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Micro Co-generation of Heat and Power Hybrid with Renewables: State of the Art

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<p>The purpose of this bachelor's thesis was to find out the possible options to construct a hybrid micro cogeneration of heat and power. This report analysed the available micro cogeneration heat and power technologies and possibilities to combine them with the renewable energy sources and clean energy technologies for the campus lab of Helsinki Metropolia University of Applied Sciences.</p> <p>The research mainly focused on the solar photovoltaic-thermal energy combined with the micro cogeneration technologies that use renewable and nearly clean energy sources like biomass and biogas and use the remote monitoring for the system. This thesis also tried to put some light on the hot topic in CHP: Fuel cell, which is still, at a research and development stage.</p> <p>The report focused on the integration of the existing micro CHP technologies and mainly solar energy. The report analysed the emission factors and energy savings from the use of CHP and renewable energy in residential building thus helping EU to meet the target set to achieve in 2020 (now pushed to 2030). Study of the report will give an overview of a movable hybrid micro cogeneration of heat and power and potential towards using in private and commercial sectors.</p>	
Keywords	Micro CHP, hybrid, renewables, solar

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1 Introduction

The energy consumption of about 160 million buildings in Europe accounts for 40% of total energy consumptions in Europe and the demand is mostly fulfilled by centralized cogeneration of power and heat. 36% of total carbon emissions in the European Union is produced due to the centralized cogeneration of heat and power. For the production of the heat and power, around 100 million litres of gas are used and 8 million gas boilers are sold in Europe annually, which produce even more greenhouse gases. (1.)

Micro-cogeneration of heat and power (micro-CHP) means the generation of electricity and heat for a residential building or small office buildings. The process includes the production of thermal energy and electricity simultaneously. Since the heat is primary product, the production of power is slightly more in micro cogeneration system than when producing power primarily and using the excess heat for domestic hot water and space heating purposes, as done in a large system. According to the EU legislation, installations of micro cogeneration of units in the buildings should not have the output more than 50 kW of electricity. With an ability to gain 85-90% efficiency, micro CHP units can meet the demand of providing electricity and heat for space heating and domestic hot water and reduce the greenhouse gas emissions and saves the energy costs up to 25%. (2.)

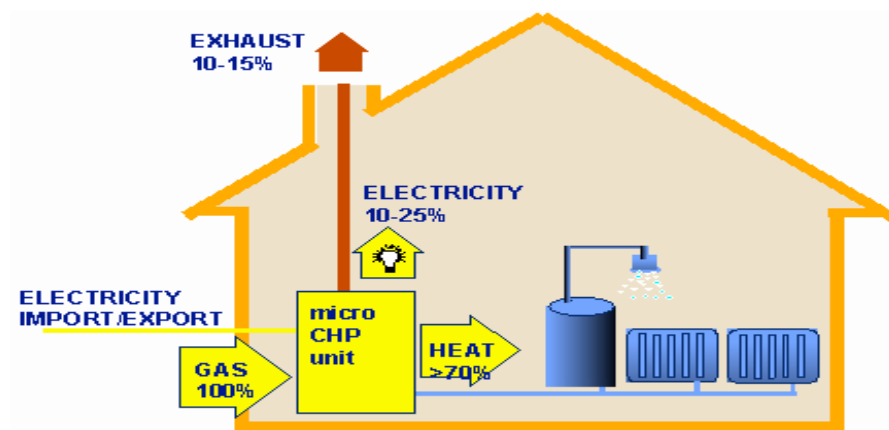


Figure 1. Micro CHP system (3)

Figure 1 shows the production of electricity and heat energy in residential building using a micro CHP unit as well as the amount of energy produced and lost during the process.

Centralized CHP is currently the most common option to provide heat and power to buildings. However, it is necessary to reduce carbon emissions and save energy by using renewables by 2030. Centralized CHP is good for densely populated areas but the loss of heat and power during transmission is a major reason to change into micro CHP. Decentralized cogeneration can be combined with the use of other clean source of energy according to the availability and the affordability, such as wind and solar energy thus helping to meet the target set by the European Commission.

The main objective of this study is to make an analysis of the available micro CHP technologies and the renewable energy technologies so that a hybrid micro CHP system can be constructed for the lab of Helsinki Metropolia University of Applied Sciences. The report analysed few existing technologies that use almost clean fuel sources and integrate them together with the renewable energy production.

2 Existing Technologies

There are five technologies of micro-CHP currently being used in the world. Four of them use engine to drive a generator and produce energy while one relies on fuel cell technology. (4.) Below, the existing technologies are briefly discussed.

2.1 Fuel Cell Technology

Fuel cell technology is at a trial phase in Europe. A fuel cell can be compared to a battery that generates electricity through an electrochemical reaction, as both batteries and fuel cells convert chemical energy into electrical energy and produce heat. A fuel cell uses an external supply of chemical energy and runs continuously unlike batteries, which need to be recharged or discarded after a definite period of time. Generally, in a fuel cell system an electrolyte is used as the fuel source. The electrolyte is then oxidized which, releases electrons and electric current via an external circuit, that is, from the anode to the cathode. (5.)

There are primarily two fuel cell technologies that are being used for micro combined heat and power production. They are proton exchange membrane (PEM) and solid oxide fuel cell (SOFC), however hydrogen fuel cell is also being developed. The solid oxide fuel cells are high temperature fuel cells that operate in the range between 800

and 1000°C. The working principle is mostly the same as other fuel types. The difference is that the electrolyte is solid ceramic such as Zirconium oxide stabilised with yttrium oxide. Oxygen is supplied at the cathode, and the ceramic electrolyte conducts oxygen ions from the cathode to the anode while electrons go around the circuit producing electricity. At the anode the oxygen ions combine with hydrogen to produce water alongside heat and CO₂. (6.)

Proton exchange membrane fuel cells (PEMFC) use an ion-conducting polymer as the electrolyte. The electrolyte works at low temperatures, which allows for a fast start up. In this system, hydrogen gas is ionized in the proton exchange membrane anode, which releases electrons and protons. Protons are passed for the external circuit while oxygen molecules are reduced in an acidic environment by electrons from the circuit at the cathode. Protons pass through the PEM, from anode to cathode, which completes the circuit.

