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UTILIZATION OF RENEWABLE ENERGY IN EUROPE

Bachelor's Thesis

Energy Technology

January 2016

KYAMK
University of Applied Sciences

KYAMK
University of Applied Sciences

Tekijä/Tekijät	**Tutkinto**	**Aika**
Aleksandr Chernykh	Energiatekniikka	Huhtikuu 2016

Opinnäytetyön nimi
Utilization of Renewable Energy in Europe
Uusiutuvan energian hyödyntäminen Euroopassa

50 sivua

Toimeksiantaja
Kyamk automaatiolaboratorio

Ohjaaja
Yliopettaja Merja Mäkelä, Lehtori Tuomo Pimiä

Tiivistelmä

Tässä opinnäytetyössä on tarkoituksena käsitellä uusiutuvan energian käyttöä Euroopassa. Ensiksi opinnäytetyössä käsitellään uusiutuvan energian käyttöä nykyään ja tulevaisuudessa 9 maan (Suomi, Ruotsi, Tanska, Norja, Saksa, Espanja, Italia, Ranska ja Venäjä) osalta. Toisessa osa-alueessa tarkastellaan tuotannon hallintaa uusiutuvien energialähteiden osalta.

Tässä opinnäytetyössä analysoidaan, mallinnetaan ja pohditaan lämmön ja sähkön tuotantoa uusiutuvilla energialähteillä. Kappaleessa kaksi pohditaan tilastoihin perustuen suosituimpia uusiutuvia energialähteitä, niiden energiatuotantoprosessia ja tuotannon hyötysuhteita. Kappaleessa kolme pohditaan tuotannon monimutkaisuutta ja sen hallintaa niin tavallisten kuin monimutkaisten hallintamenetelmien osalta. Pohdintaan on sisällytetty prosessin kannalta tärkeimmät mittaukset sekä säädettävät ja ohjattavat muuttujat.

Opinnäytetyön tuloksena saadaan laaja katsaus sekä vertailu uusiutuvien energiamuotojen käytöstä eri Euroopan maiden välillä. Lisäksi tämä opinnäytetyö antaa tarkempaa tietoa ohjausjärjestelmien vaatimuksista uusiutuvia energialähteitä hyödyntävissä voimalaitoksissa. Opinnäytetyössä esitetään myös tärkeimmät laitteet ja osaprosessit sekä säädettävät ja ohjattavat suureet.

Asiasanat
uusiutuvan, energian, hyödyntäminen

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University of Applied Sciences

Author (authors)	Degree	Time
Aleksandr Chernykh	Energy Technology	April 2016

Thesis Title	
Utilization of Renewable Energy in Europe	50 pages

Commissioned by
Kyamk Automation Laboratory

Supervisor
Merja Mäkelä, Principle Lecturer, Tuomo Pimiä, Senior Lecturer

Abstract

The main focus of this thesis study on the utilization of renewable energy in Europe. Firstly, the general conditions and future trends of 9 European countries (Finland, Sweden, Denmark, Norway, Germany, Spain, Italy, France and Russia) in using renewables are discussed. Secondly, the management of production processes with renewables is studied.

The methods how to produce heat and electricity from renewables are analyzed and reviewed. This thesis includes a consideration of heat and electricity production from renewables. In Chapter 2, based on statistics, the most popular renewable sources, their energy production processes and efficiency are discussed. Furthermore, this thesis study includes in Chapter 3 a study about the complexity and management of the processes which are divided to the conventional and complicated control system processes. The most important measurements, controlled and manipulated variables are presented.

As results of this thesis, an extended review and a current comparison of different countries concerning the utilization of renewable energy in Europe can be presented. In addition, this thesis will help to give some more exact information on control systems in each type of a renewable power plant. The most important machines and sub processes, as well as controlled and manipulated variables are introduced.

Keywords
renewable, utilization, thesis, Europe

CONTENTS

1 INTRODUCTION

Many countries use fossil fuels such as coal, oil or natural gas for producing the desired amount of electricity, but these are non-renewable sources and the amount of them can be ended. Currently, all the world is trying to avoid this problem, or it can become more expensive and in the end, it can run out. At the same time, fossil fuel produces much harmful emissions such as greenhouse gases. In contrast to fossil fuel, renewable resources suggest cleaner alternative. Renewable energy resources produce much less toxic pollutions and greenhouse gases, and as the main point, they will not dwindle. (Top renewable energy sources 2016).

The main goals of this thesis include receipt information about the usage of renewable energy in nine European countries and information about focusing and analyzing control systems which are used for the production of the renewable energy.

2 HEAT AND ELECTRICITY FROM RENEWABLE SOURCES

Renewable energy is the energy which can be produced from natural recovering resources, such as water (Figure 2.1), geothermal heat (Figure 2.2), wind (Figure 2.3), sunlight (Figure 2.4) and biomass source (Figure 2.5). This energy is widely used in certain important areas, such as air and water heating and cooling, producing electricity, transportation and rural energy services.

The percentage of produced electricity in the world from water sources is approximately 16.3%. The rest of all renewable sources together such as wind, geothermal, waste, biomass and solar total 5.4% of the world's generation of electricity. Nuclear sources production is 10.9% of the world's electricity production (Nuclear energy around the world July 2015). There are not too many optimal fields for installing nuclear power plants in the world, so the relation nuclear sources from that 10.9% of the world's electricity production is not so little.

Figure 2.1. Hydropower plant (Hydropower plants 2016).

Figure 2.2. Geothermal power plant (How geothermal energy works 2014).

Heating of water, which is made by sunlight, takes an important part in many countries, for example, solar water heating in Germany has 6.1% share of gross electricity consumption (36.056 GWh/year). The great part of these systems are installed on the roofs of multi-family apartment buildings. Heating which is made by biomass continues to grow as well. For instance, in Sweden, the utilization of biomass energy has exceeded that of oil. Geothermal heating is also growing rapidly. (Renewable energy 2016).

The new addition to heating is from geothermal heat pumps which can produce heating and cooling and also equalize the electric demand curve and thus it can increase national priority. (Solar power in Germany 2014).

Figure 2.3. Wind power plant (Wind power projects 2013).

Figure 2.4. Solar power plant (The beauty of solar power plants 2013).

Figure 2.5. Biomass power plant (Recycled energy development acquires California biomass power plant 2016).

In 2013, the gross electricity generation from renewables increased by 11% compared with 2012 (Figure 2.6). Between 1990 and 2012, the total electricity generation from renewables increased by 177%. In 2013, the renewable electricity generation accounted for 26% of total gross electricity generation. (Renewables – Made in Germany 2014/2015).

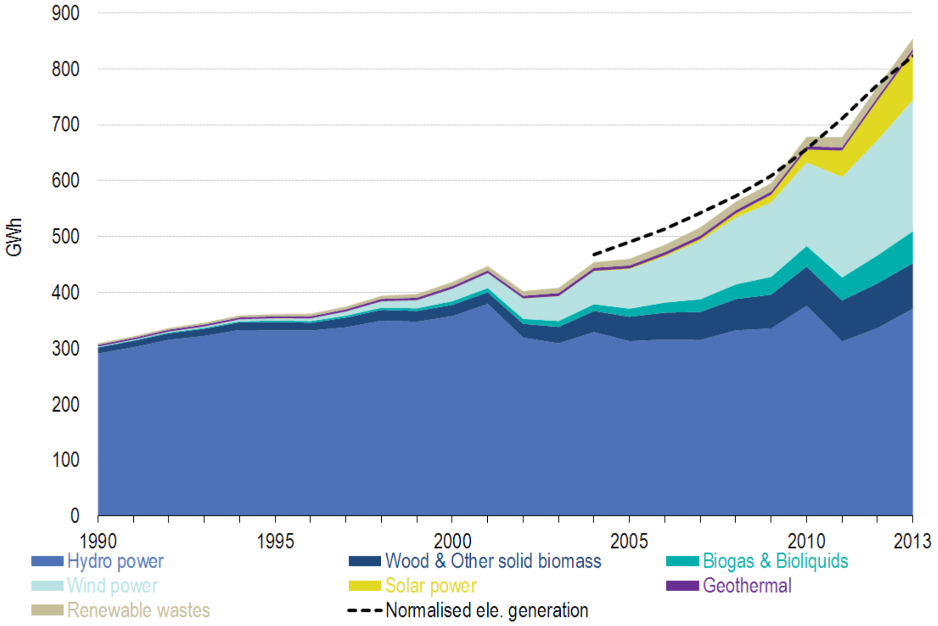

Figure 2.6. Renewables electricity production (Eurostat statistics 10 February 2016).

The heating and cooling take approximately 16.5% of the total energy production in the EU-28 in 2013. It was increased from 9.9% in 2004 to 16.5% in 2013. The share of energy from renewable sources in heating and cooling is presented in Table 2.1.

Table 2.1. The share of energy from renewable sources (Eurostat statistics 10 February 2016)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
EU-28	9.9	10.3	10.9	11.9	12.0	13.7	14.1	15.0	16.1	16.5
Denmark	19.9	22.1	23.0	27.0	28.1	29.5	30.7	32.0	33.5	34.8
Germany	6.3	6.8	6.9	8.3	7.4	9.2	9.7	10.4	10.4	10.6
Spain	9.5	9.4	11.4	11.3	11.7	13.3	12.6	13.6	14.1	14.9
France	12.3	12.4	12.1	12.9	13.4	15.2	16.4	16.3	17.3	18.3
Italy	4.3	4.6	5.8	5.9	6.4	8.7	10.4	12.2	16.9	18.0
Finland	39.5	39.2	41.4	41.6	43.4	43.5	44.4	46.2	48.4	50.9
Sweden	46.6	51.8	56.2	58.6	60.9	63.5	60.9	62.5	65.7	67.2
Norway	25.7	29.0	28.6	29.5	31.1	32.1	32.6	34.2	33.8	31.8

2.1 Sun

Solar energy is the energy which can be produced from the sun. Sunlight can be used also for district heating, photovoltaic systems, solar thermal energy, solar architecture and artificial photosynthesis. Solar panels and solar cells are very important sources of renewable energy (Figure 2.7). Solar power plants are mainly located in the central or the south parts of Europe. The main countries in the European Union which are using solar energy widely are Germany, France, Italy and Spain.

Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the sun, selecting materials with auspicious thermal mass or light dispersing properties, and designing spaces that naturally circulate air. (Solar energy 2016).

Figure 2.7. Solar panels (Solar panel 2016).

Solar energy can make thermal comfort in passive buildings, disinfect and heat water, heat or cool water, heat spaces, give thermal energy for cooking, achieve high temperature for industrial purposes and electrical generation by thermal or photovoltaic means. (Solar energy 2010).

2.1.1 Solar Panels

A solar panel typically consists of connected 6x10 solar cells, and it makes a photovoltaic module (Figure 2.8). Photovoltaic panels generate solar electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions, and it typically ranges 100 - 365 Watts. The efficiency of a photovoltaic module is determined by the area of a module, for example, a 9% efficient 240-Watt module has half of the area of an 18% efficient 240-watt module. One solar module can produce a certain amount of electricity which means that producing more electricity multiple modules should be used. It is very common to use an array of solar modules, a solar inverter, and sometimes a battery or solar tracker and interconnection wiring for a photovoltaic system. Nevertheless, the price of solar power has continued to fall, so that in many countries it is cheaper than fossil fuel electricity from the grid.

The solar panels are made of many separate solar cells. Sunlight from the sun hits the large flat solar panels, the solar panels collect sunlight and convert it to electricity. After producing electricity, electric current goes to a charge controller which divides this current to a battery system or to an inverter.

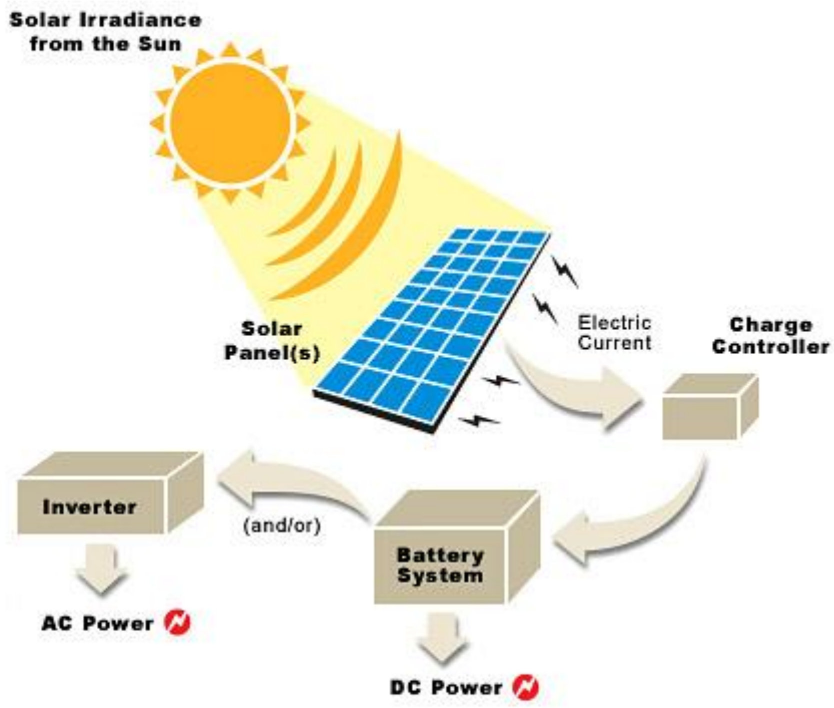

Figure 2.8. Producing of solar electricity (Solar power 2016).

