RECENT

# Renewable Community Empowerment in Northern Territories

## BASELINE REPORT


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# INTRODUCTION

This report is published within the Renewable Community Empowerment in Northern Territories (RECENT) project. RECENT is a three-year project of the Northern Periphery and Arctic (NPA) Programme, which provides a service for small-scale rural communities to improve their energy profile based on the utilization of unused potential through the application renewable energy and energy efficiency solutions. The project is led by the International Resources and Recycling Institute in Scotland, in partnership with Action Renewables in Northern-Ireland, Mayo County Council and Clár-ICH in Ireland, University of Oulu in Finland and Jokkmokk municipality in Sweden. The Northern Periphery region and the location of partners are illustrated in Figure 1.

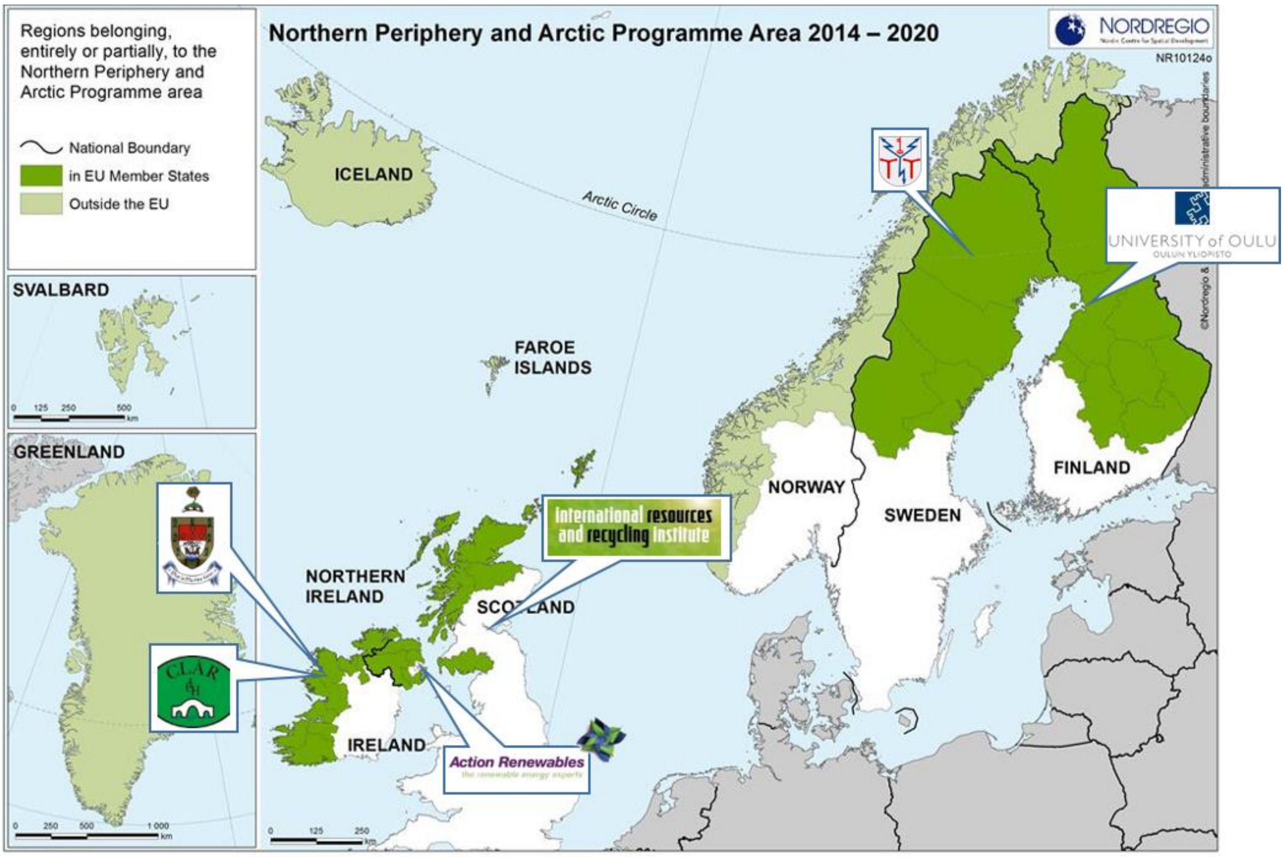


**Figure 1** Northern Periphery and Arctic programme area with the locations of RECENT project partners

The aim of RECENT is to improve energy security of northern communities via implementation of available energy technologies in the sector of public critical infrastructure: water, energy, waste and others. Symbiotic solutions are also considered in the project and will be developed for the pilot communities in the RECENT partner countries. As a result of conducted activities, there will be twenty four pilot sites chosen, monitored and assessed. Six of them will include synergies of unused energy potential within such sectors as water, energy and/or waste.

This report provides baseline information regarding northern communities involved in the NPA project – at most, on a country level – their critical infrastructure state, in particular, water services; and energy solutions intended to improve regional energy security and self-sufficiency. The report describes water services in Scotland, Northern Ireland, Ireland, Finland and Sweden. Regional comments regarding areas involved in the project are provided in the end of each section. The main aspects discussed are water coverage, organization of water services, ownership issues, water regulation and financing water services. Available energy efficiency and renewable energy technologies are discussed to recommend the solutions to work in the Northern Periphery and Arctic region. Existing financial mechanisms for implementation and support of the considered energy solutions are also listed, in each country interests. This report represents the first publication executed within the RECENT project.

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# 1 WATER SERVICES

Water services are critical for the society to function properly. If water supply would suddenly stop, it would affect every sector in the society, from consumers to producers. The water supply network is part of a critical infrastructure. All parts of the critical infrastructure are interconnected and exist in coherence. This is also a common feature of the critical infrastructure; and as a rule: if one system fails, then usually others do too. (Puolustusvoimat, 2013)

This report describes the water services of Scotland, Northern Ireland, Ireland, Finland and Sweden. Below is description of differences and similarities in organization of this critical service. This chapter aims to provide an overview enough to serve as a baseline for further decision making in energy security improvements.

## 1.1 Scotland


Scotland is famous in the UK for its abundance and purity of fresh waters; 90% of the British freshwater volume is concentrated in Scotland. Freshwater lakes and rivers cover 2% of the Scottish territory, and one of the deepest lakes in Europe, Loch Morar, is situated in the country. In total, there are more than 30 000 lakes and 10 000 rivers in the country. The tap water in Scotland is potable: 99,91% of water samples taken from customer taps comply with drinking water standards. (SE, 2003; SNH, 2001 and 2002; Scottish Water, 2013a) When it comes to water supply, 93% is from surface water and 7% from groundwater. Water services are provided by a single public company: Scottish Water. Water supply and wastewater treatment are available for about 98% of the population. The rest rely on private water supply sources that do not belong to Scottish Water. (Ó. Dochartaigh, *et al*., 2011; Scottish Water, 2014a; SmithsGore, 2014)

### Water supply and sanitation in Scotland

The organization of the water supply and sanitation system in Scotland is illustrated in Figure 2. The water users are connected to water supply and wastewater treatment system operated by Scottish Water. (Scottish Government, 2013)