Due to its smaller size, lighter weight and potential to provide high power densities, PEM is a better option than other fuel cells as SOFC requires high temperatures to operate. (7.)

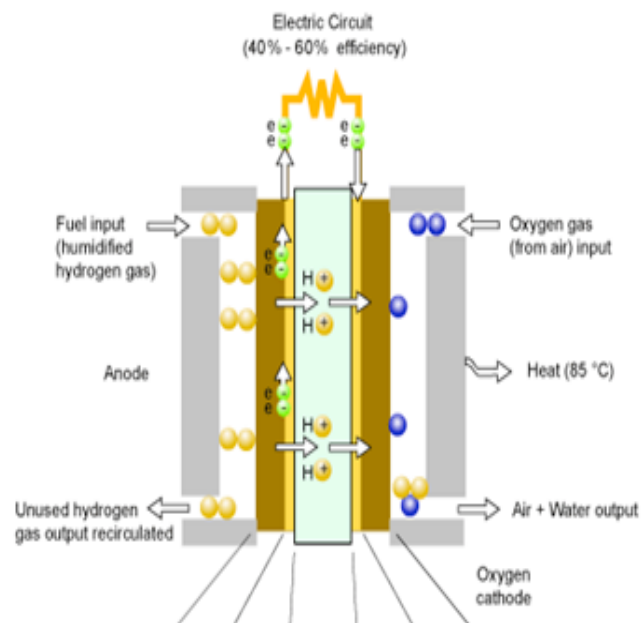


Figure 2. Diagram for PEM FC (8)

Figure 2 shows the working principle of the proton exchange membrane fuel cell in which hydrogen is used as fuel, which produces heat and electricity along with water.

2.2 Types of Existing Engines

A stirling engine is device that simultaneously transforms mechanical energy into electrical energy and heat energy and the stirling engines can be used as micro CHP system in residential and small commercial purpose (can also be used for larger production units). In this system, the fuels that are usually used are natural gas, biomass, biogas or wood, which are burned with oxygen. The heat generated from the combustion of the fuel is used for mechanical power generation using generator or alternator. The waste heat is used for space heating and domestic hot water. Solar heat can also be used as the alternative source of fuel which uses the solar heat to generate steam and drive the engine. (9.)

An internal combustion engine, also called as a reciprocating engine can be defined as the machine that gain mechanical power by using the energy produced by the fuel burned within the combustion chamber of the engine and produce heat and power. When used in micro CHP, the engine drives an electric generator and the exhaust heat from the engine is used according to the demand of the space that is to be heated. Since an internal combustion engine is compact in size and has higher efficiency, there is wide use of the engines in small power plant. There are two types of IC engines; Diesel engines and spark ignition engines. Diesel engines use rape oil, gas, biogas as fuel and the power range is between 5kw to 20 Mw, whereas spark ignition engine uses gas, biogas, naphtha as fuel and the power range varies from 3kw to 6Mw. (10.)

The Rankine cycle is a power cycle that is used to convert one type of energy into another. In heat power cycles, chemical energy is converted into thermal energy and that thermal energy is used to transform into mechanical energy or electricity. (11.) The Organic Rankin cycle is similar to the Rankine cycle, except the fluid that drives the turbine being a high molecular mass organic fluid .The working fluids allow the use of low temperature heat sources to produce a wide range of power outputs (>1kw to 3Mw). The evaporator vaporises the organic fluid with a heat source in the evaporator. The vapour expands in the turbine and is then condensed with water flow in a shell-tube heat exchanger. (9.)

Micro turbines are small high-speed gas turbines that take their energy from hydrocarbon fuels (natural gas, propane, and diesel). The process includes the compression of

the fuels, combustion and hot gas expansion. A compressor draws the air from the space, increasing the pressure of the air which is mixed with the fuel and burned in the combustor. The hot gas that is expanded through the turbine drives the generator thus producing electricity. Exhaust gases can be used for heating spaces and domestic hot water. If used for electricity generation only, the efficiency of a micro-turbine is close to 30% but if used in CHP the efficiency goes up to 90%. The continuous combustion of fuel inside the turbine makes it less polluting than an internal combustion engine. Carbon monoxide from micro turbine emissions are nearly zero while NO_x (mono nitro oxide) emissions are less than 9 ppm. (12.)

The systems used for micro CHP have various advantages and disadvantages depending on the needs and situations can be seen in table 1 that compares the existing CHP technologies.

Table 1. CHP technologies (13)

System	Thermo-dynamical cycles	Fuel Used	Total Efficiency(%)	Electrical Efficiency(%)	Power range	Present price€/kw
IC engine (Diesel)	Diesel Cycle	Gas, biogas, rape oil	65-90	35-45	5kw-20Mw	15000
Spark Ignition	Otto Cycle	Gas, biogas, naphtha	70-92	25-45	3kW-6MW	
Micro Turbines		Natural gas, gasoil, diesel propane, kerosene	65-90	15-30	15kW-300kW	
Stirling Engine	Stirling Cycle	Natural gas, butane, alcohol	65-95	25	3kW-1.5Mw	10000
ORC	Rankin cycle	Biomass, waste	80	20		
SOFC			82	27		17000
PEM		Water , H2	76	29		150000

Table 1 above shows that the IC engine, stirling engine and ORC systems are suitable for micro CHP. A clean source of fuel such as biogas or biomass can be used.

3 Hybrid with renewables

The use of renewable sources of energy is rapidly increasing along with the other micro-CHP technologies in order to minimize carbon emissions and build energy efficient buildings. Hydro-power, which needs high head and pressure to create power and requires very high investment, other sources of renewables like solar energy, geothermal energy and wind power are being used in micro heat and power generation.

The freely available energy sources or the easily available sources in Finland, which are clean or nearly clean, are given below in table 2 with their production and consumption potential.