Most modules use wafer-based crystalline silicon cells or thin-film cells based on cadmium telluride or silicon. Usually the cells are protected from mechanical damage and moisture. Most solar modules are rigid, but it is possible to see semi-flexible ones based on thin-film cells. These early solar modules were first used in space in 1958.

2.1.2 Solar collectors

Solar collectors use mirrors to concentrate the energy from the sun to drive traditional steam turbines or engines which produce electricity. The thermal energy which is focused in a solar collector can be stored and used to produce electricity when it is needed, day or night (Figure 2.9).

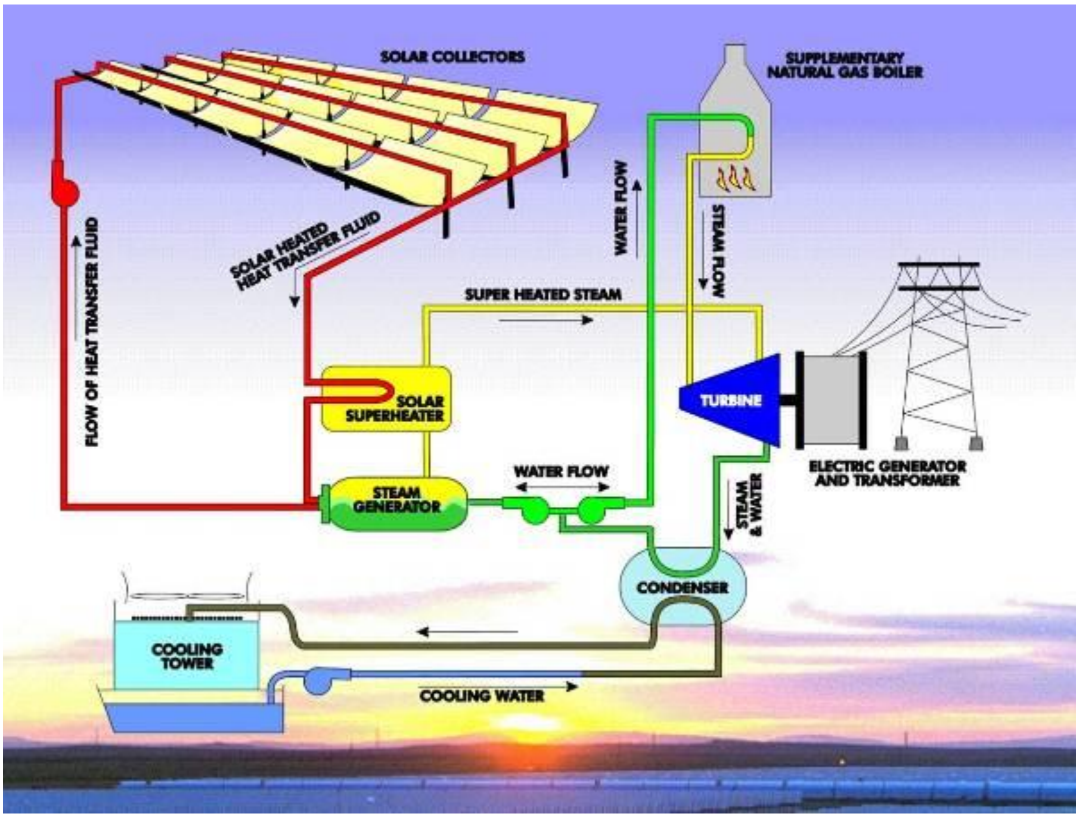

Figure 2.9. Solar collectors for producing electricity (How solar plants work 2016).

Solar collectors concentrate sunlight to the pipe which includes therminol (synthetic oil). The concentrated sunlight on the pipe heats water, which helps to create steam. The steam is transferred to the turbine to create electricity. This electricity is transmitted to power lines. If the weather is cloudy, solar power plant uses a natural gas boiler which heats the water without the sun. (How solar plants work 2016).

Solar collector technology consists of four different technological approaches: trough systems, power tower systems, dish/engine systems and Compact Linear Fresnel Reflectors (CLFR):

- **Parabolic trough systems** use curved mirrors to focus the energy from the sun onto the receiver tube (Figure 2.10). In the receiver tube, a special liquid (for example, synthetic oil) is heated to approximate temperature 400 °C or even higher, and flows through a heat exchanger to heat water and produce steam. The steam comes to the turbine which is connected to the generator. (Concentrating solar power technologies 2015).

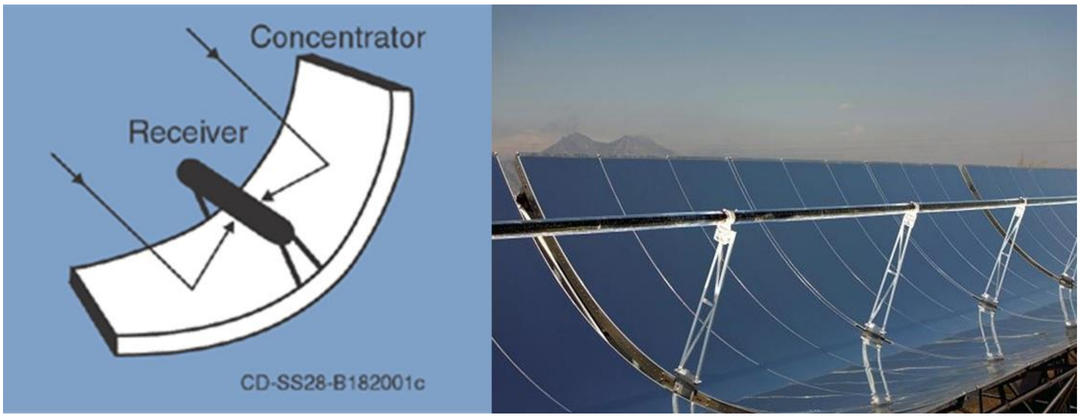

Figure 2.10. Parabolic trough system (Solar technology 2015, Concentrating solar power technologies 2015).

Power Tower Systems use a receiver tower with special liquid which is heated for the process of the energy production (Figure 2.11). Mirrors are controlled by microprocessors, and they concentrate the sunlight on the top of the receiver tower. The overheated liquid inside of that tower is evaporated to the steam (which is circa 540 °C). The steam comes to the turbine which is connected to the generator. (Concentrating solar power technologies 2015).

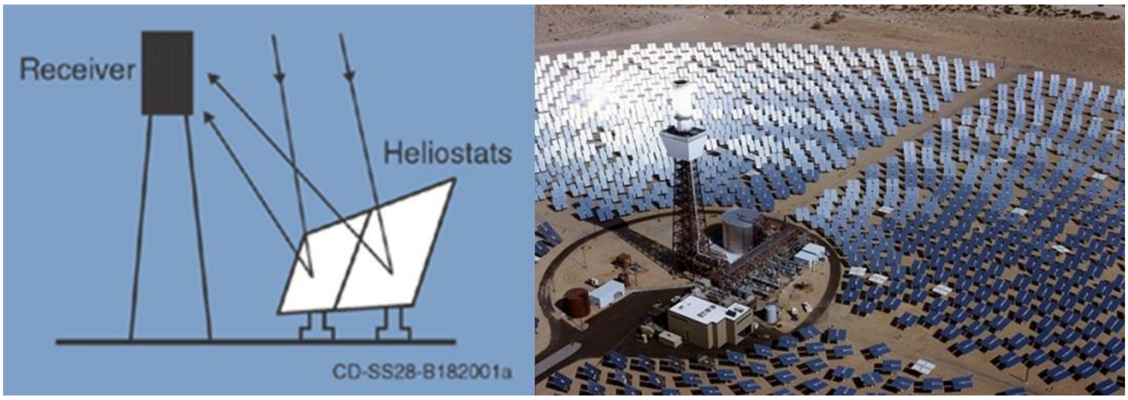

Figure 2.11. Power tower systems (Solar technology 2015, Concentrating solar power technologies 2015).

- **Dish Engine Systems.** Mirrors in this kind of systems have a dish form, and the receiver is located in front of each dish (Figure 2.12). In contrast to other CSP technologies which are using the coming to the turbine overheated steam, a dish-engine system usually uses a such fluid inside the receiver as hydrogen which is heated up to 650 °C. This fluid helps to rotate an engine such as the Sterling motor. Each dish can be rotated along two axes to track the sun. (Concentrating solar power technologies 2015).

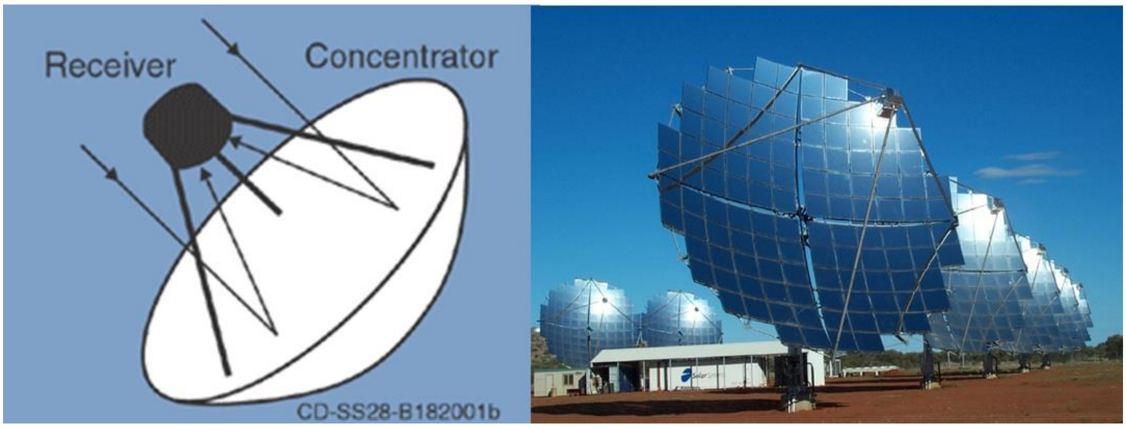

Figure 2.12. Dish engine systems (CSP 2009, Concentrating solar power technologies 2015).

- **Compact Linear Fresnel Reflector.** This kind of solar collectors uses long mirror plates which are parallel to each other (Figure 2.13). The absorber tube is located in front of all mirrors. These mirrors focus the energy from the sun on elevated receivers. Tubes inside of these receivers consist water which flows to further elements in the system. The concentrated sunlight heats the water, makes high-pressure steam which comes further for the energy generation. (Solar technology 2015, Concentrating solar power technologies 2015).

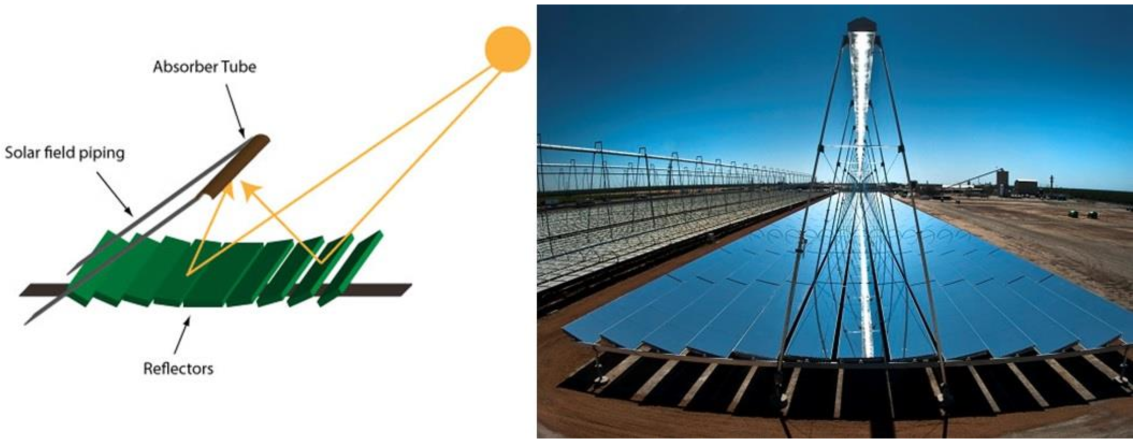

Figure 2.13. Compact Linear Fresnel Reflector (Solar mirror 2012, Concentrating solar power technologies 2015).

Solar collectors with liquid circulation for heating can be divided in two types: a flat-plate collector and an evacuated-tube collector. Flat-plate collectors are the most common for systems which heats water in homes. Evacuated-tube collectors are used more for industrial and commercial buildings.

A normal flat-plate collector consists of iron case with glass shelter and absorber plate whose color is black because black color attracts more heat than other colors (Figure 2.14). The main principle of this type of collector is that sunlight penetrates through the glass cover and heats a liquid inside of the flow tube. For example, it can be imagined as a glasshouse. Liquid flows inside of the flow tube near the absorber plate, and its temperature after heating is about 82 ^{o}C. After that, hot liquid flows to the house district system. (Solar hot water basics 2016).