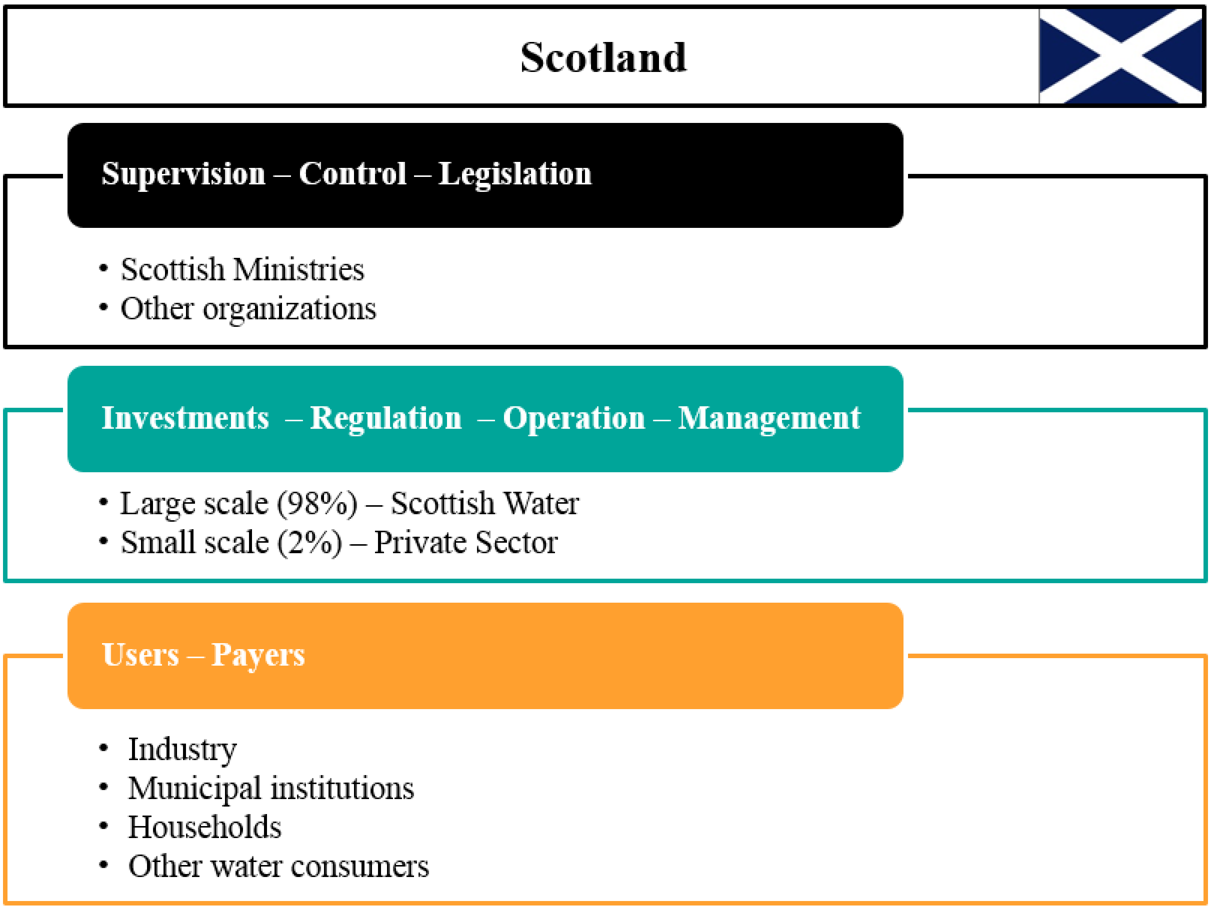


**Figure 2** Organization of water supply and wastewater treatment in Scotland

In terms of operation, Scottish Water own 98% of water facilities and is in charge of water services. A small share, 2% is taken by private water treatment facilities, mainly in rural areas. Scottish Water operates 252 water supply facilities and 1 865 wastewater treatment plants. Scottish Water is a state-owned company that is subordinated by the Scottish Parliament. At the same time, its management and structure are similar to private companies. The company owns not only such assets as water preparation and wastewater treatment facilities, pumping stations, pipeline networks and sewers, but also land. According to Thomson (2013), Scottish Water holds more than 240 sq km as rural catchment estates. Recently, there has been renewable energy development (mostly wind energy and micro-hydropower) on these estates. This serves as an answer to the current goal of the public company to transform from being one of the largest energy consumers in Scotland towards energy self-sufficiency. In terms of water resources in the country, historically, it was common that land owners had an extended water ownership right. Currently, this is not considered as appropriate for water resource management. In practice, the right to manage water resources has shifted from the private sector to a public entity. Water ownership has become a problem of public interest and object of its control. (EC DGRP, 2004; Hendry, 2013; Scottish Water, 2014a; Scottish Water, 2013b; Thomson, 2013)

The water supply originates mostly from lakes, rivers, reservoirs and partly from boreholes. The drainage system collects storm water and wastewater coming from households and industry. One third of wastewater is composed of storm water from roofs, sidewalks, parking areas and public roads. Scottish Water is responsible for the full cycle of drinking water supply and wastewater treatment including sludge utilization. A larger part of the sludge is recycled whereas a smaller part is disposed at landfills. (Scottish Water, 2014a; Scottish Water, 2014b)

On the supervision level, there are number of Scottish Ministries influencing water services, such as water fees strategy, policy and vision of the water sector, environmental aspects, drinking water quality, customer service and so on. Public authorities are also responsible for making decisions about the amount of financing available to lend to the water company. (WICS, 2013)

Other regulators, to which Scottish Water is responsible to, are the Water Industry Commissioner for Scotland, the Scottish Environment Protection Agency, the Scottish Executive Water Services Unit (Drinking Water Quality Regulator) and Consumer Futures. The following organizations play important roles and have key functions in the Scottish water sector (Mohajeri, *et al.*, 2003; Scottish Water, 2014d; WICS, 2013):

- The Water Industry Commission for Scotland (the Commission): it deals with the amount of customer fees and acts as an economic regulator;
- The Scottish Environment Protection Agency (SEPA): it conducts monitoring of wastewater discharges as well as determines the standards for it. The main role of SEPA is to promote sustainable development and environmental protection as well as to prevent negative influence on human health. It acts as an environmental regulator;
- The Scottish Executive Water Services Unit (Drinking Water Quality Regulator [DWQR]): it monitors the quality of supplied drinking water and sets the standards for it;
- Consumer Focus Scotland (CFS): it acts as a voice of the water consumers in water issues and water fees;
- The Customer Forum: it represents customers' interests when working with strategic issues in the water sector: e.g. water charges, customer preferences;
- The Outputs Monitoring Group: it is responsible for monitoring the outputs that Scottish Water has to deliver. The main goal is to make it clearer and easier for water consumers to

understand the outputs. The group consists of representatives from CFS, the DWQR, SEPA, the Commission, the Scottish Government and Scottish Water.

There is a number of water related regulations in Scotland, the most important being (Scottish Government, 2014a):

- The Water Industry Scotland Act 2002;
- The Water Services etc. (Scotland) Act 2005;
- The Water Supply (Water Quality) (Scotland) Regulations 2001;
- The Provision of Water and Sewerage Service (Reasonable Cost) (Scotland) Regulations 2011 (SSO 2011/119).