Table 2. Renewable Energy Consumption by energy source in 2013 (14)

Sources of Energy	Year 2013 (PJ)	Target set for 2020 (PJ)	Production Potential (PJ/year)
Solid wood processing industry by products	71	68	
Hydro power	60	50	
Heat Pumps	16	29	
Forest Fuels(chips)	59	90	80-140
Biogas	2	4	8-64
Wood pellets	3	7	9-27
Firewood	60	43	50
Other renewables (solar, wind)	4	23	

1Peta Joule = 10^{15} Joules

Table 2 illustrates the different sources of renewable energy and their real consumption of in year 2013 and targeted consumption in the year 2020. (14)

3.1 Solar energy

Europe aims at increasing the share of renewable energy sources to 20% by 2020. The production of electricity with renewable energy is on target, but the heating and cooling sector that shares 50% in the energy consumption of buildings is far below the

target in Europe. (15.) Currently, the market of solar energy is comparatively small in Finland, although there are signs of gradual interest towards solar energy and renewable energy sources. The climate and the existing CHP technologies in Finland are the main factors for the slow interest in solar technologies. Although, Finland has a long winter, the efficiency in the production of photovoltaic energy is very negligibly low than in summer time. Solar power can be used for the production of electricity in the summer time and the heat from the solar thermal can be stored and used for winter. Hot water is needed throughout the year and space heating is needed in spring and autumn. There are a few companies that are offering the technologies and services to the solar market.

A map that shows the solar radiation in the continent of Europe and rest of the world is shown below in figure 3.

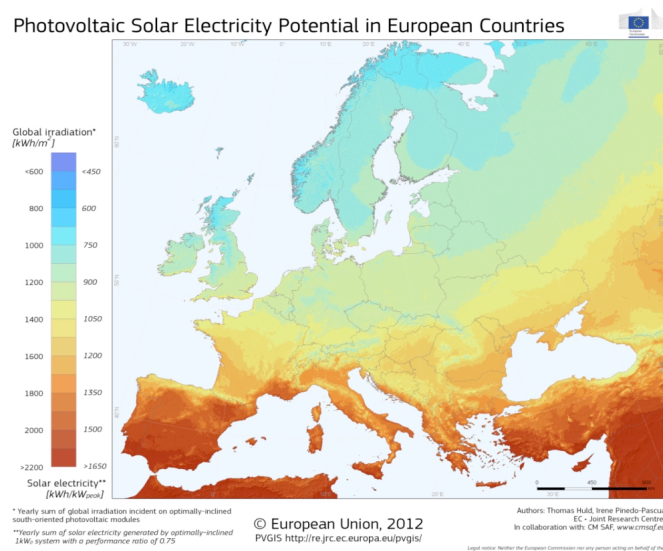


Figure 3. Solar PHOTOVOLTAIC electricity in European countries (16)

Figure 3 shows the solar irradiance and the potential photovoltaic electricity in Europe. The map shows that the irradiance of southern Finland is on par with the UK and Germany, which are two solar giants in the world. However, the statistics show that the installed capacity in the region is a lot less than in those two giants.(16.)

3.2 Solar Technologies

Though the irradiance in Finland is almost as much as in the UK and Germany, the market and usage is very low comparatively to other EU countries. Solar energy technologies are basically divided into solar photovoltaic, solar thermal and concentrating

solar power technology. Solar thermal is used for thermal production whereas other two are used in electricity production. (17.)

3.2.1 Photovoltaic Technology

The term Photovoltaic is used to refer to the conversion of solar light into electricity. Photovoltaic devices are designed as cells or modules so that they can be placed in arrays and connected together for producing direct current and voltage. Those voltage and current can be stored in batteries. (17.)

Figure 4 shows the Photovoltaic production capacity installed in Europe from the year 2000 to the year 2014.

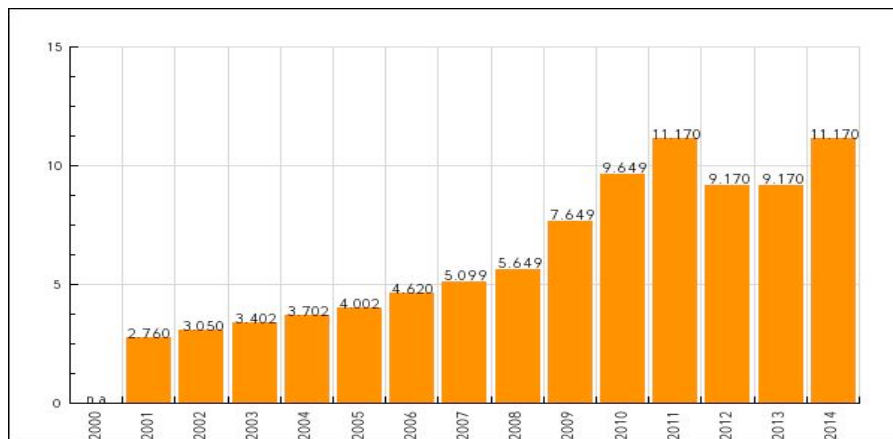


Figure 4. Total Photovoltaic production capacity installed (MWp) (18)

Figure 4 gives a clear picture of the total production of electricity with solar energy. There was a gradual growth from 2000 to 2011, but it seems to have stopped. (18.)

3.2.2 Solar thermal technology

Solar thermal technology converts sunlight into heat. The main use of the solar thermal system is for domestic hot water and space heating for residential or small office buildings. Solar thermal energy can also be used to drive a generator and to produce electricity. (19.)

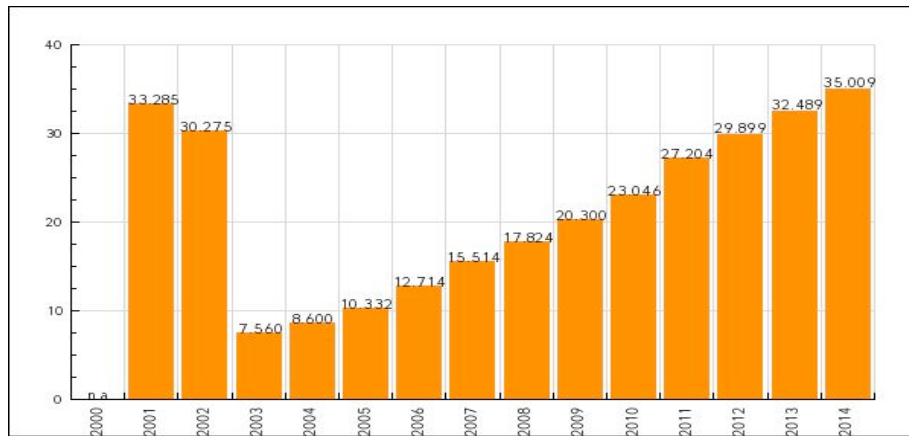


Figure 5. Total installed solar thermal capacity (MWth) (20)

Figure 5 above refers to the solar thermal installed in Europe 27(27 member states of the EU) from 2000 to 2014 and it shows the gradual increase in the installations after drastic fall in the year 2003. (20.)