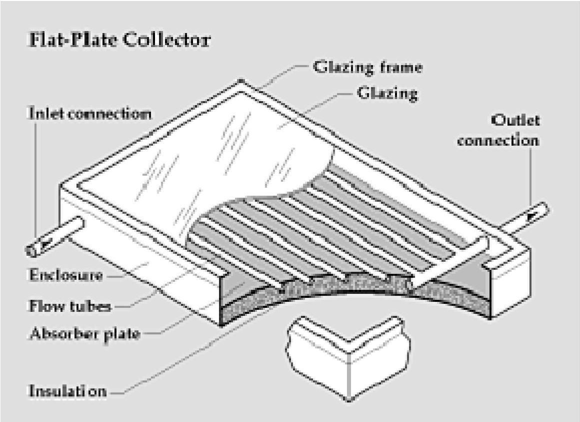

Figure 2.14. Construction of the flat-plate collector (Solar hot water basics 2016).

Evacuated-tube collectors cost twice as much as flat-plate collectors but they can produce approximately a twice higher temperature (77 ^{o}C to 177 ^{o}C). This type of collector normally consists of parallel glass tubes (Figure 2.15). These tubes include an external glass tube and an iron tube which is affixed to a flipper. This flipper is covered with special coating which helps absorb solar energy better but suppresses radiative heat losses. There is no air between tubes which means a vacuum forms inside the collector which removes conductive and convective heat losses. The main operational principle of this type of collector is that sunlight pronounced to the special coating and heats a liquid inside the evacuated tube. (Solar hot water basics 2016).

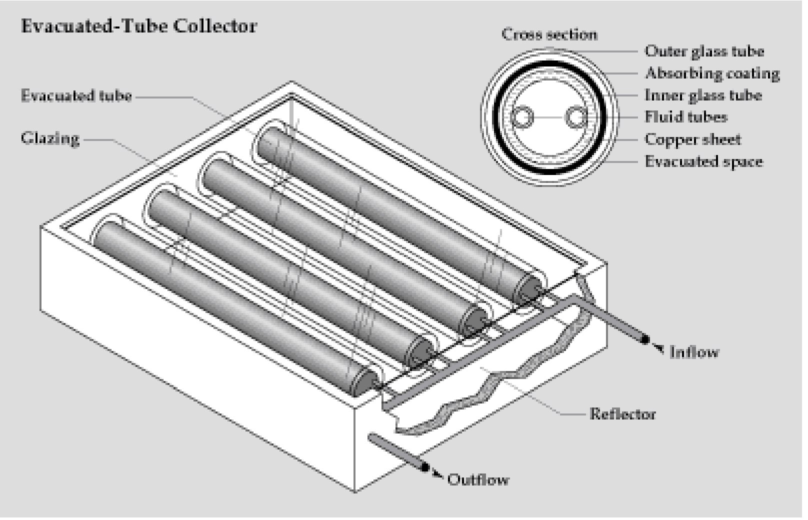

Figure 2.15. Construction of the evacuated-tube collector (Solar hot water basics 2016).

2.2 Wind

The wind power plant is a renewable source of energy which converses the energy of wind to electricity. Generally, a wind turbine includes elements for converting mechanical energy to electricity and control units for safety and for producing the needed amount of energy (Figure 2.16).

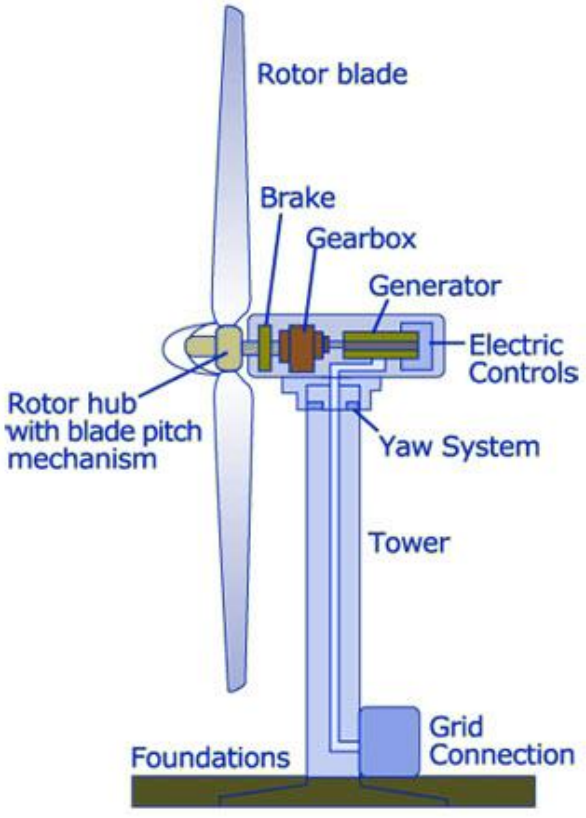

Figure 2.16. Elements inside of wind turbine (Working of solar wind hybrid system 2015).

When wind is strong, blades are moving quickly. The rotation of the blades makes kinetic energy from the wind. Kinetic energy from the rotating blades makes the rotor rotate (Figure 2.17). The rotor is connected with a generator, and the generator converts rotation energy from the rotor into electricity. After that, a generator current flows to the inverter or to the batteries for accumulation. (How wind power works 2016).

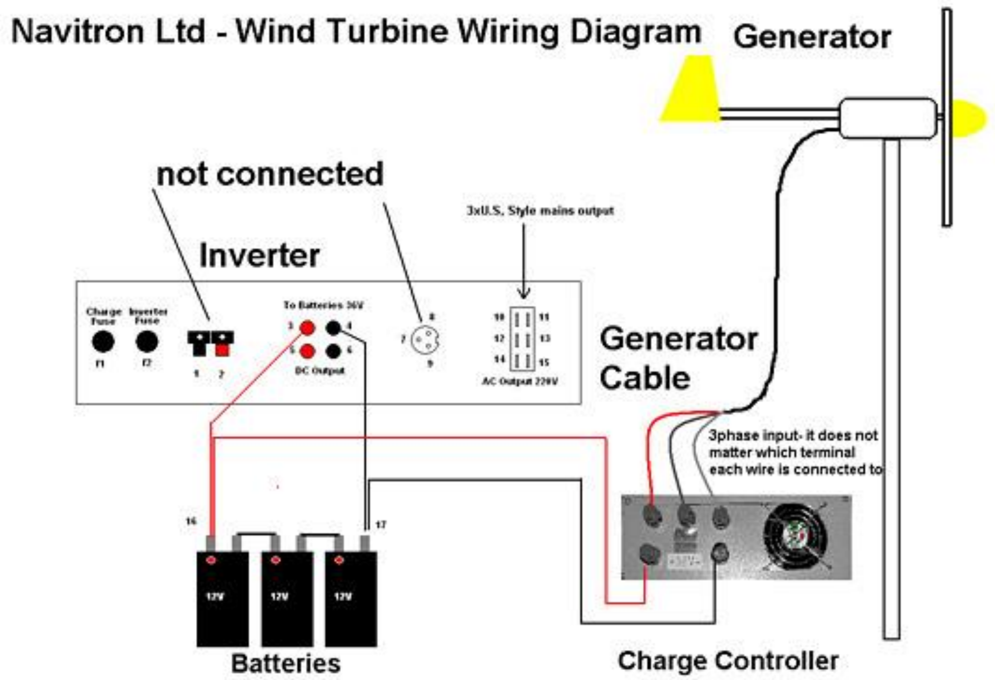

Figure 2.17. Wind Turbine Wiring Diagram (Wind power 2016).

The wind power plants are mainly installed in coastal countries. The main countries in the European Union which are producing the great amount of energy from wind power plants, are Germany, Spain, France and Italy. The wind power capacity in the world grew rapidly to 336 GW in June 2014, and the wind energy production was circa 4% of the world’s electricity usage. Wind power is widely used in European countries, and more recently in the United States and Asia. In 2012, the wind power accounted for approximately 30% of electricity generation in Denmark and 18% in Spain. (Wind power 2016).

2.3 Water

Hydroelectricity is the electricity which is created by hydropower. Falling or flowing water produces electrical power by going through the gravitational force (Figure 2.18). Hydroelectricity is the most widely used renewable energy (approximately 16% of the world's electricity generation) – 3,427 TWh in 2010, and it is expected to grow for approximately 3.1% each year for the next 25 years. Hydroelectricity is used in many countries, for example, the Asia-Pacific region generating 32% of the world's hydropower in 2010. Hydropower is mainly used in countries where are many large rivers. The main country in the European Union which is producing the great amount of energy from hydro power plants, is Norway. Russia also produces the large amount of electricity from hydropower.

The price for hydroelectricity is comparatively low. For example, the cost of hydroelectricity from a hydro power plant larger than 10 MW is 3 - 5 U.S. cents/kWh. In addition, it is a flexible renewable source of electricity because the hydropower can be increased or decreased very rapidly to adapt to changing energy demands. Nevertheless, damming interrupts the flow of water and can harm local ecosystems, and also the building large dams and reservoirs often deprives people's life. The harmful emissions from hydroelectric complexes are very low. There are no direct waste, and also greenhouse gases such as carbon dioxide emissions are lower than in fossil fuel powered energy plants. (Hydroelectricity 2016).

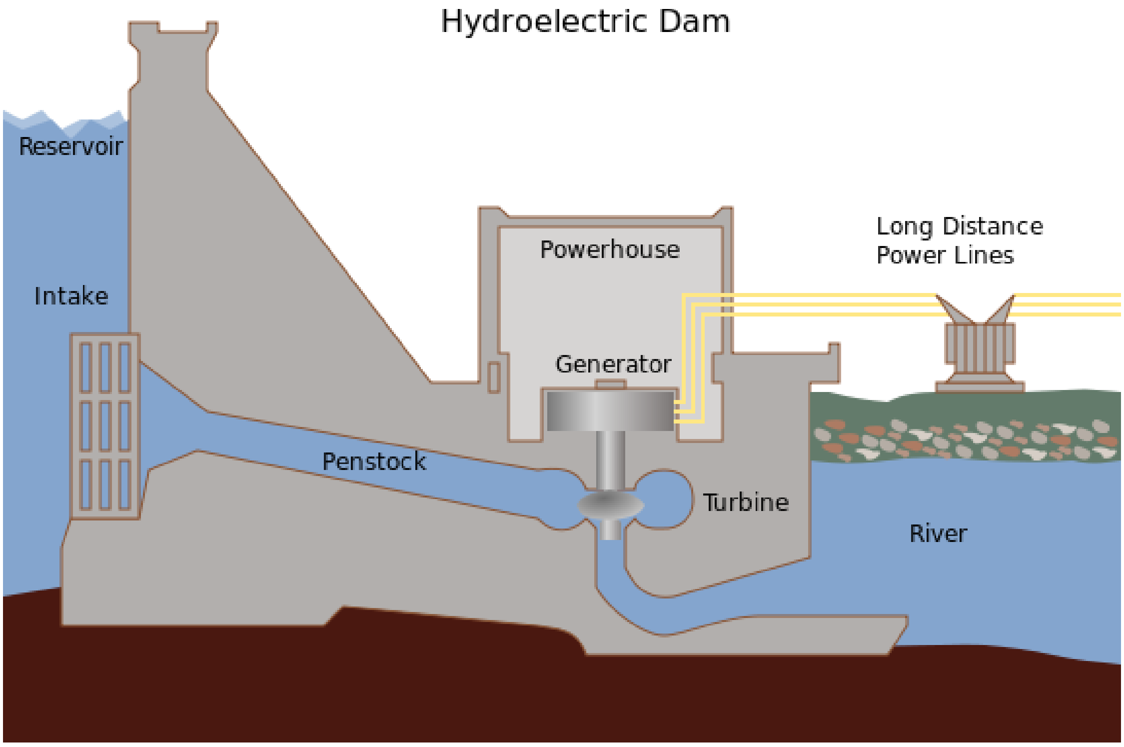

Figure 2.18. Scheme of hydroelectric dam (Hydroelectricity entry 2014).

The electricity of hydro power plants is produced by the potential energy of dammed water. There is a penstock which is a large channel for flowing water from the head. The falling water flows through the penstock and makes kinetic energy. After that, the water with kinetic energy rotates a turbine which is connected to a generator. Because of the rotating turbine, the generator produce electricity. The amount of energy extracted from the water depends on the volume and on the difference in height between the source and the water's outflow. The height difference is called the head. The amount of potential energy in water depends on the head.

At the time of a high-peak demand for electricity, a pumped storage creates electricity by flowing water between reservoirs at different elevations. At the time of a low electrical demand, the excess generation capacity is used for pumping water to the top reservoir. When it is time of higher demand, water is released back to the lower reservoir by flowing it through a turbine. Thereby, pumped storage schemes currently provide the only commercially important means of grid energy storage and improve the daily load factor of the generation system. (Hydroelectricity entry 2014).

2.4 Biomass

Biomass power plants create electricity and heat by burning biomass in a boiler. These plants use peak, wood chips and other types of biomass in the same way as coal or natural gas. The greatest biomass-based power plants in Europe are Finland and Sweden, because Scandinavian countries have the largest fields of forest.

For electricity production biomass power plants use (Figure 2.19):

- **Forest products** such as woody biomass from different kind of forests are used. They can be briquettes, pellets which are compressed from bark, sawdust or small diameter ground wood, because it is easier to transport.
- **Waste** such as residues which include manure, sewage, sludge and other degradable waste, can be utilized.
- **Energy crops** are not used widely in our days for a large production of electricity and heat. This kind of biomass can be represented as woody short rotation crops such as poplar, willow or eucalyptus.