The EU Water Framework Directive is implemented in Scotland. (Scottish Government, 2014b)

### Customer water fees in Scotland

The main source of funding to maintain water services comes from customer fees. Other possible financial support flows are provided by the Scottish Government. (Scottish Water, 2014d)

There are three general categories of customer water fees in Scotland (Scottish Water, 2014c):

- Water supply fee;
- Wastewater treatment fee;
- Other fees.

The first two categories are applied only if a household or business property is connected to the public water network. The third one includes such services as connection to the public network, standpipe license issue, septic tank de-sludging, provision of information, inspection and application processes. (Scottish Water, 2014c)

Water supplied fees are charged from those consumers, who have a water meter in their household. A metered household is charged with two fees: the annual fixed fee and the volumetric water fee. The annual fixed fee is paid for operation and maintenance of the pipeline system, wastewater treatment facilities and pumping stations. An approximate value for this fee is about 174 euros. The volumetric water fee is collected for every cubic meter of water consumed. It applies to the first 25 $m^3$ of fresh water consumption with one rate (approx. 2,7 euro/$m^3$) and from the $26^{th}$ $m^3$ and further with another rate (approx. 0,9 euro/$m^3$). If a household is not equipped with a water meter, a variation of the water supply fee is used. For households, the collected fee can vary from 155 euros to 465 euros and the amount of fee depends on the Council Tax Band system. It consists of 8 levels: from A to H. The lowest fee is charged according to Tax Band A and, respectively, the highest according to Tax Band H. (Scottish Water, 2014a; b; c)

The annual fixed fee and volumetric fee for wastewater treatment are based on the same factors, which determine the water supply fees. However, wastewater generation is considered to be 5% less compared to fresh water consumption. An approximate value for the wastewater treatment fee is around 179 euros. The volumetric fee for the first 23,75 $m^3$ is about 3,5 euro/$m^3$ and, for volumes beyond 23,75 $m^3$, approximately 1,7 euros/$m^3$. In case there is no water meter in a household, based on the Council Tax Band system, the collected wastewater fees varies: from 180 to 540 euros. (Scottish Water, 2014d) Therefore, the average combined water service fee in Scotland is about 415 euros, which is lower than in England or Wales. (Scottish Water, 2014d)

Apart from the regular wastewater treatment fees, Scottish water consumers pay two other charges (Scottish Water, 2014b):

- Property drainage fee;
- Roads drainage fee.

The drainage fees are also related to the Council Tax Band system. The two fees are identical in cost. The lowest fee of Band A is about 36 euros, whereas the Band H value is approximately 108 euros. The property drainage fee is collected for rainwater, which is directed to the sewer system of the public company. Usually, this water originates from the property roofs, private parking areas and private roads. The roads drainage fee, in turn, concerns storm water from public roads and sidewalks. Both of the fees are levied from households only if applicable. (Scottish Water, 2014b)

The secondary services, which are covered by other fees, are rather varied. One of the most essential services is connection to the public network. In this respect, there are two types of connection fees: for the connection to the pipeline system providing water supply and for the connection to the wastewater treatment network. Both of the fees are equal and are about 409 euros each. (Scottish Water, 2014c)

## 1.2 Northern Ireland


Marine waters have both industrial and recreational importance for Northern Ireland. Due to growing energy demand during recent years, there is a tendency of utilizing offshore wind energy, as well as tide and wave power. About 7% of Northern Ireland is covered by surface water bodies. (Christie, 2011; NIEA, 2013) In total, there are about 3 200 rivers and 1 700 lakes in the country

(Mehaffey, 2014). The 1,8 million inhabitants of Northern Ireland receive about 562 000 $m^3$ of drinking water on a daily basis. In Northern Ireland, the water supply originates mostly from lakes and rivers (55,95%) as well as reservoirs (44%). The biggest lake, Lough Neagh, supplies 50% of the country's drinking water. Only 0,05% of water supply comes from groundwater sources. In England and Wales, by comparison, about 35% of the water supply is from boreholes. Water services are provided by Northern Ireland Water, a public authority. Public water supply is available for 99,9% of the population of Northern Ireland. In turn, wastewater treatment is provided for 96,5% of the inhabitants. The water is potable; 99,83% of samples taken comply with drinking water standards. (Christie, 2011; NIEA, 2013; NIW, 2012; NIW, 2013; Rippey, *et al.*, 2001)

### Water supply and sanitation in Northern Ireland

The organization of water supply and wastewater treatment in Northern Ireland is illustrated in Fig.3.

