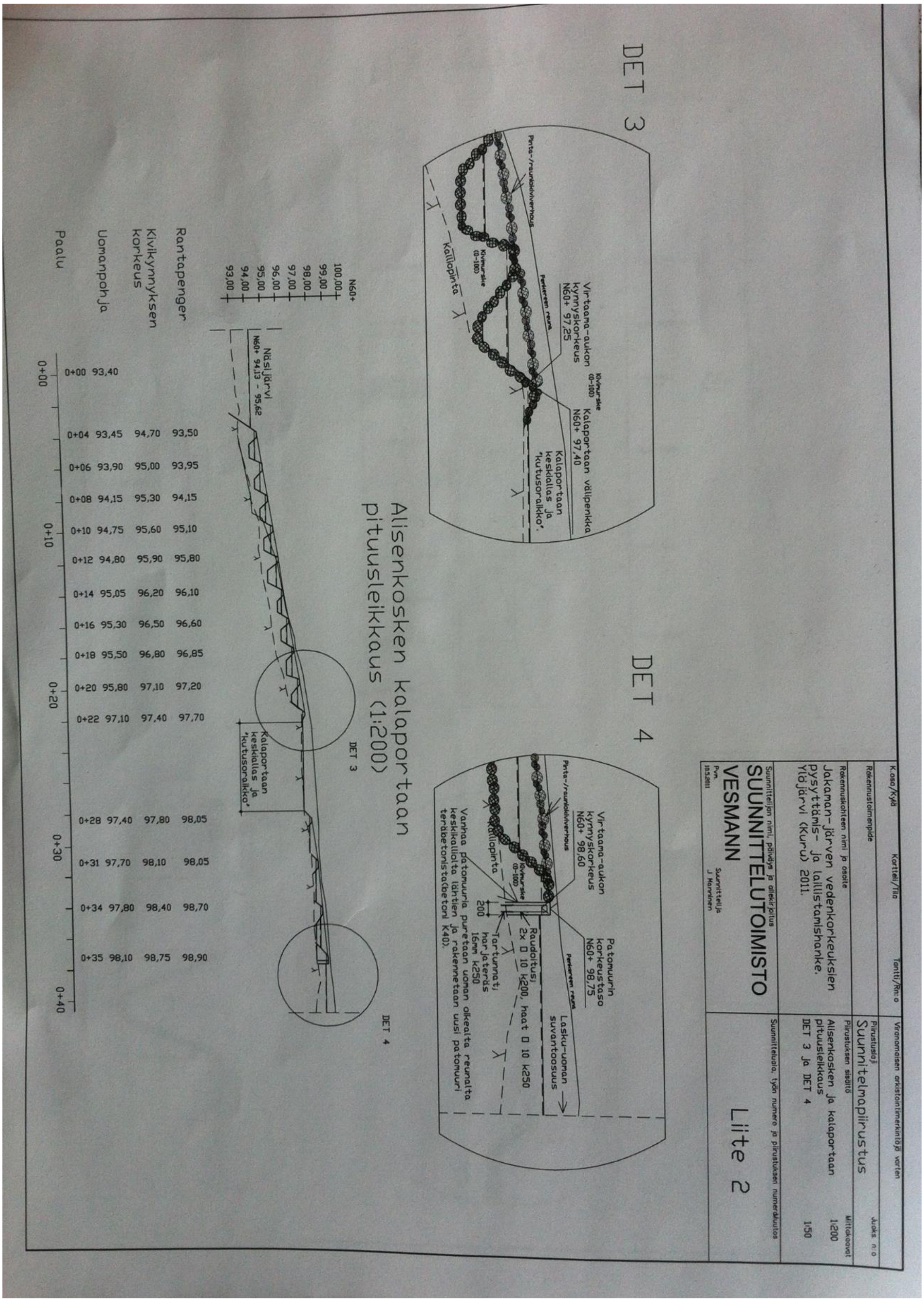
13	**Oletteko saaneet valituksia (etenkin lähiasukkailta) vesivoimalan arkisesta toiminnasta?** Jos ei, siirry kysymykseen 15	Yes