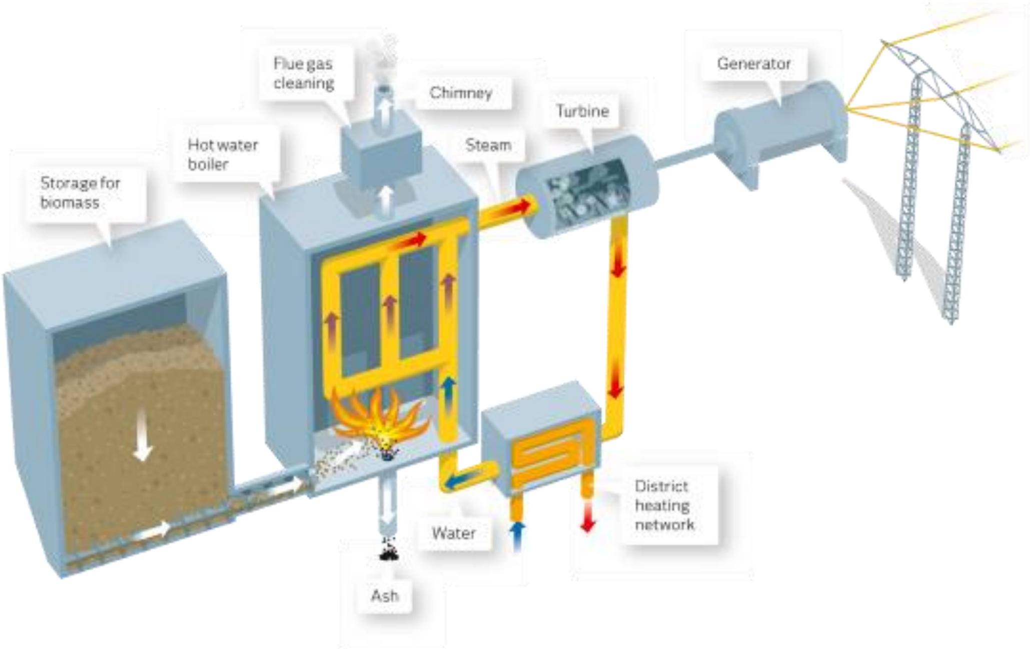

Figure 2.19. Working principle of biomass power plant (Biomass. How it works 2014).

Biomass is stored in a special bunker for a further delivery to the boiler. Inside the boiler, water is heated to a high temperature under high pressure. This superheated steam from heated water is taken to a steam turbine which is connected to a generator. The passed steam from the turbine comes to a heat exchanger of district heating and it heats the circulating water. (Biomass. How it works 2014).

A gasification process changes biomass into electrical energy and products such as ethanol, methanol and others (Figure 2.20).

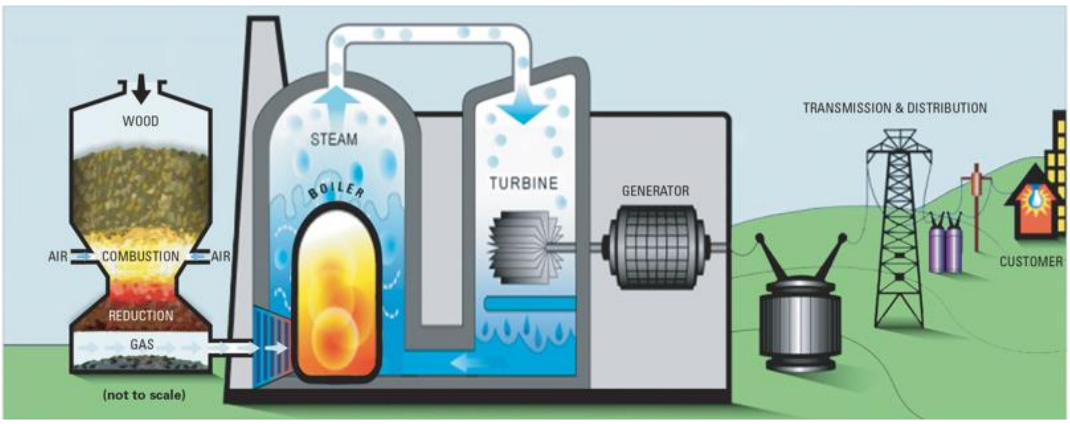

Figure 2.20. Gasification process on the biomass power plant (Biomass gasification 2012).

The gasification process includes a feed handling process where wood or some other feed materials are taken from storage, and then they are combusted. Hot flue gases from this combustion process come into the boiler furnace, and water boils. After that, the hot steam is cooled down. The next process feeds the cooled steam by a turbine which is connected to a generator. After that, products are needed such as steam, power and chemical products.

2.5 Geothermal source

Geothermal power plants work with a principle of converting heat from the earth to energy. These kinds of power plants are used in 24 countries in the world for producing electricity. Geothermal power is considered as a renewable source of energy because the utilization of the heat from the earth is very small compared with the earth's heat content. (Geothermal electricity 2016). Geothermal energy are mainly used for district heating in France. Geothermal power plants such as an electricity source is used in Italy, Germany and Sweden.

The natural heat from the earth creates geothermal resources which come from molten rock or magma, located very deep in the earth below the geothermal resource (Figure 2.21). In many years, rain water has collected in the earth's underground reservoirs. The magma makes the water hotter until it becomes a superheated fluid. Production wells are drilled 1500 to 3000 meters below the surface of the earth. These wells bring the superheated fluid to the earth's surface where it can be used for generating electricity by a turbine and generator. The condensed steam from turbine comes back to the earth's geothermal reservoir by an injection well. (How a geothermal plant work 2007).

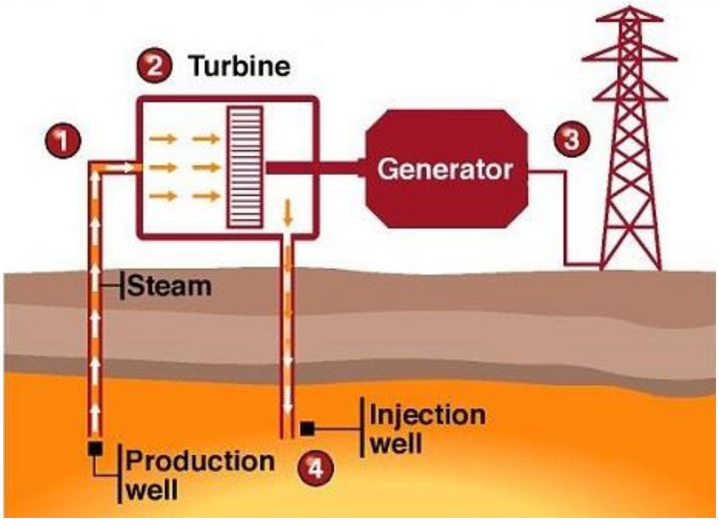

Figure 2.21. Geothermal power plant principle scheme (Geothermal power plant 2009).

2.6 Hydrogen and fuel cells

The fuel cell technology converts the chemical energy from a fuel such as hydrogen, gasoline or other into electricity. This happens in a chemical reaction when positively charged hydrogen ions react with an oxidizing agent which can be, for example, oxygen (Fuel cell 2016). Fuel cells can produce electricity as long as reagents inside of this fuel cell are available. This kind of a renewable source generates electricity quietly and efficiently, without harmful emissions. The fuel cells can power anything from small chips to power plants. Hydrogen and fuel cells are more used for commercial proposes nowadays. These technologies are widespread in Germany. The hydrogen and fuel cells usage is increasing every year.

As shown in Figure 2.22, hydrogen from the tank comes to the proton exchange membrane through an anode. This membrane separates the hydrogen's negatively charged electrons from positively charged ions (protons). The protons can move through that membrane to the cathode, but negatively charged electrons cannot. Those negatively charged electrons are forced around the membrane through an external electrical load before coming to the cathode side. As a result of that, the resultant flow of electrons is an electrical current. On the cathode side, negatively charged electrons and positively charged ions emerge with oxygen from air and produce water and heat. (PEM Fuel cell technology 2016).

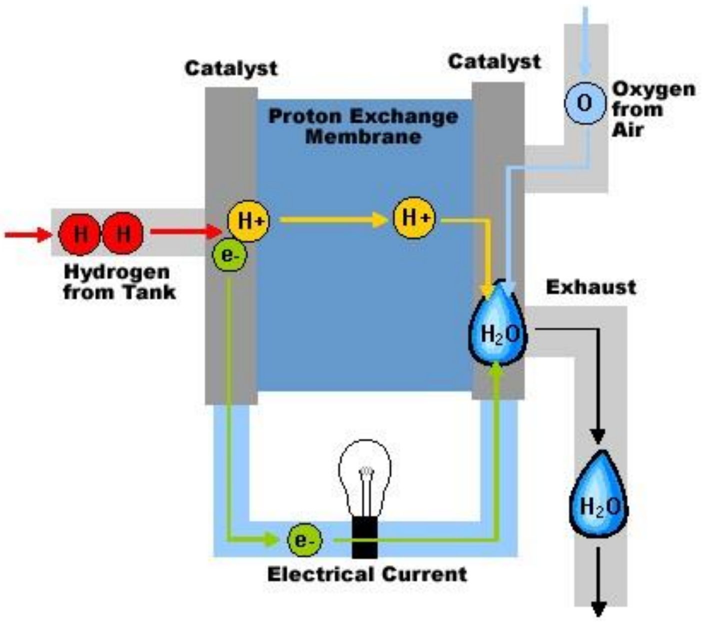

Figure 2.22. Fuel cell working principle (PEM Fuel cell technology 2016).

3 MANAGEMENT OF PROCESSES

All power plants have to be provided with control systems, otherwise it can be difficult, or even impossible to control every part of the power plant. For example, small biomass power plants have many locations, where pressure has to be measured and controlled. If the owners had engineers for each location, this power plant would have losses because of high payments. If there is a control system, the most important variables will be controlled automatically. The analyzing and optimizing work is managed by few operators.

3.1 Control systems in distributed small scale power production

Solar panels and solar collectors in homes or independent wind turbines on farms can be called small scale power plants. The distributed small scale power plants do not use large control systems. Often, all small scale power plants use analogue relay technology or small programmable logic controllers (PLC) which are digital computers for the automatization of all measurements and controls loops.

3.1.1 Solar panels and collectors in homes

Solar energy is a very powerful renewable source. Sunlight is a “free” source, but the preparing for the producing energy from the sun has to be very careful. Solar energy as a source of power is widely known in three categories:

- DC output with low-voltage and energy collecting for data log and Internet of Things (the network of physical subjects which is used for backup or reserve power)
- AC output with line-voltage and as a main, backup or additional source
- AC output with thousands volts and as a fragment of grid for power-generation structures.

This solar source has some sub-functions which are responsible for many functions of the solar panels. From one side all solar systems look very simple, but from another side this structure includes many fragments which control each part of the full solar system. For example, all power measurements have to be recorded for further analyze.

All energy from the sun is collected and put into the energy storage. The power being extracted from the storage is controlled by a microprocessor (Figure 3.1). Measured values come to the microprocessor for monitoring. Values are taken from the sensors go through the A/D converter first and after that they come to the microprocessor. The microprocessor processes all information and sends it to the communication link.

Not all sunlight energy reaches solar collectors because of the atmospheric absorption. This means that the efficiency of solar collectors is approximately 15 - 20 % and the possible energy from the cell presents approximately 10 mW/cm^2. All these factors mean that the efficiency of solar power of taking solar power directly from the solar cell is very low.

In order to taking energy from sunlight as much as possible, all these problems have to be solved by optimizing the solar system. This optimization aims to decrease power losses in the system and increase output energy. (Management for efficient solar energy capture 2016).

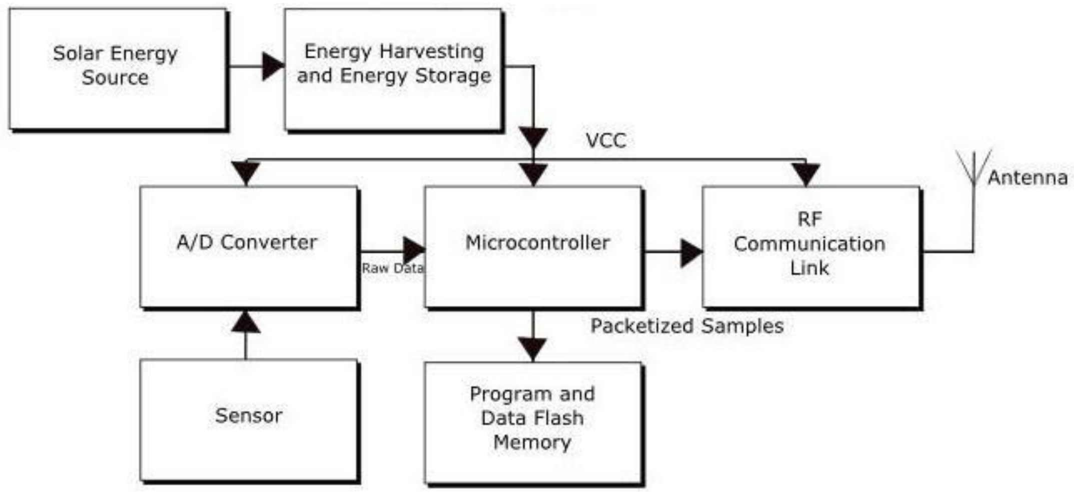

Figure 3.1. A home solar power system in the case of Internet of Things (Management for efficient solar energy capture 2016).