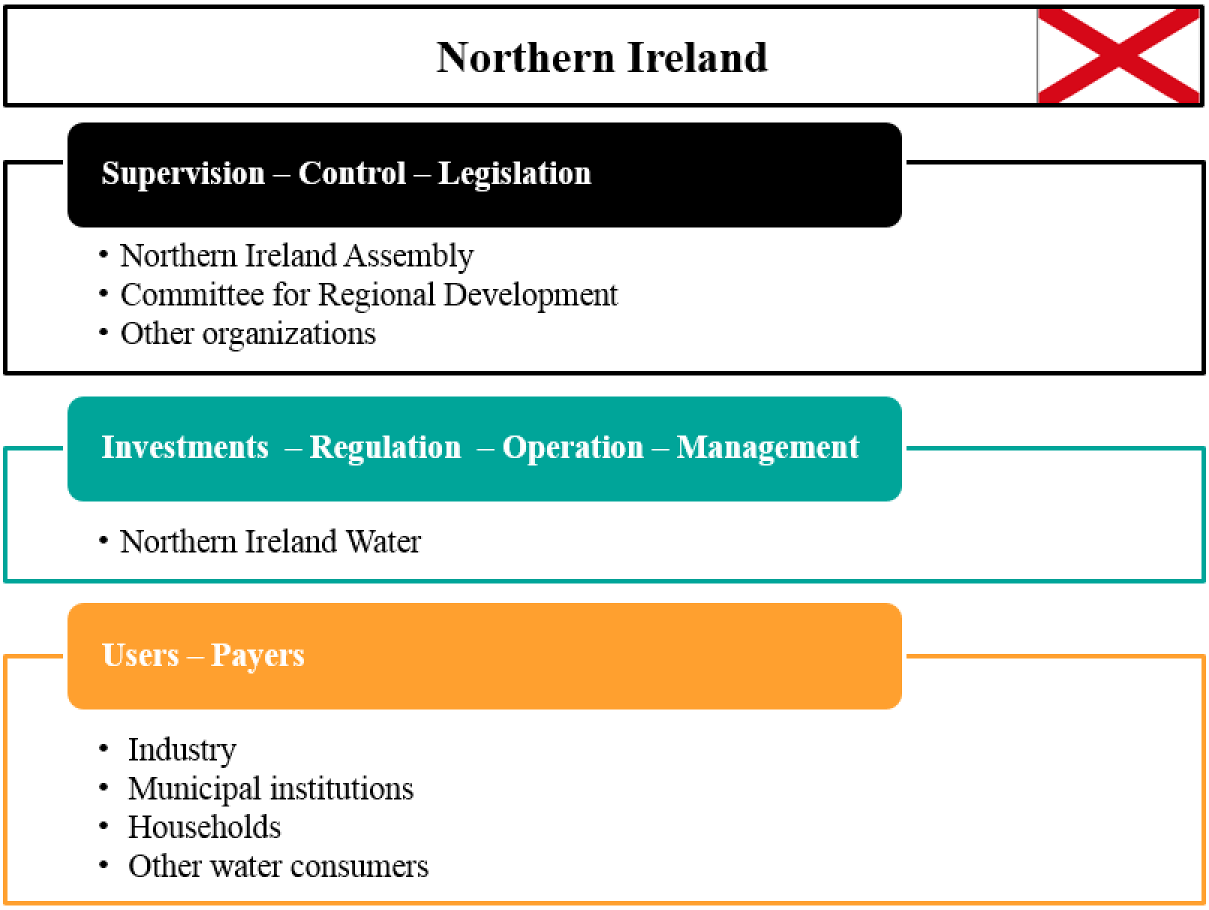


**Figure 3** Organization of water supply and wastewater treatment in Northern Ireland

In Northern Ireland water services – both water supply and wastewater treatment – are provided by a government owned company – Northern Ireland Water (NIW). (NIW, 2013b; McGuigan, G, 2010) NIW is responsible for investments, operation, regulation and management of water services. The water treatment services provided by NIW consist of screening, chemical treatment and clarification, filtration, disinfection and pH adjustment. There are 25 drinking water preparation facilities in the country. NIW is also responsible for wastewater collection and the treatment that the water can be discharged into rivers and the sea. Storm water is also collected into the public sewer network. The wastewater treatment process includes 4 stages: preliminary step (screening, grit removal), primary step (sedimentation), secondary step (biological filtration/activated sludge) and final step (sedimentation). NIW operates more than 1 000 wastewater treatment works in the country. The operating area of the water company is mainly rural. Northern Ireland Water owns 71 impounding reservoir structures, some land holdings, a network of pipes, pumping stations, sewers, water treatment and wastewater treatment works. (NIA, 2014; NIEA, 2013; NIW, 2012; NIW, 2013; NIW, 2014a; UR, 2013)

In terms of supervision and control, the Northern Ireland Assembly and the Committee for Regional Development monitor the activities of NIW. (NIW, 2013) Ministry for Regional Development under the Northern Ireland Assembly and the Committee for Regional Development are the key legislative bodies. The Department for Regional Development of the above mentioned ministry is in charge of water policies as well as deals with funding of the water company and solving problems related to customer subsidies, investments, lending, etc. The other organizations relevant to water services are (NIW, 2013):

- Northern Ireland Environment Agency. The agency deals with natural environmental heritage and its preservation. It regulates the NIW activity in terms of its compliance with all the needed regulations and environmental permits;
  a) Drinking Water Inspectorate for Northern Ireland: it is responsible for drinking water quality control;
  b) Water Management Unit: it is in charge of the water pollution and protection of water bodies;
- Northern Ireland Authority for Utility Regulation: it provides information for water users and acts as an economic regulator on water, electricity and gas markets;
- Consumer Council for Northern Ireland: it acts as the water consumers’ voice and represents their interests. It also gives advice and provides information to water service users.

The EU WFD is also in use in Northern Ireland. In addition, there are various water related policy drivers and regulations, such as (NIEA, 2013):

- The Groundwater Directive (2006/118/EC): it regulates and prevents contamination of groundwater reserves;
- The Drinking Water Directive (80/778/EEC): it controls pollution of and ensures drinking water quality to protect human health;
- International Decade for Action 'Water for life' 2005-2015: it promotes implementation of water related measures as international commitments by 2015;
- The Water Environmental (Water Framework Directive) regulations (Northern Ireland) 2003: it controls and sets standards for quality of river waters.

### Customer water fees in Northern Ireland

The water service fees in Northern Ireland are (NIW, 2014b):

- Water supply fee;
- Wastewater treatment fee;
- Other fees (e.g. connection fee, septic tank de-sludging).

The system of fees is rather close to that of the Scottish system. However, domestic water users are not obliged to pay any fees. Instead, the Department for Regional Development is covering the fees. The other fees can be collected from domestic customers, for example, if a septic tank de-sludging procedure is ordered more than once a year. Other than that, domestic water users are subsidized by government, with a 100% water service discount. Water use by default is not measured in the households of the country. (NIW, 2014b)

Non-domestic water customers, in turn, must cover water services provided by NIW by paying respective annual fees. The used fee depends on whether there is a water meter installed or not. (NIW, 2014b) If water consumption is metered, the only variable parameter is a supply pipe diameter. The bigger the size of supply pipe, the higher the payment will be. There is a range from less than 20 mm to more than 100 mm. For instance, if it is up to 50 mm, the annual fee for water supply will be 388 euros. If it is over 100 mm, water supply will cost for a non-domestic customer 1 971 euros. The latter fee is called a standing charge for water supply. As an additional fee to a standing charge, there is a variable charge. This fee is collected from a water user depending on the volume of water measured by the water meter. For every cubic meter, the charge is 1,25 euros. When it comes to wastewater generation and related fees, the situation is similar to water supply; there are standing and variable charges. The standing charge can, in accordance with the size of supply pipe, be from 93 euros (for the pipe less than 20 mm in diameter) to 2 256 euros (for the pipe more than 100 mm diameter). The variable charge for wastewater is set at 2 euro per $m^3$. (NIW, 2014b)

When water consumption is not metered, there are the same types of fees as in the previous scenario, with a difference in variable charge. This is set in proportion to the non-domestic property valuation. This procedure is done by Land and Property Services on request. For every 1 000 pound sterling (1 228 euro) of the property value, a non-domestic customer should pay about 12 euros as a variable charge for water supply and approximately 17 euros as a variable charge for wastewater. The charge cap is set at the level of 497 euros for water supply and 528 euros for sewerage. The standing charge is respectively 32 euros for water supply and 44 euros for wastewater. Other possible fees include septic tank de-sludging (91 euros) and connection fee (310 euros). (NIW, 2014b)

## 1.3 Ireland


Republic of Ireland occupies five-sixths of the territory of the Island of Ireland. The country is rich in water resources: surface water bodies cover 2% of the country and availability of fresh water is one of the highest in Europe. (Mohajeri, *et al.*, 2003; CIA, 2014)

There are a total of 4 467 lakes and 80 rivers in Ireland. The main source of water supply (around 82%) is the lakes and rivers. The share of groundwater is about 10% of the total water supply, whereas the rest, 8%, originate from springs. 99% of the population has access to water supply and 99,5% to wastewater treatment. The numbers include both public and private water services. Public water supply provides water for approximately 80% of the population. The water supplied by public water authorities is potable. The chemical compliance with drinking water standards is 99,5%. The wastewater treatment share provided by public authorities is about 70%. (Mohajeri, *et al.*, 2003; DCC, 2009; OEE, 2011; ECLG, 2012)

### Water supply and sanitation in Ireland

Water services are run by a single state organization – Irish Water. (ERVIA, 2015) Figure 4 shows the Irish system of water supply and wastewater treatment. Water services are provided by the public sector. The average daily water supply provided by water authorities is 1,6 million litres. (CIA, 2014; ECLG, 2012) Irish Water is in charge of the provision of water services for domestic and non-domestic customers as well as for strategic planning and development on national level, investment programs, operations and upgrading of current water infrastructure. It is of present importance to draw attention to aged and variable quality infrastructure in the country.