An integrated photovoltaic and thermal collector can provide both electrical and thermal energy at the same time. There are two types of collectors that are divided on the basis of the heat driving matter.

The photovoltaic thermal concept offers an opportunity to increase the overall efficiency of photovoltaic panels by using the waste heat generated in the photovoltaic modules. The increase of heat in the photovoltaic modules decreases their electrical efficiency. It is beneficial to cool down the photovoltaic panels with cooler substance like water or air, at the rear or front surfaces of the systems. (21.)

An air photovoltaic thermal collector uses both photovoltaic cells and thermal collector in a single frame. In this collector, ventilation is used in order to make the air pass through the photovoltaic cells and that air carries the heat of the photovoltaic cells through the pipes installed in the collector. Ventilation helps to cool down the photovoltaic modules and increases their efficiency. Furthermore, the heat is used for space or hot water heating. (22.)

A water photovoltaic thermal collector is a thermal collector with photovoltaic modules on the absorber that produces thermal and electrical energy. In this system, photovoltaic cells are posted either directly on the absorber or inside of a cover-plate with dielectric material. The cold water that is used to transfer the heat of the photovoltaic cells

passes from one entrance to the other thus increasing the efficiency of the photovoltaic cells and providing heat for space or domestic hot water heating. (22.)

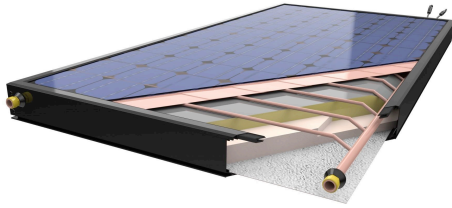


Figure 6: Typical photovoltaic Thermal collector (23)

Figure 6 shows a typical glass-covered photovoltaic thermal in which one end gives electricity and the other end heat and the photovoltaic cells. Water is used as the medium to transfer the heat. (23.) When the solar energy is not enough for the demands of the building, the building can draw power from the grid to meet the demand. This policy is called net metering. (24.)

4 Biomass micro CHP integrated with Photovoltaic Thermal Collector

The energy sources that are derived and produced from the biological materials found in the nature are called Biofuels. Biofuels can be solid, liquid or gaseous. Solid biofuels are the materials derived from wood, crop residues, animal waste, municipal waste and other organic materials, generally called biomass. Finland has enormous amount of biomass. In Finland, the use of wood biomass is around 26-27 Tera-Watt hours per annum. The wood supply is mainly dependent on the forest industry. (25.)

Wood pellet combustion units are a low-emission and comfortable solution to provide heat for space heating and simultaneously generating electricity for small-scale applications. The working principle of the wood chip fuelled micro combined heat and power system depends on the engine that is used. Generally, for micro CHP stirling engines are used. (26.) The potential of hybrid biomass micro CHP with the renewable energy sources is vast. The combination of the solar energy to the existing micro CHP biomass technologies will help to reduce GHGs, energy and money.

In the system studied in the report, solar photovoltaic thermal cells are integrated to the heat and power cogeneration system powered by a wood pellet stirling engine system. The system under analysis is a micro combined heat and power system that

uses solar energy, integrated with biomass (wood chips/pellet) CHP technology in a college lab. The produced heat and power can also be used for campus usage. The heat and power is produced with two sources in the daytime and from the biomass in nighttime while the load is full on the CHP. The heat source is separated and arranged in parallel for solar and biomass systems. (27.)

The following diagram (figure 7) shows the layout of the combined heat and power plant with gas circuits. The operating principle is as same as stirling engine which is fueled by biomass.

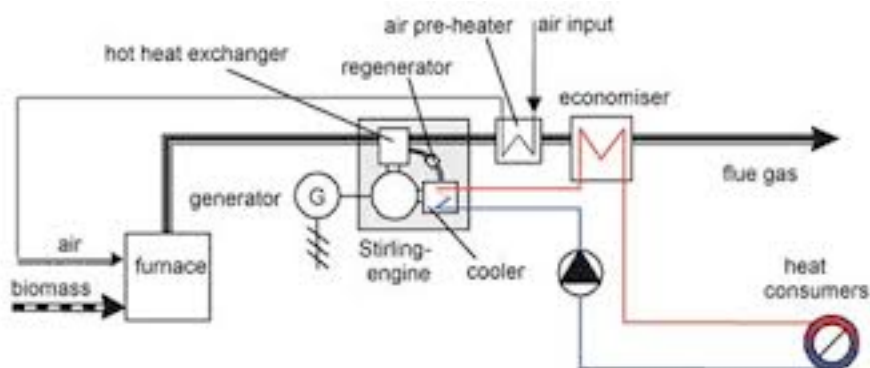


Figure 7. Biomass micro cogeneration of heat and power. (28)

Figure 7 shows the general idea of the generation of heat and power by using stirling engine and feeding biomass as fuel. It shows that the biomass fed is burned with air and supplied to the generator via engine thus producing power and heat simultaneously. (28.)

There are three advantages of using biomass as a fuel to produce heat and power.

1. The wood pellets or woodchips are easily and abundantly found in Finland thus beneficial for the biomass market.
2. The carbon emissions are relatively very less than those of fossil fuels, unless the transportation of the biomass is not near to the plant and therefore, requires a relatively bigger space for storage.
3. The price of biomass is a lot lower than that of fossil fuels. (29.)

5 Heat Pump with Photovoltaic panels integrated with Biogas micro CHP

A heat pump is a device with a motor and a compressor. It requires electric power to run the motor. The motor in turn runs the compressor, compressing a vapor to a higher pressure and temperature. The superheated vapor then condenses, releasing the latent heat to the circulating fluid for heating. (30.)

The studied heating system is based on an air source heat pump, which is supported by the solar thermal collector system. A water storage tank is used to distribute the hot water for space heating and domestic hot water.

Different heat pumps have different working principles and mediums to carry the heat from one place to another. Some other characteristics of the available heat pumps are presented in the table 3.