3.1.2 Small wind turbines

Small wind turbines have less environmental impacts than large wind turbines. In addition, small wind turbines have lower prices, higher reliability, lower levels of noise and high efficiencies of producing energy.

A wind turbine control system ties all subsystems for processes together. For example, a control system can control blade speed, define any problems with devices, rotate pitch and can close connection of wind turbine with the grid at the right moment. That is why wind turbines have to have control system for safe and efficient the producing energy. (Manwell, Mcgowan & Rogers 2009, 359).

Single wind turbines feature computer-based controllers (PLC) which controls the all processes of the turbine (Figure 3.2). The PLC starts or stops the turbine if there are any problems or errors which can be harmful for the turbine. All measurements such as the speed of blades, generator voltages, and other data from the wind turbine system come to the PLC, so it can be controlled using one computer. ISU (internal supply unit) can take power from the grid or directly from the wind, and it is used for giving the starting power to the auxiliaries of the wind turbine. The chopper is used to disperse excess energy from the RU (remote unit) for safety reasons. The LCU (local control unit) is a component for measuring and controlling variables which flows through the unit. (Working types and history of wind turbine 2016).

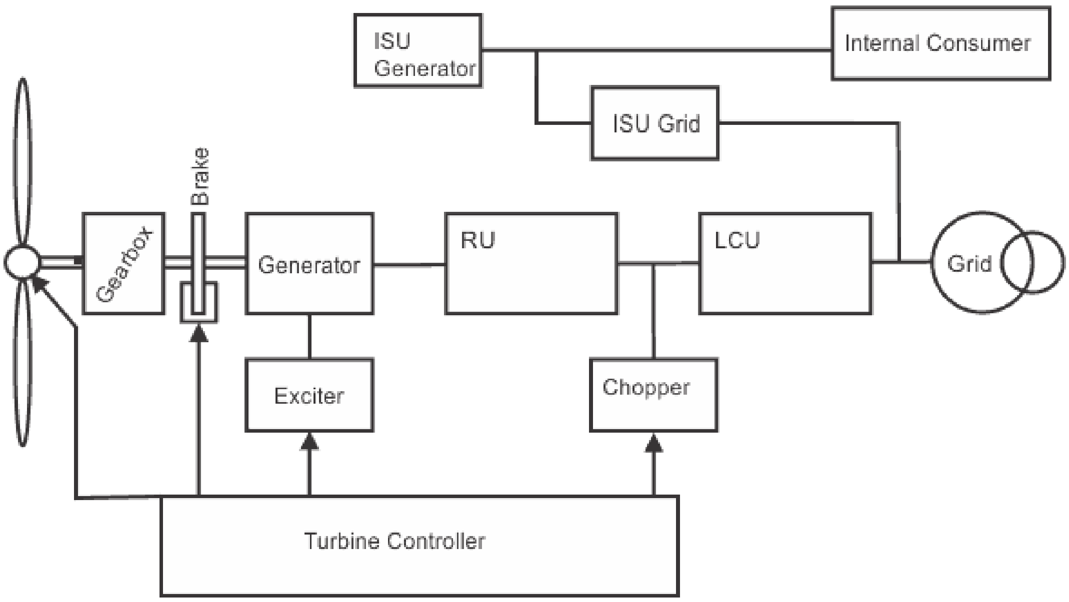

Figure 3.2. Working of the wind turbine (Working types and history of wind turbine 2016).

3.1.3 Geothermal heat

The management of geothermal heat should include a measurement and control system of temperatures, flows and heat. All sensors which measure temperatures send information to data loggers (Figure 3.3). The main data logger processes all measured values and sends information to the main block in the control system which can be monitored by engineers. One temperature sensor measures the temperature of the well pump, and the second one measures the temperature of the discharge. The difference between those temperatures must not be more than 10 ^{0}C. Water has to enter into the open-loop system with the temperature of approximately 10 ^{0}C. After that it uses all heat and it should flow to the exit with the temperature of about 4.5 ^{0}C. Likewise, the data logger takes information on the temperature from the outside and inside building temperature sensors.

Sensors measure the water flow and temperatures in British Thermal Units (BTUs) connected to the well pump and are used for identifying the level of the entered water to the system. The second sensor is installed in the heat circulation to check how much liquid there is inside these pipes.

In order to determine the kWh consumption into this system, sensors are installed in the heat pump, well pump and flow pumps (one of them helps to circulate water through the floor and the other one helps to move water from the heat pump to the hot water tank).

All these sensors help to determine the electricity cost of the system and control the efficiency of the production from this kind of renewable source. (Monitoring geothermal heat pumps 2010).

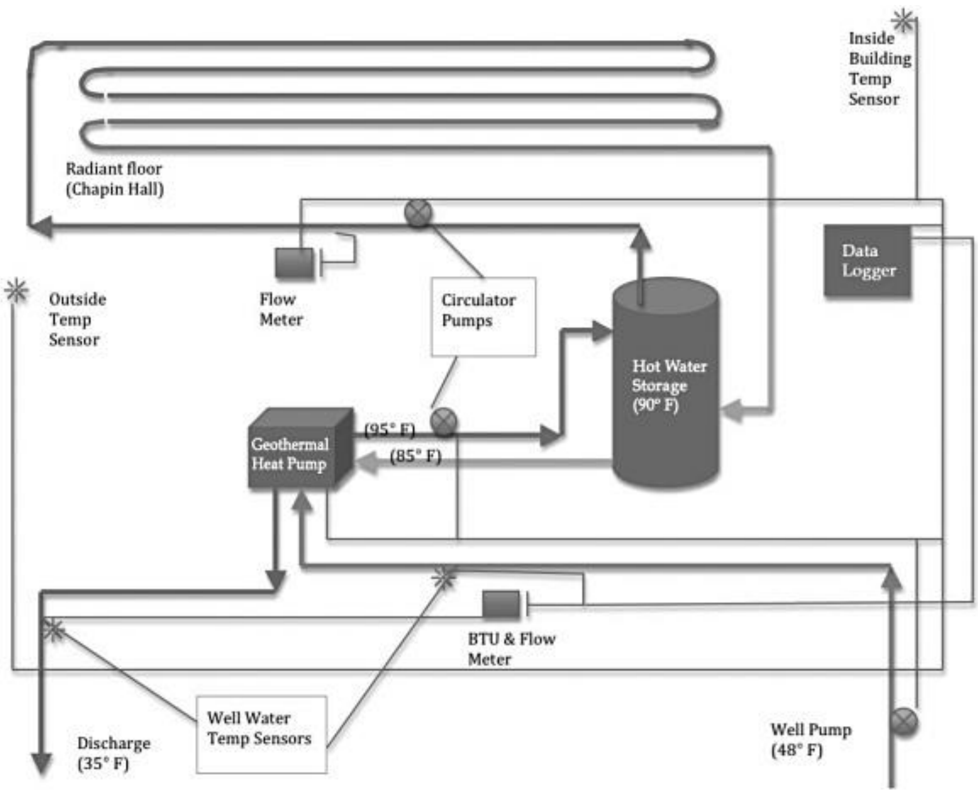

Figure 3.3. Monitoring of the geothermal heat plant (Monitoring geothermal heat pumps 2010).

3.2 Control systems in extensive production processes

Complicated production processes need a large control system because each sub-process in a great power plant has a controller of its own, and all these small controllers are connected to the same main control system network.

3.2.1 Powerful wind turbines and wind farms

Powerful wind turbines have two or three giant blades which are connected to a rotor, affecting it to rotate and to turn a shaft attached to a generator. This generator produces electricity which is transferred to a transformer and after that to the power substation.

The size of wind turbine depends on amount of produced energy. For example, in the model which can produce 1.5 MW of energy consists of approximately 35 meters blades and 65 meters tower. The total height of wind turbine these sizes is approximately 100 meters. The generated voltage of a wind turbine is typically 690 V. Then wind turbines are connected to a 20 kV wind farm network and finally to 110 kV national grid power lines. The typical frequency level is 50 Hz in Europe.

The control system of powerful wind turbine has to control all large and small parts of wind turbine. Wind turbines have many modules which have to be controlled and monitored, for example, blades have to have a definite direction which depends on an airflow direction for the better efficiency. Otherwise, wind turbine owner will not take enough electricity, and the wind turbine will have not enough efficiency. (Siegfried 2006, 297).

The wind rotates the blades of a wind turbine where aerodynamic power extraction control is installed (Figure 3.4). This control is used for limiting the aerodynamic power extraction to keep the rate speed of rotating blades in values which are still safe during high wind speed conditions. A permanent magnet synchronous generator (PMSG) which produces generator power from the wind controls the rotary of the generator within an optimum range.

After that, the produced current flows through an AC/DC converter, and the DC comes to the braking chopper which controls the DC bus voltage in unstable operations of the wind turbine. This means that if there is much more energy power from the PMSG than transferred into the grid, the additional power can be dissipated through a dummy resistor, and this helps to keep a constant voltage in the DC bus.

The DC/AC converter helps to produce the specified grid power and it also maintains a constant DC from the braking chopper and keeps the required reactive power. (Control systems small wind turbines 2010).

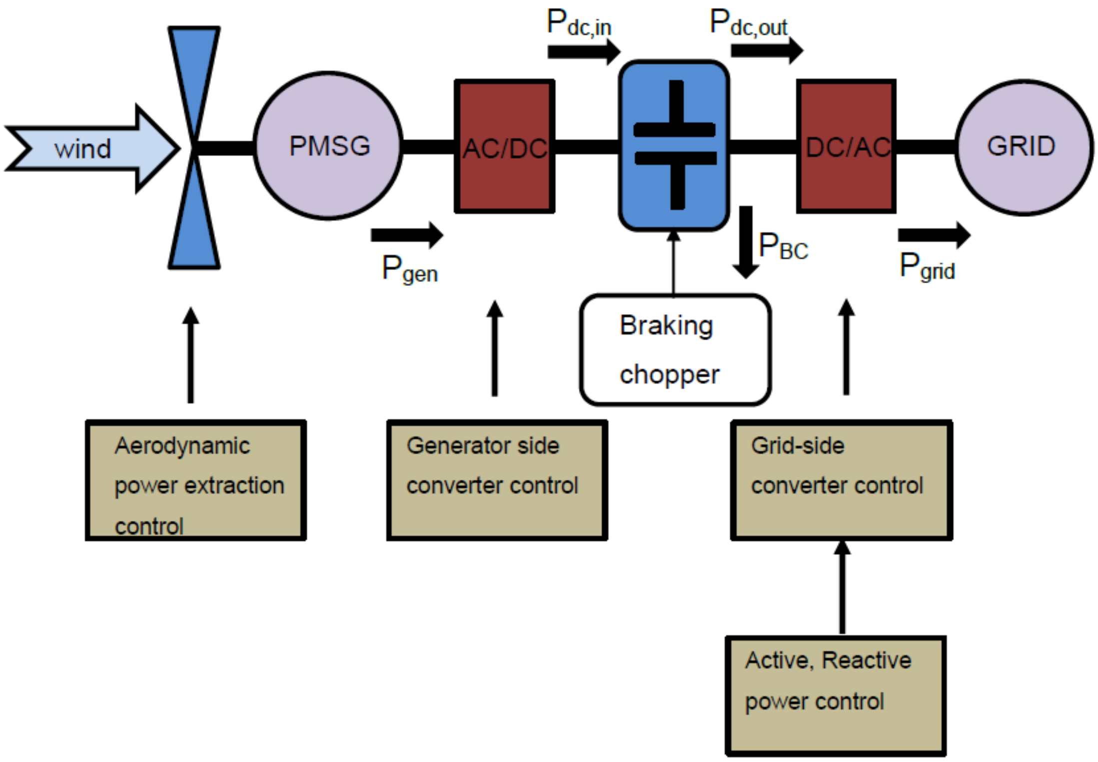

Figure 3.4. Control system for permanent magnet synchronous generator based small wind turbines.

Usually, a wind turbine has three main control objects - rotor speed, control blade pitch and control rotor pointing - which optimize energy production and are controlled by PLC (Figure 3.5). The first one monitors and controls the rate of the rotor according to the wind speed. This control loop monitors, for example, the speed, and if the speed more than 90 kilometers per hour, it will shut down the turbine to avoid damages. The second one controls the blade pitch (angle) according to the wind speed. With higher wind speeds, there is less contact area of the blade against the wind. The third one controls the rotor pointing (yaw). This control loop determines the direction of the wind and changes the nacelle against the wind to keep the maximum power from the wind.

However, inside the wind power plant there are great amounts of other different controllers which manage more than 50 other parameters, for example, the vibration level or gear oil temperature. (Wind turbine availability excellence 2010).