14	**Millaisia valituksia olette saaneet?** Vastaa tähän

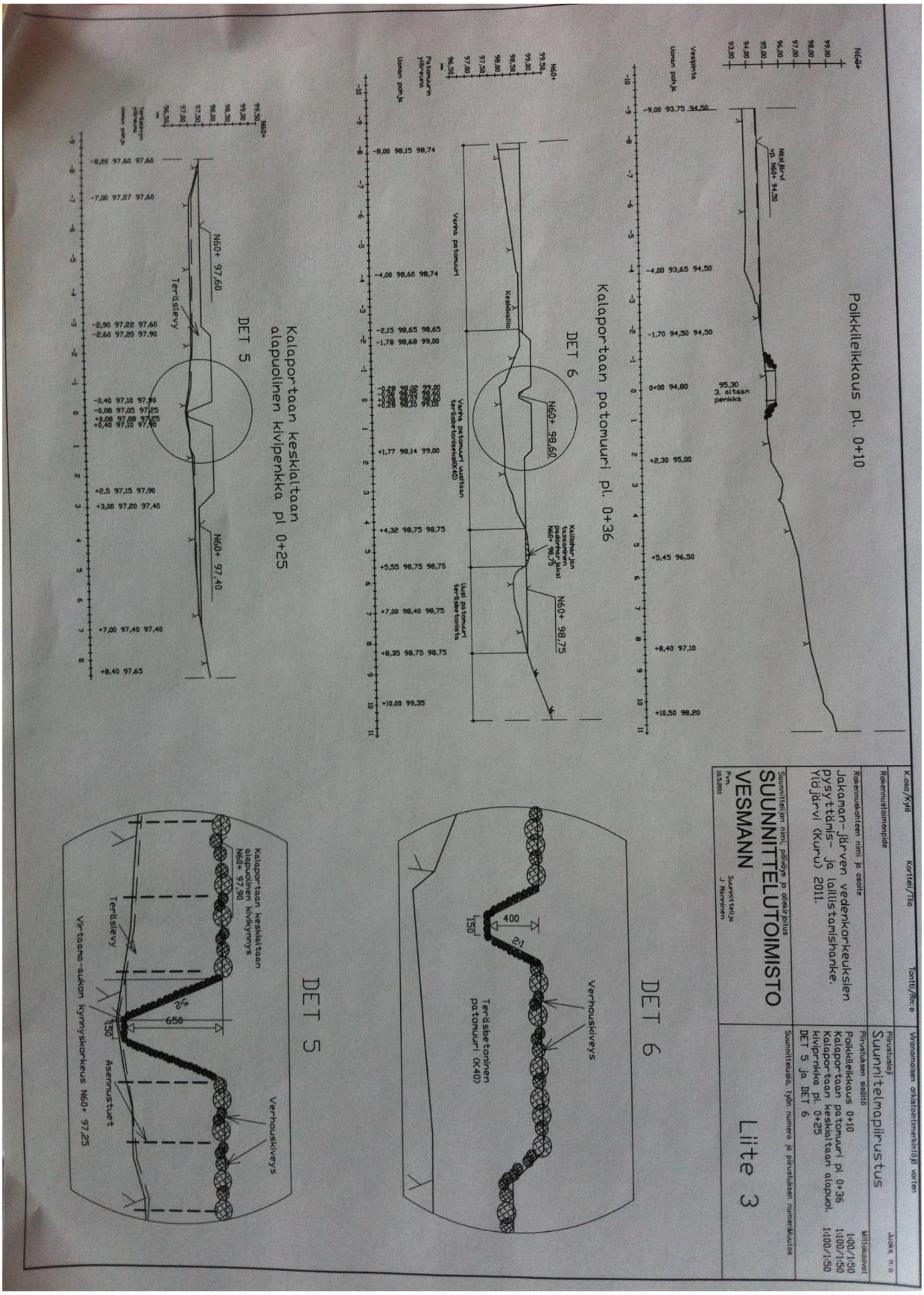
15	**Millaisia asioita ja kompromissejä joudutte tekemään varmistaaksenne vesivoimalan sosiaalisen hyväksyttävyyden?** Vastaa tähän

17	**Mitä hyötyä on asua lähellä vesivoimalaa?** Vastaa tähän

Appendix 5: Fish Way construction plan for the renovation of a micro hydropower plant.



Appendix 6: Fish Way construction plan for the renovation of a micro hydropower plant.



Appendix 7: Overview of the water level, set by the authorities