Table 3. Features of various Heat Pumps. (31)

Features	Outdoor Air	Exhaust air	Ground	(Ground) Water
Availability	Everywhere	Ventilation system	High in the earth's crust	Restricted
Capacity of source	Upon Volume flow rate	Limited when air exchange	Upon bore-hole, dry soil and wet soil	Range of capacity upon ground water and surface water
Temperature Range	-20°C-40°C	20°C-28°C	1°C-15°C	8°C-13°C
Frosting Risk	Up to -7°C	In case of coupling with heat recovery	Almost none	none
Permission	None	None	Required	required
Heating Capacity(2016 est.)	2 980226 kW	108 807kW	1 517810kW	365071kW

Table 3 can be used to compare the advantages and disadvantages of the available pumps. (31)

Heat pump systems with photovoltaic thermal collectors and a borehole heat exchanger as heat source can achieve higher efficiencies and help providing cooling to the photovoltaic modules. The borehole can be used to store heat to be used in winter.

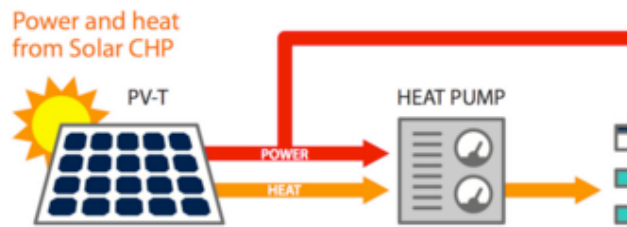


Figure 8. Photovoltaic Thermal panel integrated with Heat Pump. (32)

The hybrid photovoltaic thermal system in figure 8 is integrated with a heat pump. A heat storage is used for domestic hot water and space heating. The system is designed to maximize the efficiency of the heat pump and solar photovoltaic thermal system, thus minimizing the use of micro cogeneration of power and heat. The photovoltaic thermal system is integrated with heat pump and biogas micro CHP system for cogeneration of the heat and power.

The photovoltaic thermal panels not only generate electricity but also use thermal conductive substrate, which conducts heat away from the photovoltaic thermal modules cooling the panels and generating the hot fluid/air which can be used for space heating. The heat pump is driven by the power generated by solar energy and excess energy is used to run other appliances.

Ground source heat pump is efficient in a climate like that in Finland where it is freezing cold, frost and snow for almost four months. Though the installation cost is comparatively higher than other heat pumps, the reliability and high efficiency and high heating and cooling capacity of GSHP makes it more feasible than other pump types. Furthermore, in summer time the GSHP can be used for cooling purposes while saving the excess heat from photovoltaic for heating purpose in the wintertime. (33.)

An example of a building that has used solar photovoltaic-thermal technology along with a ground source heat pump for the power and heat required for building.

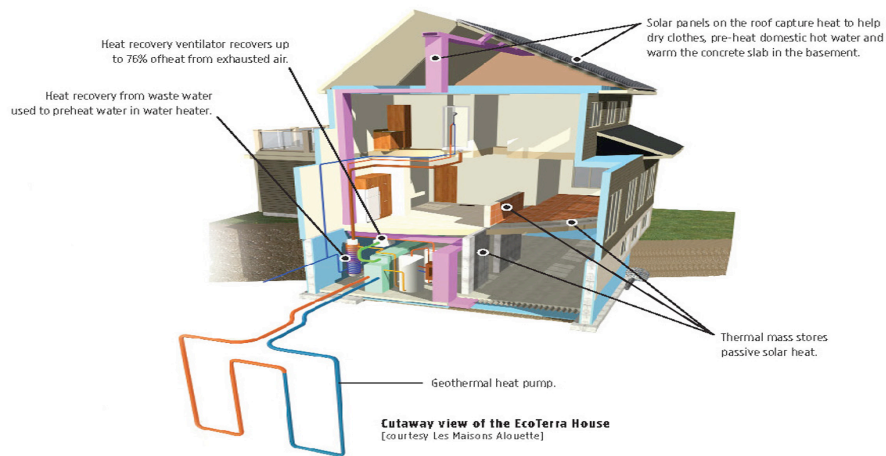


Figure 9: EcoTerra™ Home (34)

Figure 9 above is a Canadian Net Zero Energy building in which solar photovoltaic thermal system is integrated with heat pump and the thermal storage.

A CHP system based on biogas is simple and efficient. Biogas is generated during the fermentation of organic material. Kitchen waste and other organic waste fermentation is one of the easiest ways to get biogas. Biogas is produced when the bacteria degrade organic matter in the absence of air. Biogas contains of 30-40% of carbon dioxide and 55-65% of methane. The biogas is used in organic rankine cycles or micro turbine to produce heat and power once it is cleaned and dewatered. Furthermore, the slurry produced after the process can be used as agricultural fertilizer. (35.)

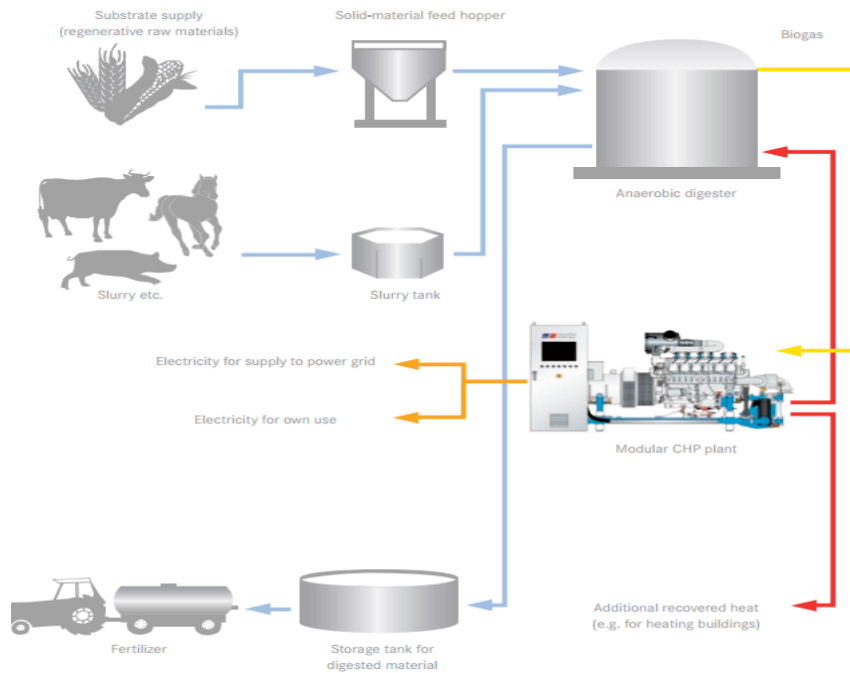


Figure 10. Biogas CHP using bio waste (36)

Figure 10 describes the general principle of a biogas production and the production of the heat and power with it. It can be seen that biogas can be produced from any kind of organic waste and furthermore, the residues can also be used as fertilizer. (36.)