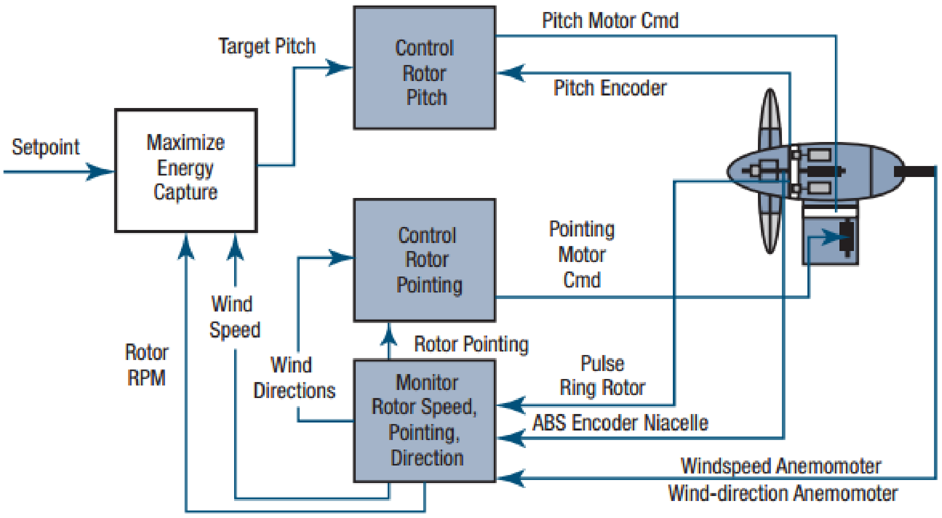

Figure 3.5. Control principles of the powerful wind turbines (Wind turbine availability excellence 2010).

Supervisory Control And Data Acquisition (SCADA) is used for wind turbine farms (Figure 3.6). A full farm can be started or stopped by this system. Furthermore, SCADA is used for receiving the wind turbine farm overview, the control, for the overview and operation of each wind turbine.

The farm overview helps to check all wind turbine conditions separately or together with the one main computer. The controlling of the wind turbine farm is carried out by SCADA using the main computer as well. Moreover, separate wind turbines are also controlled using the main PC.

The SCADA system sends all log data coming from the wind turbines to the main block of the network server, so it can be organized and controlled easily. The generator operation is also reported to the main PC by the SCADA, and it is based on the log data. All reports can be presented graphically, which helps to view them easily. (Wind turbine control, SCADA systems 2014).

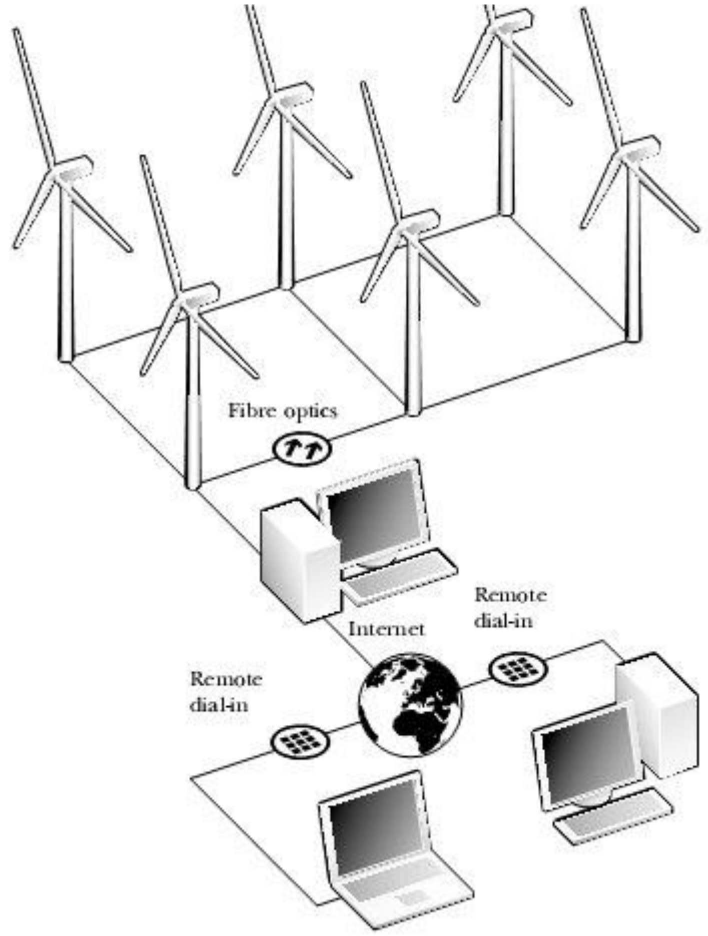

Figure 3.6. SCADA communication for wind turbines (SCADA systems 2007).

3.2.2 Commercial biomass power plants

Every biomass power plant has operators who are able to manage an operation support. Those operators monitor and control the behavior of every part of the power plant manually.

Biomass power plants are controlled by distributed control systems (DCS) which help to monitor all system of the power plant and can also help to present full power plant processes (Figure 3.7) on PCs, for example. For example, every sensor, flowmeter or pressure indicator are presented. If something harmful happens for the power plant, it is immediately shown on the PC screen and automatically or manually fixed. The power plant automation also includes safety PLC systems which separately monitor sub-stages of all processes and shuts down the power plant if something dangerous happens.

PLCs have a smaller capacity and they are mostly used in some more limited applications. These programming tools use very basic fundamental commands, such as combination logic commands and PID controllers. With more sophisticated software, more complicated applications are possible. Programming with PLCs means very basic commands, and in the DCSs there is a selection with greater readymade blocks related to loops. The basic PLC programming does not support loop thinking.

Also, biomass power plants are fitted with many measurement instruments which help to control the efficiency of the power generation. The main measurement instruments include flow rate meters, pressure indicators, liquid level indicators, temperature sensors and pH level indicators include, for example. These measurement instruments help to control the parts of the power plant where they are located. For example, the pressure indicator of steam flow from the furnace can identify incorrect steam flow pressure and send it to the station controller. After that, the problem can be fixed by changing the input airflow or input fuel flow manually or automatically.

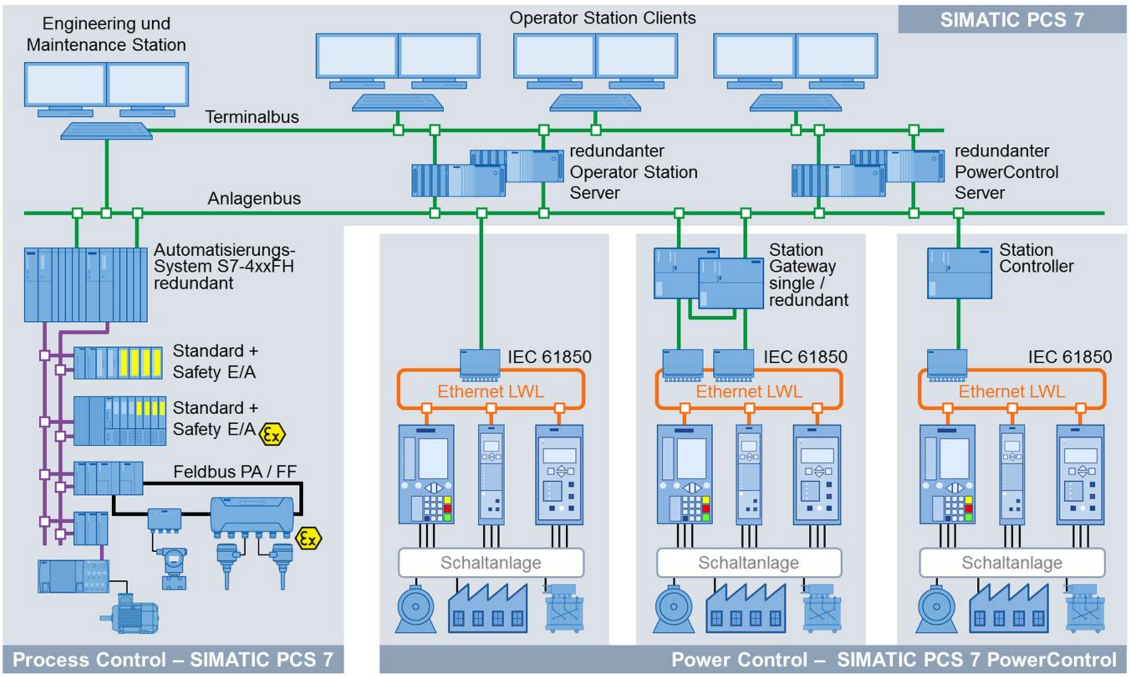

Figure 3.7. Biomass power plant control system (Siemens PCS7 control system 2016).

A full control system for a biomass power plant (Figure 3.8) includes calculations for airflow control and for fuel control. Firstly, system for fuel control has to contain measurements for combustion and bed temperature, real-time energy flow and oxygen correction. Secondly, the system for airflow control has to comprise also combustion and bed temperatures, oxygen correction, bed level, also measurements for secondary, overfire and underfire airflows.

These two main calculation blocks solve the problem of boiler protection with demanding limit regulation (DLR). The DLR is the block for monitoring airflow and fuel errors. For example, if one of the measured signals is higher of the given limit, this block defines the error and changes the intensiveness of fuel feed or airflow.

Finally, the fuel control block sends signals for solid fuel screw feeders, and the airflow control block sends signals to secondary overfire and underfire dampers. All those blocks can help increase boiler optimization and improve the energy efficiency of the biomass power plant. (FBC control strategies for burning biomass 2010).

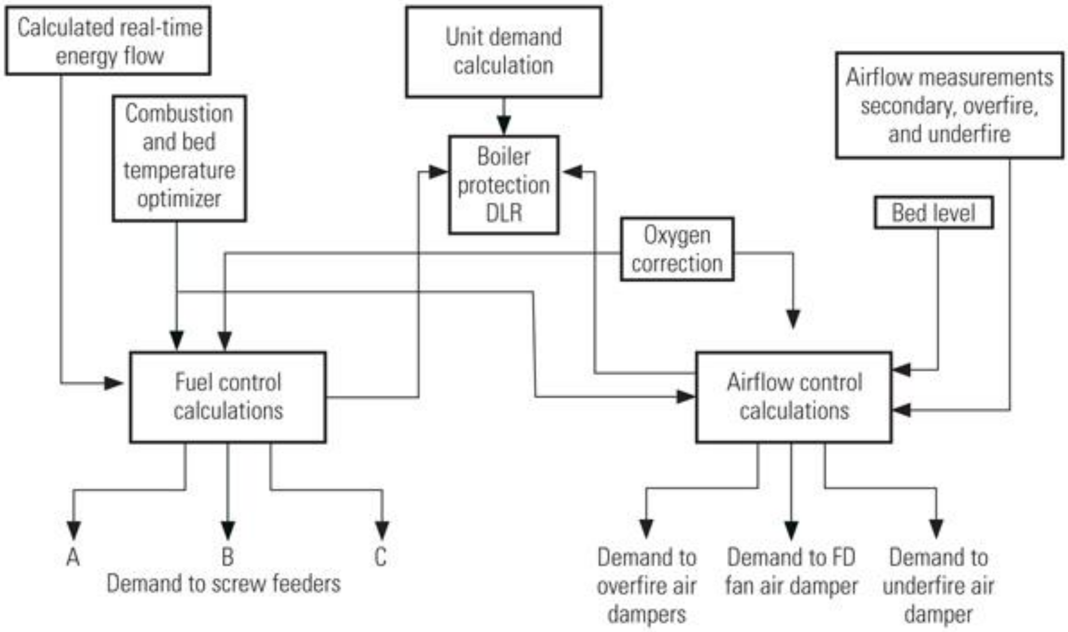

Figure 3.8. The complete control system of biomass power plant (FBC control strategies for burning biomass 2010).

3.2.3 Solar panel farms

The control system of solar panels as well as wind turbines can be connected to make one large system which is managed by SCADA (Figure 3.9). SCADA is very significant for the automatization of solar panel farms. All processes which are included into this vast system can be controlled by one operator which can greatly facilitate the work.

Separate solar panels (photovoltaic generators) are controlled in the same way as the home solar panels. Due to the need to produce plenty of energy, all these single solar panels are connected into one great farm which has to be controlled by SCADA. A solar panel farm requires many space, and that is why all large farms are divided into fewer smaller solar panel groups. Each group is connected to switchboards on the DC side, and all groups are connected also to a load regulator. Energy from photovoltaic collectors flows to the storage system for further usage if it is needed. Most often, energy comes directly through a DC/AC converter to the AC loads or without a DC/AC converter to the possible DC loads.

SCADA helps to control full solar panel farms with a main computer block and by one operator, which simplifies the monitoring of processes for taking energy from photovoltaic panels. The main PC control block also allows to control each separate solar panel. SCADA system sends to the PC all log data of the solar panels, and this data can be analyzed easily. (Solar farms 2014).