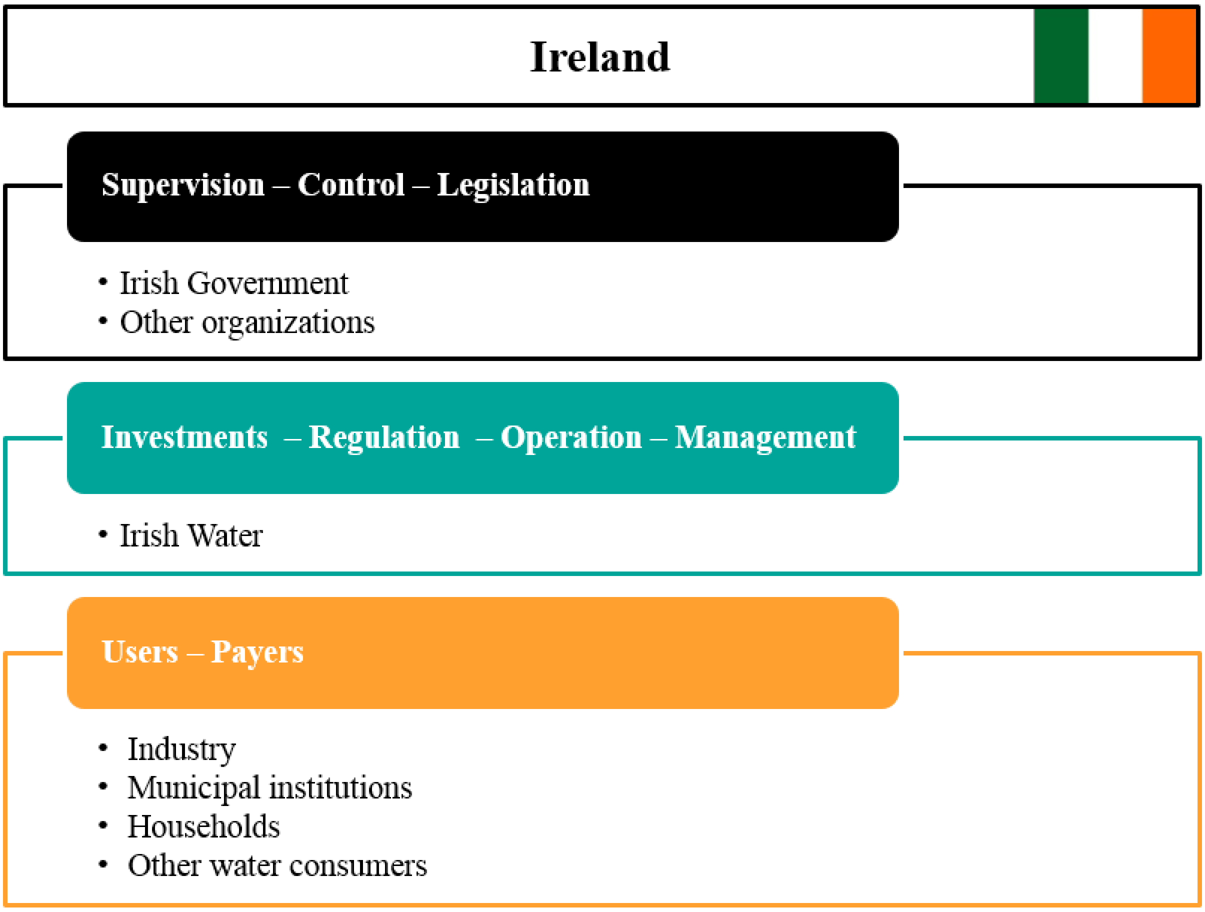


**Figure 4** Organization of water supply and wastewater treatment in Ireland

In the beginning of 2015, 180 000 properties and 120 water schemes were questioned to meet the standards for drinking water supply. As a result, these are the first priority issues to be dealt with by Irish Water. (ERVIA, 2015; BD, 2013; ECLG, 2012)

In 80% of the cases, Irish water has ownership for water services, infrastructure, pumping stations and water preparation and wastewater treatment plants. The public water supply is mainly organized from surface waters. The private companies and Group Water Schemes provide water services for the rest of the population (10% each). (Mohajeri, *et al.*, 2003; NPP, 2014c; ECLG, 2012; Tierney, 2013)

The Group Water Schemes (GWS) come in two forms: private and semi-private (Mohajeri, *et al.*, 2003). The main difference is the source of water supply. In the semi-private variant, the drinking water originates from public water network. It is metered and paid according to the amount of water consumed by the group. In this case, a group of households usually makes special purchase agreement with the public authority. Private GWS, on the other hand, receive water from the group's own water source, such as a well or springs. This scheme is used mostly in rural areas. The main reason for the existence of GWSs is that there are some households in Ireland that do not have access to a Sanitary Authority drinking water supply. In 1997, the number of non-connected dwellings was around 200 000, but nowadays it is about 3 000 households. GWSs can receive financial support from the public sector for their operations. (Mohajeri, *et al.*, 2003; ECLG, 2012)

In terms of supervision, control and legislation, the Government of Ireland is in charge of controlling the activities of Irish Water. In addition, the Department of the Environment, Community and Local Government, local authorities and Board Gáis Éireann group support the establishment and operations of Irish Water. (DECLG, 2012)

Other regulators, to whom Irish Water has to answer, are (Mohajeri, *et al.*, 2003; BD, 2013):

- Environmental Protection Agency. EPA is in charge of pollution control and mitigation of negative environmental influences from the water industry. It also issues licenses for wastewater discharges, thus, supporting the “polluter pays” principle;
- Commission for Energy Regulation. This acts as an economic regulator. It sets the water charges both for domestic and non-domestic customers.

The WFD is applied also in Ireland. In addition, there are many other regulations affecting the Irish water sector. For example, the acts and laws are listed below (Mohajeri, *et al.*, 2003; ECLG, 2012):

- The Local Government (Sanitary Services) Act, 1964;
- The Private Water Supplies and Sewerage Facilities Regulations, 1978;
- The Local Government (Water Pollution) Act, 1990;
- The European Communities (Quality of Salmonid Waters) Regulations, 1988;
- The European Communities (Quality of Water Intended for Human Consumption) Regulations, 1988;
- The European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989;
- The Local Government (Financial Provisions) Act, 1997;
- The Environment Protection Agency Act, 1992;
- The Local Government (Dublin) Act, 1993;
- The Local Government (Water Pollution) (Nutrient Management Planning Consultation) Regulations, 1998;
- The Water Pollution Act, 1990;
- The Water Services Act, 2007;
- Other regulations.

## Customer water fees in Ireland

Before 1997, there were charges for water services. In 1997, after the Local Government (Financial Provisions) Act was introduced, the water customer fees for domestic users started to be subsidized. In practice, this meant that domestic water supply and wastewater treatment became free of charge. Non-domestic customers were and are obliged to pay water fees. As a rule, water consumption at industrial, agricultural and commercial enterprises has been measured with water meters. In addition, these non-domestic users have to pay a connection fee when connecting to the public water network. The same is applicable for Group Water Schemes of more than 5 households. For other domestic water users, connection to the public network is free of charge. (Mohajeri, *et al.*, 2003)

Nowadays water charges are introduced for domestic customers. The amounts for water fees are described below. There are two possible options of water fees for domestic customers (Irish Water, 2015):

- Equipped with water meter:
    a) Water supply fee – 1,85 euro/$m^3$;
    b) Wastewater treatment fee – 1,85 euro/$m^3$.