There are some advantages and disadvantages to the use of biogas in the production of heat and power. Some of the advantages are that

- It is a renewable source and carbon clean technology.
- It residues after biogas production provides good manure.
- It is cost effective, as the fuel is generated from the waste and technology is cheap.

Some of the disadvantages of biogas are

- The fermentation of biogas is not possible onsite, so the transportation of compressed natural gas might increase the costs and carbon emissions.
- It is not a very attractive technology to urban society. (37.)

6 Photovoltaic integrated Rainwater Fuel cell CHP

The uses of renewable energy sources are gradually increasing. Solar photovoltaic and solar thermal or sometimes wind energy is used with fuel cell CHP technology. It is one of the best options for energy savings and for cutting GHGs emission.

Fuel cell micro CHP is still in a developing stage and relatively more expensive than the existing technologies. PEMFCs require hydrogen for operation and SOFCs use hydrogen and carbon monoxide as fuel. Fuel cells can generate the highest proportion of electricity of any CHP technology. PEM FC has been developed and used for many years though it has not been used for energy applications. Electrolysis of water has been in practice for centuries and it has been used to produce hydrogen for industrial applications. In water electrolysis, an electric current is used to split the hydrogen and oxygen. Rainwater is also suitable for electrolysis. The electricity required to the breakdown of water can be provided by photovoltaic cells or wind energy. The excess electricity can be further used for other purposes, Due to the flexibility to use with solar or wind energy, the electrolyser has been now gaining attention towards clean energy production. (38.)

The diagram in figure 11 below shows the general principle of a solar supported electrolyser that provides hydrogen gas to the fuel cell.

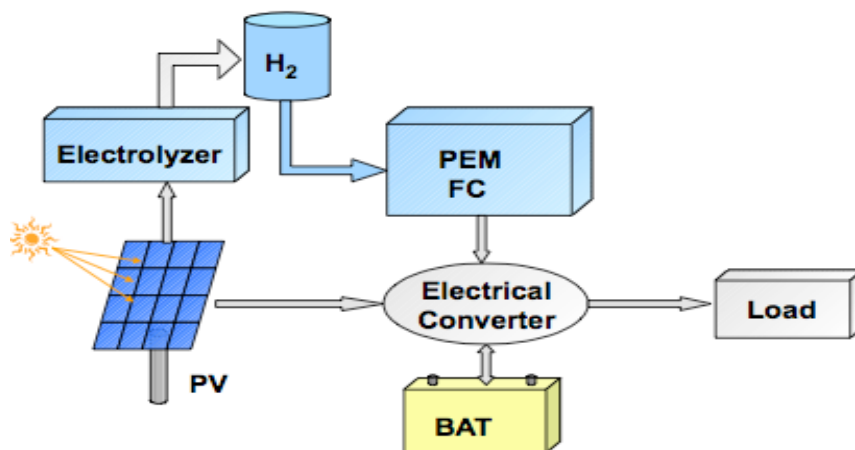


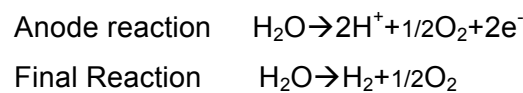
Figure 11. Photovoltaic integrated with PEM fuel cell (39)

Figure 11 shows the photovoltaic module integrated with PEM fuel cell micro CHP. It also consists of a water tank, electrolyser, battery for the storage of the electricity gen-

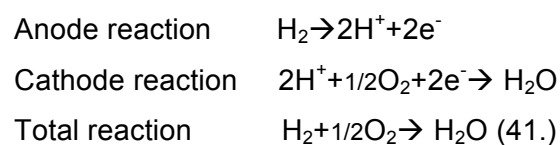
erated with solar panels and a hydrogen tank for the storage of hydrogen fuel. The electrolyser used produces the hydrogen gas, which is stored or fed to the FC system. There are batteries to supply electricity required to the breakdown of the water when the photovoltaic cells are not producing enough electricity. The proton exchange membrane fuel cell, sometimes called a polymer electrolyte membrane fuel cell, uses a water-based acidic polymer membrane as its electrolyte with platinum based electrodes. Hydrogen fuel is processed at the anode where electrons are separated from protons on the surface of a platinum based catalyst. The protons pass through the membrane to the cathode and the electrons travel to the external circuit thus generating electrical output. The cathode combines the protons and electrons with oxygen producing water. (40.)

The electrode used in the fuel cell system is the only drawback of the system as it is very expensive. Platinum and sometimes ruthenium are also used as the electrodes in PEM, which are expensive.

The reaction of the breakdown of the water during the process of electrolysis is stated below.



Fuel cell reaction of the Proton exchange membrane is shown below,



Although fuel cell micro CHP is still in the developing phase there are some devices for micro CHP.

Table 4 represents the existing fuel cell micro-chp systems and the prices along with the price of the devices in the year 2014.

Table 4. Market Prices of some Fuel cell devices (42)

Systems	Price € (2014)
PEM	
Toshiba 0.7kw	22,500
Panasonic 1kW	23 900
Plug Power 5kW	70,000
SOFC	
Kyocera 0.7kW	70,000 per kW
Sulzer Hexis 1kW	55,000
AFC (5-10kW)	10,000 per kw
Ballard 1kw	

Table 4 gives the market overview of fuel cell technologies and there are some other fuel cell micro CHP appliances found in Europe that are in use.

1. Hexis Galileo 1000N from Switzerland which uses SOFC as fuel.
2. Baxi Innotech from Germany uses PEMFC
3. Ceres from UK uses SOFC
4. Danther from Denmark using PEMFC and high temperature.
5. FutureE from Germany (43.)