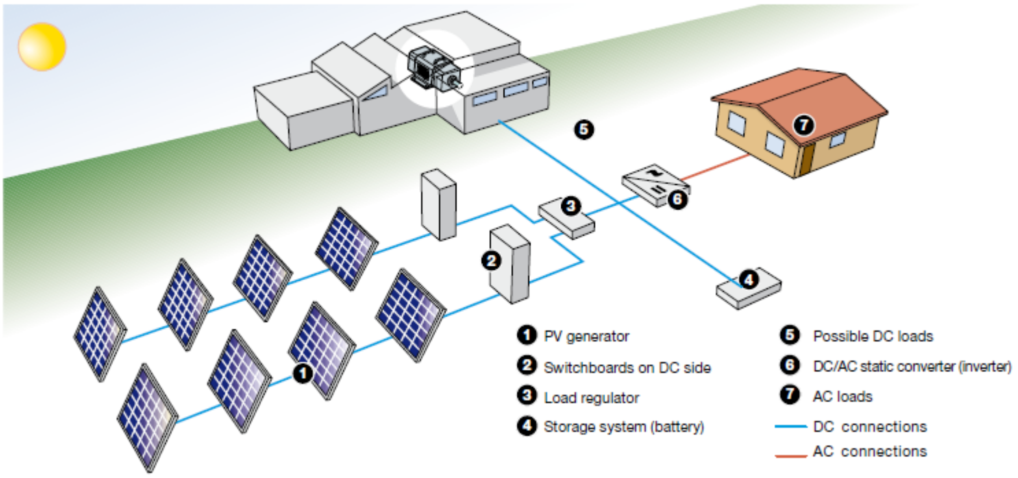

Figure 3.9. SCADA communication for solar panels (Solar farms 2014).

4 NATIONAL STATUSES OF RENEWABLES

Every European country has advantages and disadvantages for each kind of renewable sources. Countries with plenty of water resources use hydropower plants. If these countries have coasts with large seas or oceans, they use wind power plants because of the strong winds. The countries which have a longer sunlight during the days use more solar power plants. Geothermal sources are placed in countries with hot water springs or volcanic activities, and bioenergy power plants are established in countries with plenty of forests.

4.1 Scandinavian countries

Scandinavian countries need more energy for heating and lighting because they are located in the northern part of Europe. These countries have less daytime, and that is why they need more energy for lighting. Moreover, Scandinavian countries are located closer to the North Pole which means they need more energy for heating because of the cold and windy weather. In addition, Scandinavian countries are rich of forest resources.

4.1.1 Finland

Finland is a northern country, which needs much energy for lighting and heating. Finland uses various energy sources and improves energy efficiency from it every year (Figure 4.1).

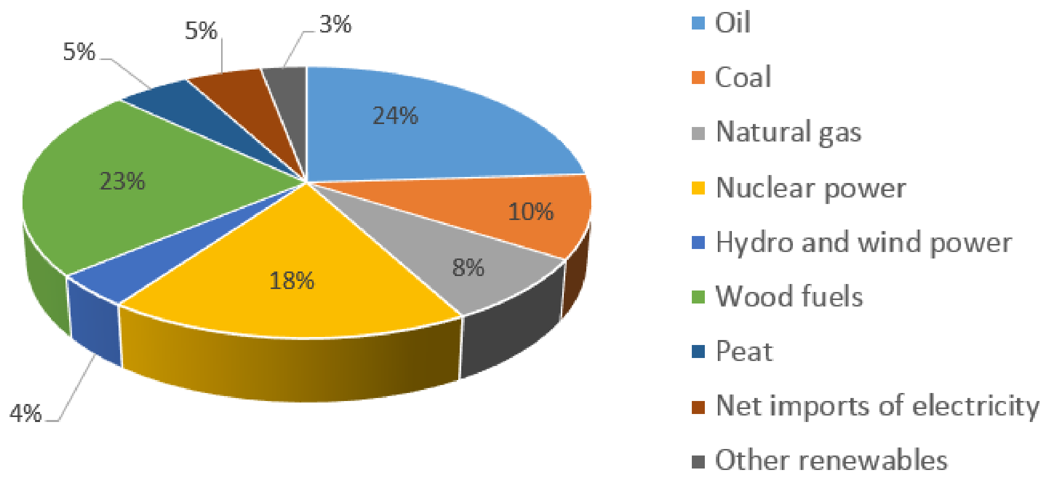

Figure 4.1. Total energy consumption in Finland (2014 year)

Finland took a third place in the statistics with usage of renewable sources in European countries in 2014. The share of renewables was 38.7% of the gross total energy consumption. (Energy consumption in EU 2014). It has been growing since last 10 years.

The largest part of Finland's renewable sources consists of bioenergy such as wood chips from forests and animal-derived biomasses from farms. The Finnish countryside is full of forests which is why wood is the most common renewable source. After bioenergy, hydro energy is the second largest renewable source in Finland with a share of approximately 20% of the electricity from renewables. Finland has approximately 200 hydro power plants.

Nevertheless, the sources such as the sun and the wind do not play a great role in the utilization of renewable energy in Finland by now. Wind power plants are mainly installed along the coast, and sun power plants are based in the southern part of Finland. Gradually, all these wind and sun sources take a larger and larger place in the electricity production in Finland. (Renewable energy in Finland 2014).

4.1.2 Norway

Norway is a country with almost 100% of its electricity produced by renewable sources. The most useful sources in this country are made by hydropower, geothermal power and wind power. However, the domestic consumption of the energy from these renewable resources only takes approximately 24%, because Norway is selling the produced energy to neighboring countries. (Countries with 100% renewable energy 2012).

The hydro power plants take the greatest part of generating energy from renewable sources (96.1%) because the Norwegian landscape offers a perfect basis for producing hydropower (Figure 4.2). Nevertheless, the thermal power plants (2.5%) and the wind power plants (1.4%) are taking a large place in the electricity production in Norway. (Renewable energy in Norway 2015).

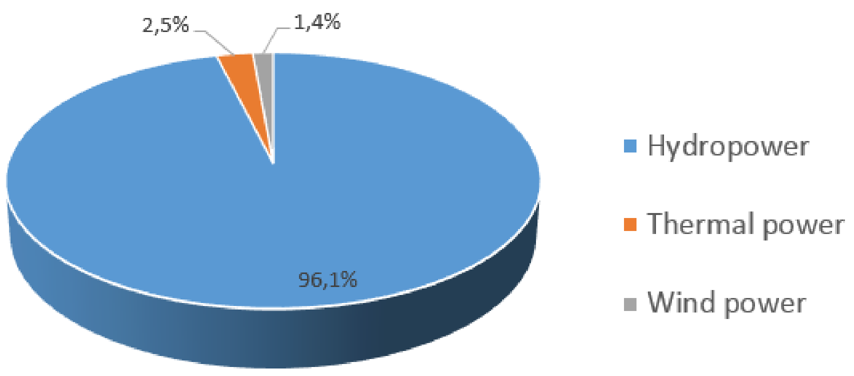

Figure 4.2. Percentage of total produced energy from different types of sources in Norway (2015 year).

Norway took a first place in the statistics with usage of renewable sources in European countries in 2014. The share of renewables was 69.2% of the gross total energy consumption. (Energy consumption in EU 2014).

4.1.3 Sweden

Sweden is one of the most powerful countries in producing energy from renewable sources. More than 50% of Sweden's energy production comes from renewable sources. Biofuel is the most common renewable source in Sweden. (Renewable energy in Sweden 2015).

The greatest source of renewable energy is bioenergy with share of 33.6% of the total electricity production in Sweden. Hydropower comes after bioenergy with 14.2%. Wind power and thermal power take the smallest part from all renewable sources, accounting for approximately 3.5% each (Figure 4.3). (Swedish energy sources 2015).

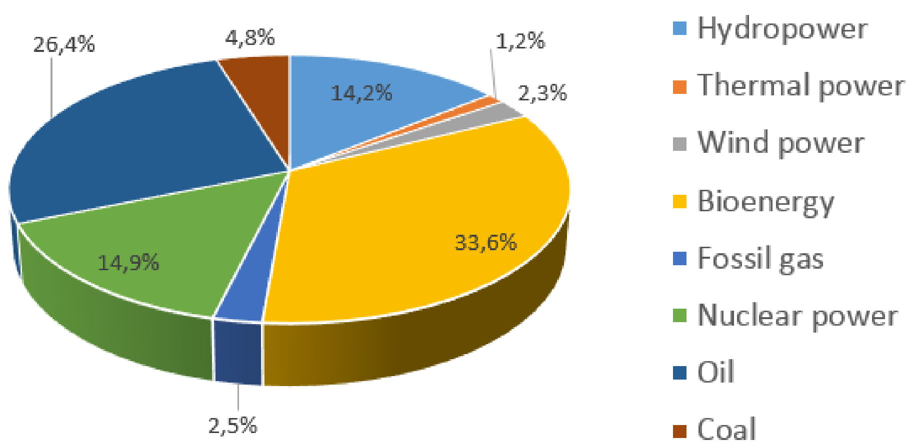

Figure 4.3. Percentage of total produced energy from different types of sources in Sweden (2013 year).

Sweden took a second place in in in the statistics with usage of renewable sources in European countries in 2014. The share of renewables was 52.6% of the gross total energy consumption (Energy consumption in EU 2014). However, Sweden is a world leader in producing energy from biofuel, and this is growing every year (Renewable energy technologies 2012).

4.1.4 Denmark

Energy produced by wind accounted for approximately 6.2% of the total amount renewable energy production in Denmark country in 2015 (Figure 4.4). Denmark hardly uses any thermal sources and hydropower. Bioenergy takes the largest part of producing energy from renewable sources in Denmark. The main plan for using energy in Denmark is producing 100% of all energy from renewable sources in the future, and this goal comes closer and closer every year. Bioenergy includes biogases (approximately 28% of the total usage of bioenergy) and biomass (approximately 40.1% of the total usage of bioenergy) including wood, straw, energy crops and biodiesel. Renewable sources account for approximately 23% of the total amount of energy produced in Denmark. (Country report for Denmark 2011, True cost of wind electricity in Denmark 2015).

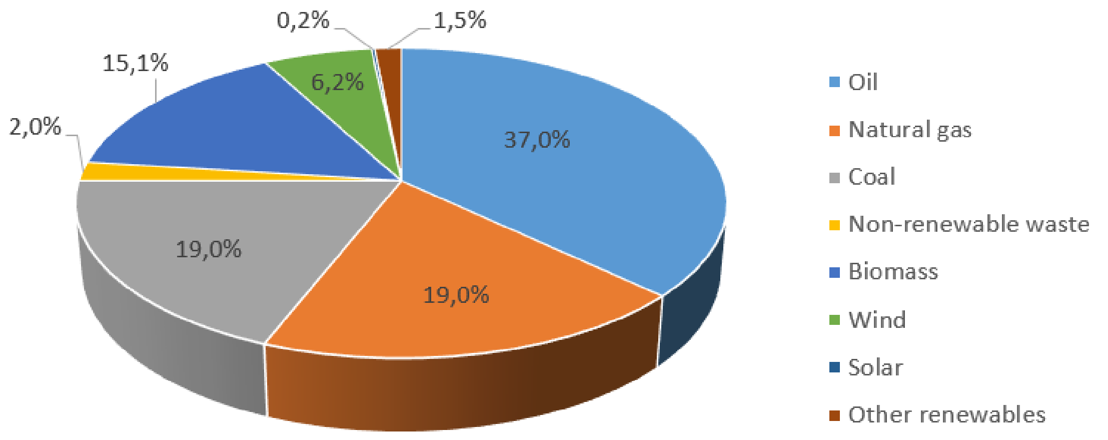

Figure 4.4. Percentage of total produced energy from different types of sources in Denmark (2015 year).

Denmark took a sixth place in the statistics with usage of renewable sources in European countries in 2014. The share of renewables was 29.2% of the gross total energy consumption. However, Denmark is a world leader in producing energy from wind, and this is growing every year. (Energy consumption in EU 2014, Denmark world record 2015).

4.1.5 Conclusion about Scandinavian countries

If the amount of population is compared with utilization of renewable sources for each country, it is possible to notice that great number of consumers in every country can take energy from renewable sources (Table 4.1). (World population 2016).

Table 4.1. Comparing of using renewable sources with population in Scandinavian countries

Country	**Renewable sources**				**Fossil sources**				Population number, mln people
	Biomass, %	Solar energy, %	Wind energy, %	Other sources, %	Nuclear, %	Oil, %	Coal, %	Other sources, %	
Finland	28	<1	4	4	18	24	10	18	5.4
Norway	<1	<1	1.4	96.6	0	0	0	0	5.1
Sweden	33.6	0	2.3	15.4	14.9	2.5	4.8	26.5	9.6
Denmark	15.1	0.2	6.2	1.5	0	37	19	21	5.6

Each country provides almost the same persentage of population from renewable sources. However, Norway supplies the largest amount of electricity from renewable sources to consumers to compare with other countries.

4.2 Southern European Countries

Southern European countries mostly use wind power plants and solar power plants because of the location near seas and the equator. Because of the seas, these countries have strong winds, and because of the location closer to the equator they have a longer daytime all year round which is beneficial for solar power plants.

4.2.1 France

The total production of energy from renewable sources in France accounted for 15.1% in 2010. The main energy source in France is the nuclear power with a 74.1% share of all energy production per year. However, oil and natural gas take 10.8% such as non-renewable sources for producing electricity. Nuclear power plants keep the largest energy production part in France because of the incapability of nuclear reactors to adapt to the different consumption demands in daytime and nighttime.

The main renewable source in France is hydropower, and it is circa 12.4% of total energy producing. The second largest renewable source is wind power which is approximately 1.7% of all energy sources. In addition, the smallest part falls on biomass and solar power (approximately 1% for both) (Figure 4.5). (France energy situation 2011).