The organization has a cap for charges depending of the house type: single adult or multi adult household. Respectively, it is 160 euro and 260 euro per year.

- Not equipped with water meter:
    a) Assessed water supply fee;
    b) Assessed wastewater treatment fee.

In this case there is also division for single and multi adult households. For single households, water supply fee is set to be 160 euro per year, whereas wastewater treatment fee is 80 euros annually. 260 euro and 130 euro are the fees for multi adult households on the annual basis. (Irish Water, 2015)

As an additional and distinctive feature in Ireland, there is also a special “water” support for children in Ireland aged 17 years old or under. Every child should have free access to 21 $m^3$/year of drinking water supply and a free wastewater treatment service for respective amount of sewage. Hence, if we consider an average Irish family of 4 people and its average water consumption of about 190 $m^3$ per year, they will have to pay for 148 $m^3$ of water supplied and appropriate volume of wastewater collected. These subsidies save more than 20% of the total amount to be paid as water service fees. (Irish Water, 2015)

## 1.4 Finland


Finland is often called the “land of a thousand lakes”. According to the statistical data of Finnish Water Forum, there are about 188 000 lakes and 650 rivers in Finland. Water bodies cover about 10% of the country’s territory and provide essential recreational value for the country. The volume of fresh water reserves is 21 000 $m^3$ per person per year. When it comes to the Finnish water supply system, ground water reserves play a more important role compared to surface waters. Ground water share of total water abstraction in Finland is 65%. The main reasons of groundwater use are high water quality, good availability and security of supply. Water supply and wastewater treatment are available for 90% and 81% of the population, respectively, provided by public authorities. The rest of the population also has access to water services but not from public water services providers. The tap water is potable all through Finland. (FWF, 2012 and 2014)

Within the RECENT project, we only consider the counties of Northern Ostrobothnia and Lapland. The territory of Northern Ostrobothnia is 37 417 km² and of Lapland 98 983 km². Northern Ostrobothnia has 4 280 lakes and its water coverage is about 5% whereas Lapland has 19 923 lakes and water coverage is about 6.4%. The use of ground water as drinking water is only 66% in Northern Ostrobothnia but 100% in Lapland. Public water supply covers 99% of the households in Northern Ostrobothnia and 91% in Lapland. Public wastewater treatment covers 79% of the households in Northern Ostrobothnia and 76% in Lapland. There are about 130 drinking water plants and 28 wastewater plants in Northern Ostrobothnia, and 95 drinking water plants and 34 wastewater plants in Lapland. Operators do not own the land or water resources. Domestic customer fees varies a lot, depending on the municipality. (Kangaskokko 2015; Ministry of Environment 2016a, b).

### Water supply and sanitation in Finland

Figure 5 illustrates the system of water supply and wastewater treatment in Finland. There are three levels of stakeholders. At the base are the customers; households, industry, different public institutions and other possible consumers. On the operational level, there is a difference between Finnish towns and the countryside. In the cities, municipalities own and provide water services. The public sector is in charge of regulation, investments, funding control, maintenance, operation and management.

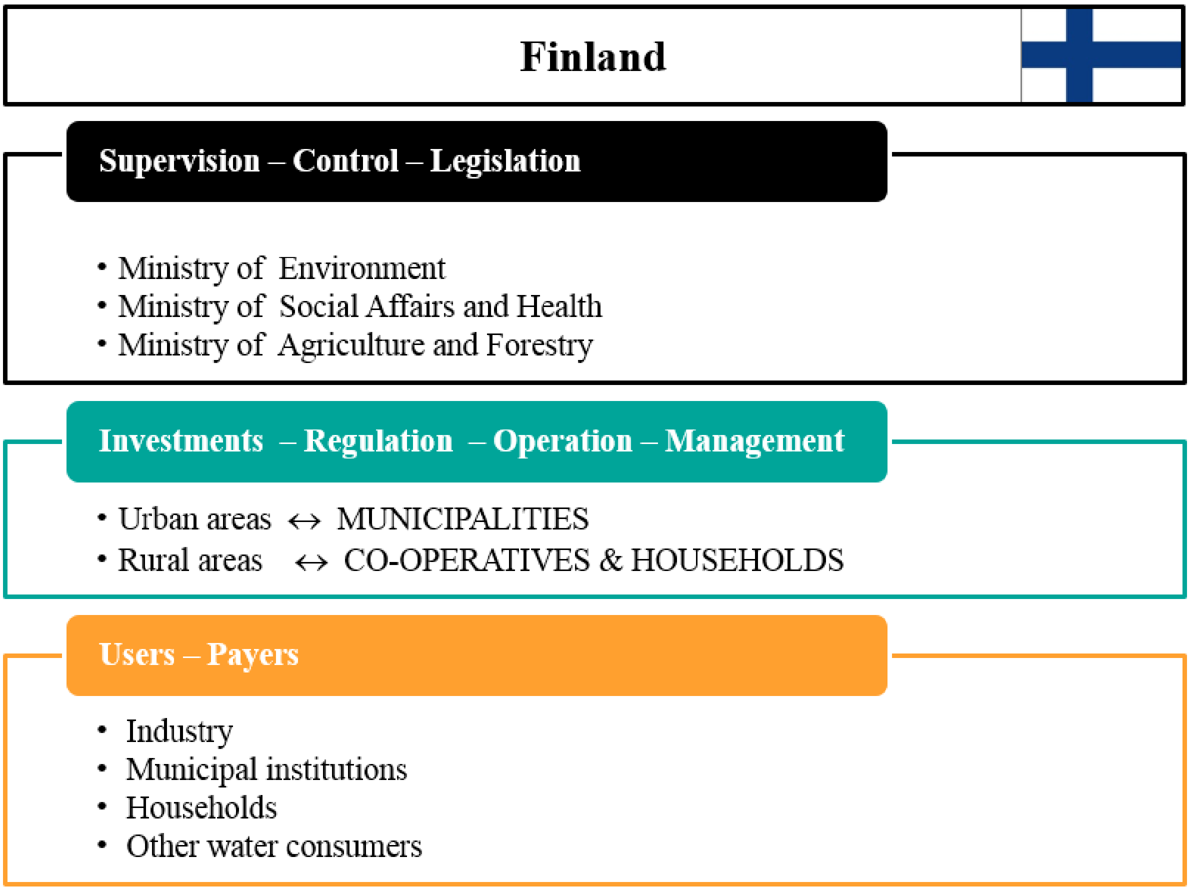


**Figure 5** Organization of water supply and wastewater treatment in Finland

The municipalities are responsible for water services only in population centers and not outside them. As a rule, water supply and wastewater treatment are carried out by municipally owned water enterprises. Private water companies are not common in Finland. However, there are opportunities according to the Finnish regulations to outsource some services to private companies. Storm water and melt water collection and treatment is also the responsibility of municipal companies. Most storm water is handled via separate pipelines. This decreases the amount of water coming to wastewater treatment facility. In sparsely populated rural areas, water service companies belong to voluntary establishments: households or co-operatives. In detached houses, it is common to drill water wells or boreholes.