The advantages of fuel cell technology are that

- Fuel cell technology has higher efficiency than existing of CHP systems.
- It is carbon free because of the breakdown of water. There is no need to burn fuel.
- It uses renewable energy sources.
- It has no moving parts, so it is noise free.
- It can run continuously as long as fuel is available and water can be used for fuel.

The disadvantages of the fuel cell technology are that

- The electrode is very expensive, requiring a high capital cost.
- It is still in an evolving phase for CHP. (44.)

7 Case studies

There are various cases that use two or more renewable energy technologies together and get a better result than a conventional boiler system. Below some European cases are introduced.

7.1 Photovoltaic Thermal integrated Heat Pump

In Northants, United Kingdom, a low-carbon four-bedroom detached building is built with the latest energy efficient solar technology integrated into the building. Solar thermal and photovoltaic systems have been used to meet the heat and power of the building demands. The carbon footprint of the photovoltaic thermal panels installed is smaller than the carbon footprints of conventional systems. The photovoltaic thermal panels are integrated with a ground source heat pump and an inter seasonal heat storage in an earth energy bank under the foundation of house which enables the low cost for heat and power. The photovoltaic thermal is *12 solar angel 250Wp* that has been installed in the roof of the building. The estimated electric output per annum-2600kWh and thermal output per annum-3000 kWh. The annual carbon savings are around 2 tonnes (45.)

7.2 Solar CHP in Sweden

In Härnösand, Sweden, a solar CHP has been installed with the peak capacity of 20kWp electricity and 100kWp heat. The photovoltaic thermal module produces thermal heat up to 75°C and electrical power 230V, by focusing the light on high efficiency photovoltaic cells, thus generating hot water and electricity at the same time. The photovoltaic thermal collector used was Absolicon X10. (46.)

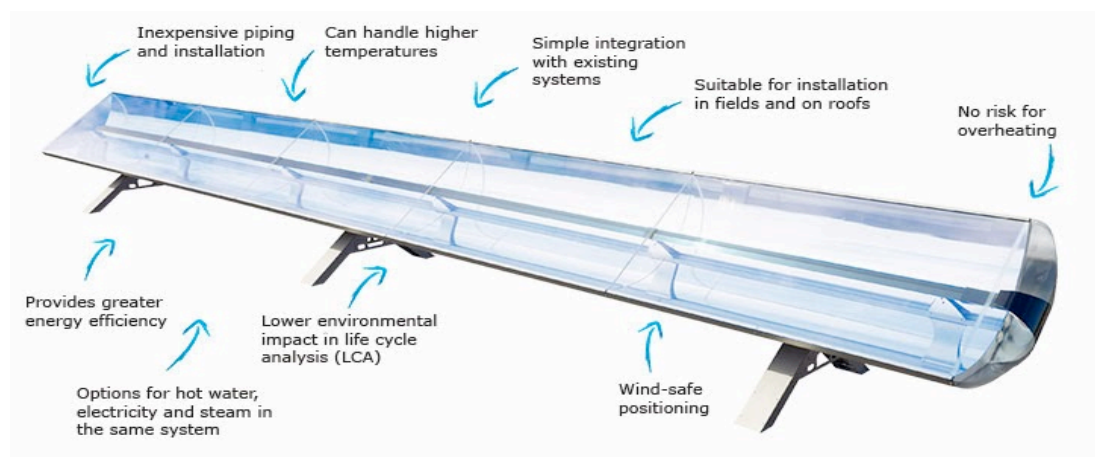


Figure 12. Diagram of Solar Collector used for CHP in Sweden (47)

Figure 12 shows the features and different parts of the Absolicon solar collector that has been used in Härnösand.

7.3 Mobile Biomass CHP

Oulu University of Applied Sciences has built a mobile CHP unit for distributed energy production. The system is built in a container which consists of an internal combustion engine, a generator and a unit to feed the energy to the grid. The container can easily be moved at different locations where the heat and power are required as well as to the site nearby the fuel is produced (wood pellet or biogas) units, in order to reduce cost of fuel transportation and helps reduce carbon emissions. The device that is used in the campus is Volter 40 (see figure 13). Wood chips are used as fuel. The electrical capacity of the container is 40 kW and the total thermal power is 100kW. A remote Internet control has been used to monitor the system. (48.)



Figure 13. Volter 40 (49)

Figure 13 shows the product Volter 40 which is used in the Oulu campus for the mobile CHP that produces heat and power from wood chips.

The other technologies used for micro CHP available in the European are listed below in table 5.

Table 5. Available Products in Europe for Biomass Micro CHP (50)

Products	Electrical output(kW)	Efficiency(Total) %
Senertec Dachs 5.5	5.5	27(88–99)
EC Power XRG1 15	15	30(92)
Viessmann Vitobloc 200	18	32(96)
Capstone C30 LP	28	25
Buderus Loganova EN50	50	34(88)

Table 5 also shows some of the existing products for biomass micro CHP along with their potentials and efficiency of the products. This may assist in the process to choose a product for the campus.

7.4 Heat pump and Micro CHP

In Norte Dame Primary School, Glasgow, United Kingdom, a ground source heat pump and biomass CHP are integrated to provide the energy for building. In the building underfloor heating has been used to optimize the space. The operating temperature of the heating system of the school is 45°C which lends low surface temperatures for the radiators making the building safe for students. The devices that have been used in the school are two sets of Baxi Commercial Division products, which produce 27.5 kW of electricity during the day and 16.5kw at night according to the requirement of the building. Baxi monitors the micro CHP through a modem link installed in plant-room. After the installation of the CHP in the school they were able to save around 60,000€ and cut the emissions by 90,000tonnes. (51.)

8 Environmental and Economic Performance Analysis

The cost of electricity from the national grid for electric and thermal energy is rising year by year. In the EU, over 100,000 people are employed in the heating industry and over eight million boilers are sold in EU. Micro CHP is one of the heating industry's next generation products worth €20billion a year. The EU innovation union has targeted to invest 3% of its gross domestic product on R and D by 2020 for the micro-CHP creating around four million jobs and adding €800 million in the GDP by 2025. (52.)

Table 6. Contribution from the Renewables (53)

Sources	Savings kwh/a	Savings €/a	Investment	CO2 savings
Ground Source Heat Pump	14000-17000	1800-2200	14000-20000	8 million tons
Air to Air	2000-7000	250-800	1500-2500	
Photovoltaic	2-4 euro per watt			

Table 6 illustrates the contribution of the solar PV energy and different heat pumps in Finland towards the emission and bill cuts.