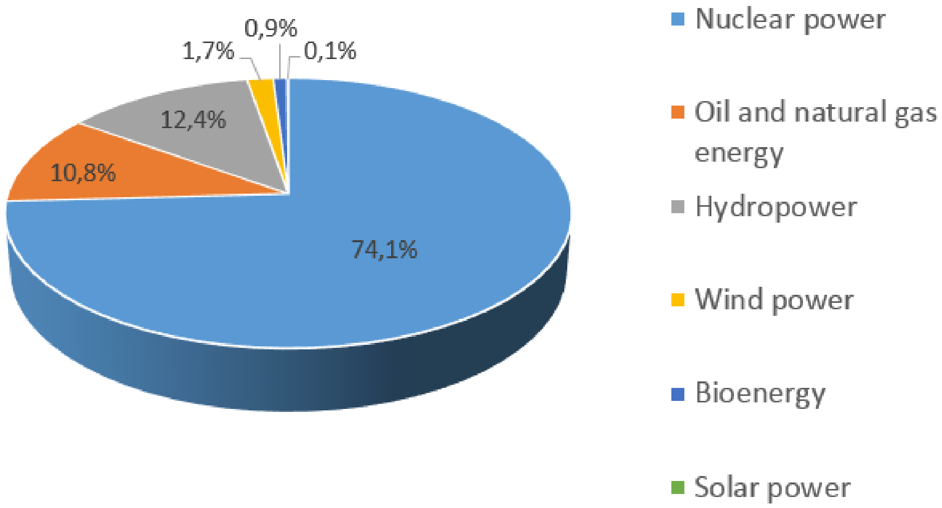

Figure 4.5. Percentage of total produced energy from different sources in France (2010 year).

4.2.2 Italy

Crude oil take two largest parts in producing energy in Italy with approximately 71% share of total electricity production in 2012. Nevertheless, renewable sources only account for a small part of the total energy production annually with a share of approximately 29%.

The largest renewable source in Italy is hydropower (14% of all generated energy in Italy in 2012). Solar power plants and wind power plants come after hydropower plants (11% of all generated energy in Italy in 2012 for each). Geothermal power plants keep the smallest part in producing energy from renewable sources which is approximately 2% of total energy production in 2012. Italy hardly uses any bioenergy, due to the lack of forests (Figure 4.6). (Energy situation in Italy 2015).

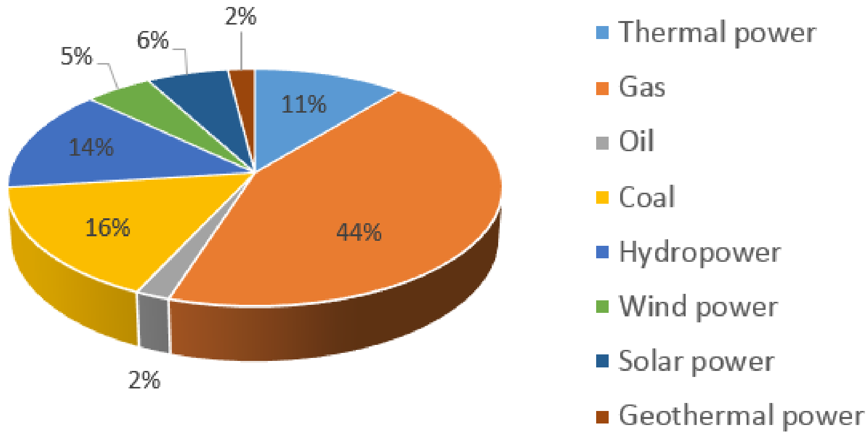

Figure 4.6. Percentage of total produced energy from different sources in Italy (2012 year).

4.2.3 Spain

Spain mostly uses renewable sources and nuclear power plants in the production energy, where are 45.2% for renewable power plants and 23.8% for nuclear power plants for March 2015. Spain has a low production of carbon emissions because of the wide use of renewable sources.

The largest part of used renewable sources are accounted for by wind power plants which take 22.5% of the total electricity production in March 2015. The second-greatest part is hydropower plants which a share of 17.5 %. Solar power plants take a third place with 5.2% of the energy production in March 2015. The smallest renewable power plant is geothermal which takes 1.8% of the total amount. Spain does not use bioenergy due to the same reason as Italy – lack of sufficient forests (Figure 4.7). (Spain electricity 2015).

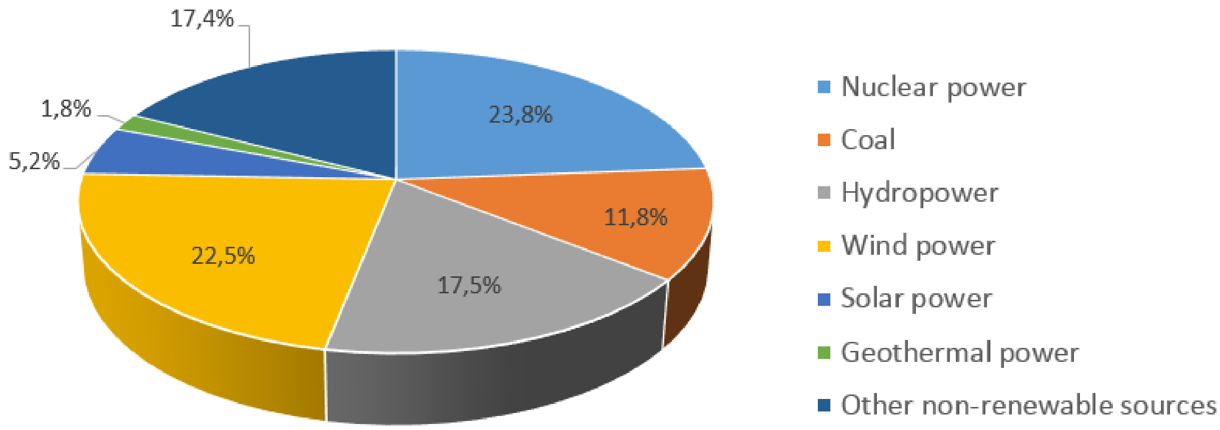

Figure 4.7. Percentage of total produced energy from different sources in Spain (2015 year).

4.2.4 Conclusion about Southern European countries

Southern European countries have a greater population than Scandinavian countries, which why these countries are not able to feed electricity for consumers from renewable sources as much as Finland, Sweden, Norway or Denmark (Table 4.2). (World population 2016).

Table 4.2. Comparing of using renewable sources with population in Southern European countries

Country	**Renewable sources**				**Fossil sources**				Population number, mln people
	Biomass, %	Solar energy, %	Wind energy, %	Other sources, %	Nuclear, %	Oil, %	Coal, %	Other sources, %	
France	0.9	0.1	1.7	12.4	74.1	10.8	0	0	67.1
Italy	0	6	5	27	0	2	16	44	60.6
Spain	0	5.2	22.5	19.3	23.8	0	11.8	17.4	47.9

Each country provides almost the same persentage of population from renewable sources except Italy. However, Southern European countries have more non-renewable sources, because this is impossible to supply so large population only by renewable sources.

4.3 Germany

Central European countries have a great amount of wind power plants due to strong winds around the year. However, these countries have many solar power plants as well because of a good location for the optimal sunshine. The countries in Central Europe use less bioenergy because they have less forest.

Germany has less geothermal power plants and it does not have a large potential nowadays. The biggest renewable energy supplier in Germany is biomass which is 10% of the total energy production in 2014. Wind power plants (9%) and solar power plants (6%) come after biomass. Hydroelectricity is only 3% of total energy production in 2014 (Figure 4.8).

However, non-renewable sources take the largest place in producing electricity in Germany. Energy from fossil fuels accounts for 50% (25% for brown coal, 18% for black coal, 6% for natural gas and 1% for oil) of all energy production. Nuclear power plants are approximately 16% of total energy production in Germany. Other sources are circa 6%. (Renewables in Germany 2015).

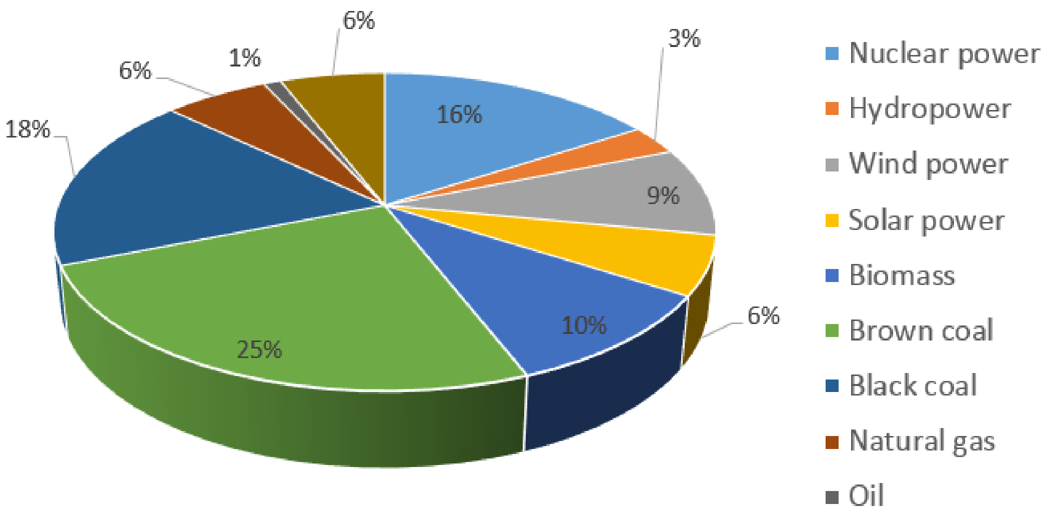

Figure 4.8. Percentage of total produced energy from different sources in Germany (2014 year).

The Germany population is approximately 79.7 million people (World population 2016). Germany has to have power plants with large efficiency and uninterrupted work during the nighttime for feeding electricity to all consumers. That is why the greater part of energy sources are non-renewable.

4.4 Russia

Russia as an Eastern European and Asian country has many non-renewable resources and the largest fields to build every kind of energy power plant. That is why Russia uses more non-renewable resources and does not pay very much attention to renewable sources. Nevertheless, Russia has many different types of power plants including renewable ones.

Russia is the greatest energy producer of oil and the second-largest producer of natural gas. Russia has many resources inside the country, and that is why there are more preferable non-renewable resources. The renewable resources of Russia keep only a small part of total produced energy (Figure 4.9). (Overview of Russian energy 2015).

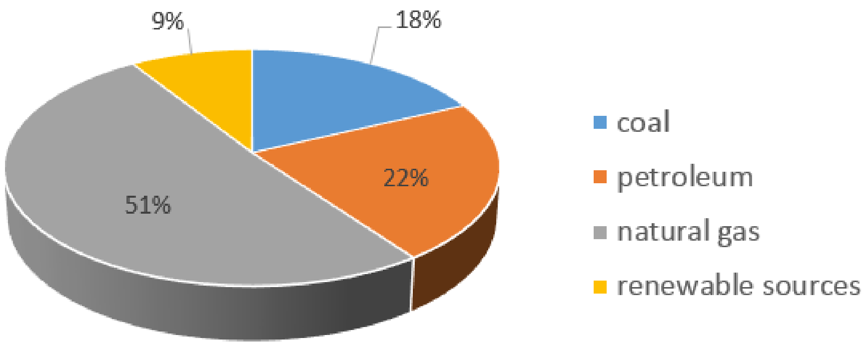

Figure 4.9. Percentage of total produced energy from different sources in Russia (2012 year).

Biofuel is the largest renewable source in Russia, and it is more than 50% of the total energy production by renewable sources. Hydropower is the second-largest renewable source which is approximately 30% of all total energy production annually. Only a small part of all these renewable sources in Russia falls on thermal power plants, wind power plants and solar power plants, and it is less than 10% of the total energy production by renewable sources. (Russian renewable energy 2012).

Russian energy sources produce very large amount of electricity. However, the Russian population is approximately 146.4 million people (World population 2016). This means Russia has to have many vast energy power plants for such a great number of consumers.

5 IN CONCLUSION

The renewable sources have many benefits. They can make use of the nearest resources for producing energy easier for each consumer. The usage of renewable sources can increase safety because these sources are less dangerous. Better localization of these sources can ensure a better efficiency. They can help to save natural non-renewable resources by lower consumption. Renewable sources have fewer emissions than non-renewable sources, which can help to protect climate conditions and protect human health. In addition, they can create more new jobs for people.

All countries which use renewable sources want to use more renewable sources in their energy production in the future. For example, Finland is planning to increase the usage of bioenergy in the future because Finland has a large amount of forests, and the utilization of forests can save non-renewable resources. By 2050, Germany has a plan to increase the amount of renewable sources for a better climate and lower emissions of CO_2 and for increasing the economic efficiency. Moreover, the federal government of Germany has a plan to start using the newest renewable sources in the future for the long term. However, Russia is not paying too much attention to renewable sources and is not planning to increase the utilization of renewable sources as much as other European countries because Russia has enough non-renewable resources for the next tens or even hundreds of years.

This thesis reviewed the usage of renewable sources in European countries. All European countries are using many kinds of renewable sources for producing energy. In addition, all kinds of renewable source processes were also reviewed from a control aspect. The most important sub processes and machines were introduced as well as the management principles.

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