The starting point of water supply is very different in built-up areas and in sparsely populated rural areas. In this sense, sparsely populated area means those outside the municipal water supply and sewerage system. The law requires such single household areas to manage their wastewater by themselves. They are expected to install wastewater treatment systems bearing the *Conformité Européenne* (CE) mark.

When it comes to co-operatives, there can be two sources of water supply: *a)* municipal water network use; *b)* own water source use. In both cases, the co-operatives have to manage related investments, operation and maintenance costs of their water systems. The major difference is that with option *a)* they only need to take care of network and pumping stations, whereas in option *b)* they should also consider water intake and treatment measures. (FWF, 2012a; Laitinen, 2012) As for wastewater treatment, co-operatives can either rely on municipal sewerage systems or their own wastewater treatment solutions. In general, co-operatives, as community-based systems allow good water resource management with lower costs to individual water users. When uniting into a co-operative, investment and maintenance costs become lower in comparison to personal *in situ* water systems. (FWF, 2014b; Laitinen, 2012) Co-operatives may also engage contractors to perform wastewater treatment and maintenance. This solution enables the fulfilment of strict local and EU legal requirements of water quality and supply. (FWF, 2012a; FWF, 2014b; Laitinen, 2012)

In Finland, there are four national programs related to natural water protection. They have been in use since the 1970s. In addition, river basin management is of priority and appropriate plans for seven Finnish regions were accepted by the Finnish government. According to these plans, by 2015, 100% of the ground water reserves, 90% of the lakes and 70% of the rivers there should maintain or reach a good water quality level. The base for the latter was the European Union Water Framework Directive (EU WFD) (Directive 2000/60/EC) about sustainable water use and supply in Europe. There are also other water-related Directives, Acts and Laws regulating (FWF, 2014b):

- Water services,
- Water quality,
- Wastewater treatment,
- Prevention and control of water contamination,
- Environmental protection,
- Healthcare,
- Sludge utilization and landfill disposal,
- Public work and service contracts,
- Procurement operations,
- Land use and construction works,
- Sustainable utilization of natural resources, and
- Other issues.

If there is any industrial or physical activity to be implemented on Finnish territory that influences surface or ground water bodies, according to the Water Act, there is a need to apply for appropriate permit. The activity is allowed to be started only after approval and permit acquisition. In rural areas, the Act for Water Services and the On-site Wastewater Treatment Decree (for the wastewaters out of municipal sewerage systems) also applies to control pollution and sewage treatment with parameters such as biochemical oxygen demand, total phosphorous content and total nitrogen content. In municipal population centers, decisions for the water industry are taken by the government. It is especially so when it is related to large scale investments. However, water companies can also be responsible for decision-making. What makes the difference is the scale. For instance, certain limits are put for investment costs, profit utilization and material investigation. Only within these limits can the head of a water enterprise make decisions. The same mechanism works with co-operatives in rural areas. The members of co-operatives can discuss problems at their meetings and send proposals to local authorities, who are in charge of the final decision. (Mikkonen, 2013; FWF, 2014b; Laitinen, 2012)

According to the Finnish Water Forum, currently, there is a tendency to increase inter-municipal cooperation toward joint water and wastewater treatment facilities as well as common sludge disposal. This is already implemented in such Finnish cities as Helsinki, Turku and Tampere with total populations of 750 000, 280 000 and 200 000 people, respectively. These numbers include populations beyond the cities; for example the Helsinki and Turku wastewater treatment facilities serve five neighboring towns in addition to the inhabitants of the two cities. As another trend, water companies are decreasing their dependency on municipal organizations. (FWF, 2012a; Pietilä, 2006)

### Customer water fees in Finland

The Water Service Act 119/2001 also regulates water fees for users. In municipalities, water fees are the main source of financing water services. The main sources of costs are investments, employee wages, energy supply, chemicals and maintenance operations. The Water Service Act states that all the costs of water supply and wastewater treatment can be covered by customer water fees. The rate of the fees should be mentioned in the water company price list. If there is a need to change the rates, for instance, due to legislation change, authority decision or investment expenses, the company is allowed to do so. It is legitimate under the Water Services Act that, if a water company incurs operational, investment or any other expenses, they be covered by customer water fees. Fees can vary from region to region. Water fees concern and include both potable water and wastewater operations. (FWF, 2012a; HSY, 2011)

There can be three main types of water fees: connection fee, fixed monthly fee, and consumption fee (Figure 6).

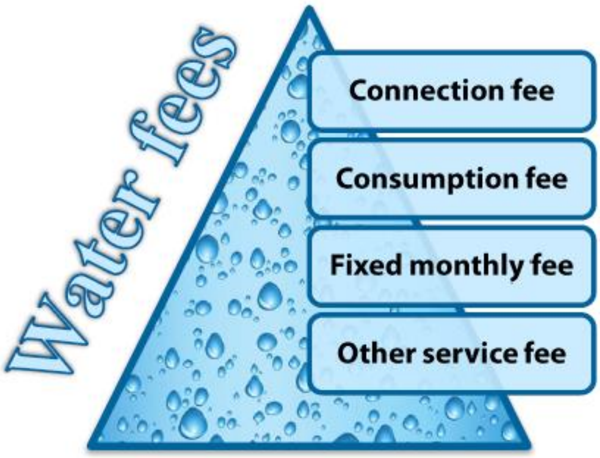


**Figure 6** Types of customer water fees in Finland

The connection fee is paid by a customer to the water company to cover the investment cost to join the water network. The consumption fee is related to the amount of supplied water that is consumed by customer. In this case, water consumption needs to be metered. This is a direct responsibility of the water company. They must install water meters at customers' premises so that the customer can follow the volume of water consumed. The water company needs to specify the meter type and provide the customer with this information. The installed water meter is considered as the property of the water company. The consumption fee in Finland is on average about 4,83 euro/$m^3$ per household in a detached house and 3,96 euro/$m^3$ per household in an apartment building flat. Based on Finnish Water Forum data, an average Finnish family of four people is assumed to have a monthly water use of 4,5 $m^3$ per person and, therefore, the monthly water fee costs a family around 2% of their income. (FWF, 2012a) The fixed monthly fee is not tied to the amount of water used by the customer. In this situation, the customer is supposed to pay the fixed fee for water service on a monthly basis. The other service fees are linked to various expenses possible for water company: e.g. water meter installation, storm water collection, pipeline renovation, some other installations or improvements and related expenses. In general, up to 80-90% of overall water company expenses do not arise from customer water consumption. They are fixed and included in the customer water fee. In turn, the municipalities and the national government collect from water companies part of their income (5-25%). Towards co-operatives and households, an obligatory income tax of 26% is applied. (FWF, 2012a; HSY, 2011)