The traditional and currently used fuel types produce plenty of greenhouse gases. In order to diminish that and create a green world, renewable sources should be used more. The table 7 shows the emissions from the combustion of traditional sources of fuel for the cogeneration of heat and power for a house that uses 20000kwh/year. (54.)

Table 7: Carbon Emission from Different Fuel Combustion. (54)

Fuel	Net Calorific Value MJ/kg	Carbon Content %	Life cycle Co2 emissions(kg/MWh)	Annual Total emissions for a house(kg)	
Oil	42	85	314	6280	
Coal	29	75	414	8280	
LPG	46	82	259	5180	
Natural Gas	38	75	227	4540	
Wood pellets	17	45	90	1500	

There are various fuel types available in the Finnish markets either produced in Finland or imported from other nations. The variation in the market price of different fuels in a course of time is shown in figure 14 below.

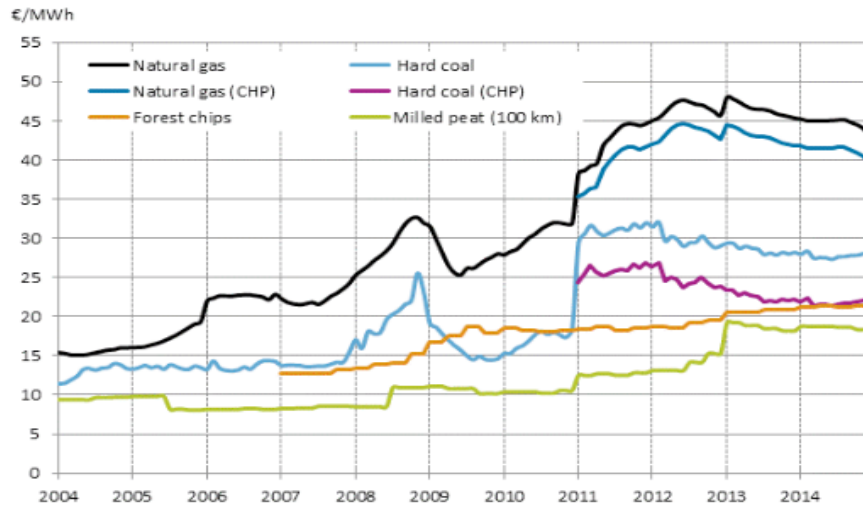


Figure 14. Cost of Different Fuels in Finland (55)

Figure 14 shows that the cost of forest chips is a lot lower than that of other existing fuel sources except for milled peat. From table 7 and figure 14 it can be clearly seen that in Finland, wood pellets or forest chips are the renewable source that is more cost effective than other energy sources, except for the free form of energy, i.e. hydro, solar and wind energy. (55.)

When all the options mentioned above are analyzed, it can be said that fuel cells are more expensive than the other two technologies. Finland has both biomass and biogas in abundance. The use of solar energy is beneficial despite the harsh winter factor. Because of the increase in prices of natural gas and oil as well as increasing greenhouse gas emissions from the conventional system of cogenerating heat and power, micro CHP with a clean and renewable energy source can play a vital role to cut the emissions and save energy costs.

The attitude towards the use of the solar energy in Finland has to be changed. The harsh winter and snow factor have been considered as the reason for not being interested towards solar energy. However, the performance of photovoltaic system is not that worse in winter. Solar thermal system might not always perform well but the use of a heat pump with integrated CHP compensates the energy required for the space

heating and domestic hot water. The excess heat from the summer can be stored in the GSHP for winter purposes. Furthermore, the GSHP can be used for cooling in the summer time if necessary.

A third of the Finnish land mass is occupied by forests. Wood is the most important source of bioenergy in Finland, almost a quarter of the total energy consumption, which is an important factor when reducing carbon emissions. The various cases introduced above clearly shows that there is significant reduction in the costs and greenhouse gas emissions after the use of clean energy technologies for cogeneration of power and heat are employed. (56.).

The main purpose of the thesis was to analyze the possibility to construct a movable hybrid micro CHP for a lab at the Metropolia Campus. The combination of biomass micro CHP with a ground source heat pump and solar photovoltaic thermal collector in a sea container can be a good option. A remote control system can be installed to both monitor the whole system and for sun tracking. Sun tracker helps to monitor the solar energy and helps to switch the CHP system on when the solar energy is negligible.

A sea container is used to fit a biomass micro CHP device (a volter 40 can be used as it is available in Finland and has been already in use). The solar panels can be installed on the roof of the container or can be used on the roof of the campus building, in necessary angle. Ground source heat pump can installed close to the container or within the campus building for the heating purpose of the building for which the campus needs a permit to dig the borehole. The heat from the solar panels can be used to heat the building. When heating is not required the excess heat can be stored in the installed heat pump.

9 Conclusion

In essence, to achieve the target set by the EU, that is to reduce the carbon emissions and energy costs by using renewable energy source, the use of micro CHP with solar, wind and geothermal energy is very productive and profitable. This project was done in order to study the possibility to make a renewable hybrid micro CHP for a lab of the Metropolia Campus to supply the heat and power produced by the system to the campus building.

In residential areas, which are connected to the district heating system where the transmission loss is comparatively low, the use of micro CHP is not very productive, though integrating the solar energy and wind energy with district heating might be effective in the control of GHG emissions. Micro CHP reduces energy costs by 30% and CO₂ by 1.5 tonnes from a typical house.

Solar CHP and using solar energy with Biomass fuelled CHP in small scale, as we have mentioned in the report, might be very effective to environment and economy. Tax reduction for new technologies that use renewable energy sources will encourage the adoption of the technologies. Increasing the awareness about micro CHP and its advantages might play a vital role to encourage locals to increase investments in the renewables and the technologies thus helping in the emission cuts.

The report provided an outlook of the hybrid micro CHP that can be built for a lab of the campus of Helsinki Metropolia University of Applied Sciences. The device when built in lab can provide the students (future engineers) the possibility of using renewable energy sources along with existing technology at the same time to achieve sustainable and carbon free environment. Students can use the idea to implement to their clients, when working, describing the benefits of the renewable resources and their uses.

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