## 1.5 Sweden


Sweden has a territory of 450 000 sq km, which is comparable in size with Spain and approximately 1.5 times larger than Finland. The distance between the southernmost and the northernmost points is about 1600 km; between the east and the west ends – 500 km. The country is flat along the coastline. However, mountain areas close to the Norwegian border create hydropower potential, with around 2000 working power stations (SvenskEnergi, 2012).. In 2013, Sweden's electricity production was 149,2 TWh, of which hydropower were 60,9 TWh. A high share of this is produced in the high North, not at least in Jokkmokk municipality where the yearly hydropower production is about 12,5 TWh. Sweden has 100 000 lakes which is 9% of the total area. The country is rich in rivers, with 200 $km^3$ of annual average run-off. About 51% of water supply comes from surface waters, 23% – from artificial groundwater, and 26% – from natural groundwater sources. Water services are organized by multiple municipal water companies; which provide it to 90% of the population. The rest are private installations. The tap water is potable in Sweden. (SWWA, 2000)

### Water supply and sanitation in Sweden

In total, there are 290 municipalities in the country, with about 2000 water works. Local authorities are responsible of water services provision, and as a rule, the municipality owns water infrastructure, including all related facilities. It is also possible that non-governmental organizations participate in water supply and wastewater treatment. As can be seen from Figure 7 Ministry of Agriculture, Ministry of the Environment as well as Swedish Parliament and the Government are responsible for governance and management of water services in Sweden.

Being part of the EU, Sweden complies with EU waste regulations, similar to as described for Finland. In Sweden, there is operating Water Services Act, 2007, which defines provision of water services, organization of sewage systems, water fees and other water related issues. One of Swedish national water programs is Strategic Water Innovation Program. It aims to contribute to environmental, social and economic sustainability by improving urban water cycle and functionality of water services by 2030. (SWWA, 2014)

### Customer water fees in Sweden

Swedish domestic water users are obliged to pay customer consumption fees, which correspond to annual average fee of 550 euros. The consumption fee has two components: a basic price per year and a current price per cubic meter of water consumed. To measure water consumption, almost all households have installed water meters in the country. Apart from the consumption fee, there is a connection fee. The water fees, as it was already seen in case of Finland, cover 99% of all costs by water services provider. Hence, water service is self-reliant and independent.

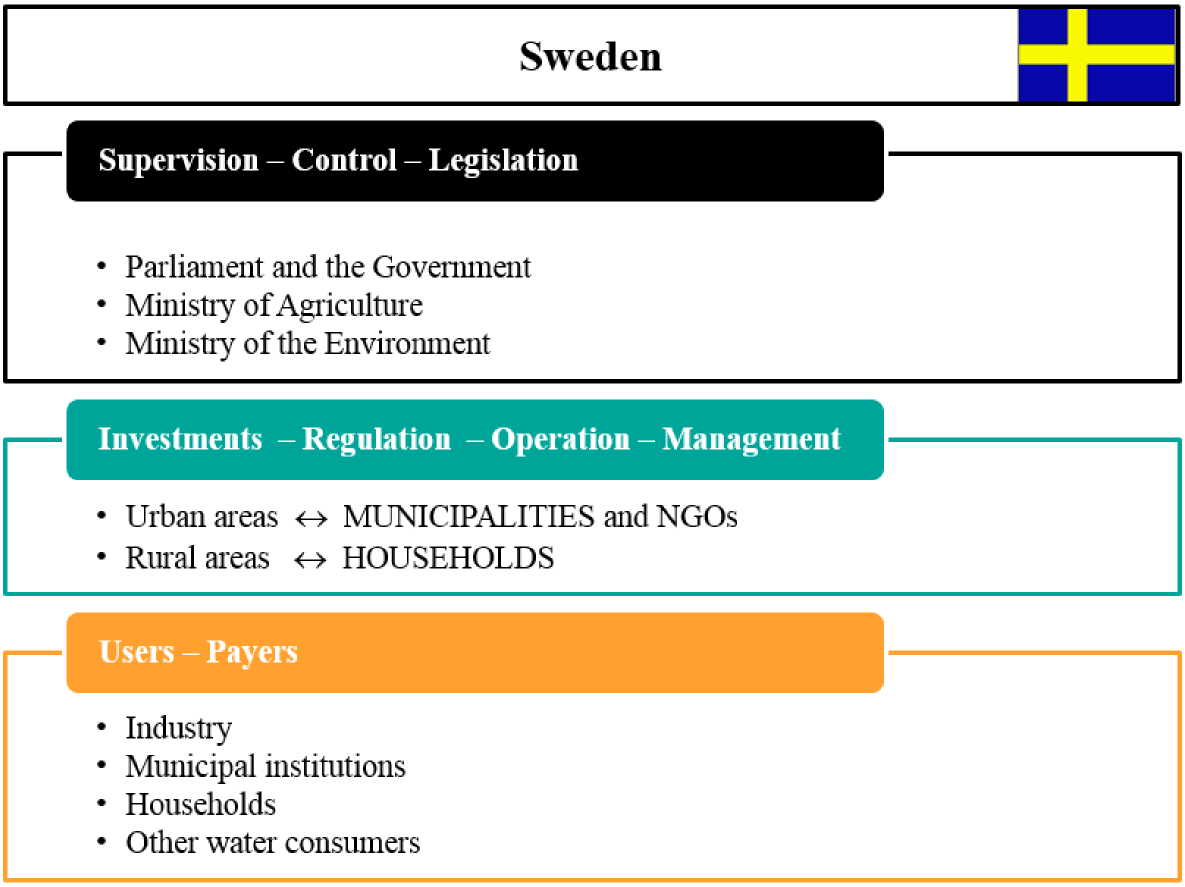


**Figure 7** Organization of water of water supply and wastewater treatment in Sweden

Only 1% of water services are supported by the local authorities, in the form of municipal tax. The fees are different in all municipalities, but have been stable for decades. Usually, citizens of municipalities with higher population pay less, compared with sparsely populated areas. By law, water services are obliged to be non-profitable. If there is an extra income, it should be spent on libraries, other public utilities or must be shown as an investment plan for future investments. (SWWA, 2000)

Within the RECENT project, only Norrbotten County is considered. It has territory of 98 000 sq km which is 8% covered by water bodies. The county has 30 730 lakes and relies mostly on surface water supply. Only 8% of drinking water comes from underground sources. Public water supply and wastewater treatment cover 85% of the county residents. Water services are provided by 14 municipal operators which have only in some cases the ownership on land or water resources in its disposal but only on water infrastructure units.

## 1.6 Summary

All five countries have abundant water supply and safe drinking water resources, enjoy high quality public services as well as possess certain water assets: would it be water infrastructure, land or water resources. There are differences and similarities between the RECENT partner countries, mostly explained by the geographical locations and scale of the regions of the British Isles and Fennoscandia.

Some countries rely more on groundwater reserves, as Finland and Ireland; some organize water supply mostly from surface waters – Scotland, Northern Ireland and Sweden. In all countries the water companies are mostly run by the public sector. The biggest difference between these public organizations is their right to own land and water resources. Scottish Water, as the main public water company, owns significant amounts of land in rural catchment estates. Northern Ireland Water in turn, can own water resources in the form of impounding reservoirs. In Finland and Sweden, multiple municipal water companies do not own land or water resources; but only infrastructural objects. This can correspond to certain challenges, for example, when having synergetic project within water-energy nexus.

Figures 8-10 provide a visual comparison of total areas and coverage of water services in Scotland, Northern Ireland, Ireland, Finland and Sweden.

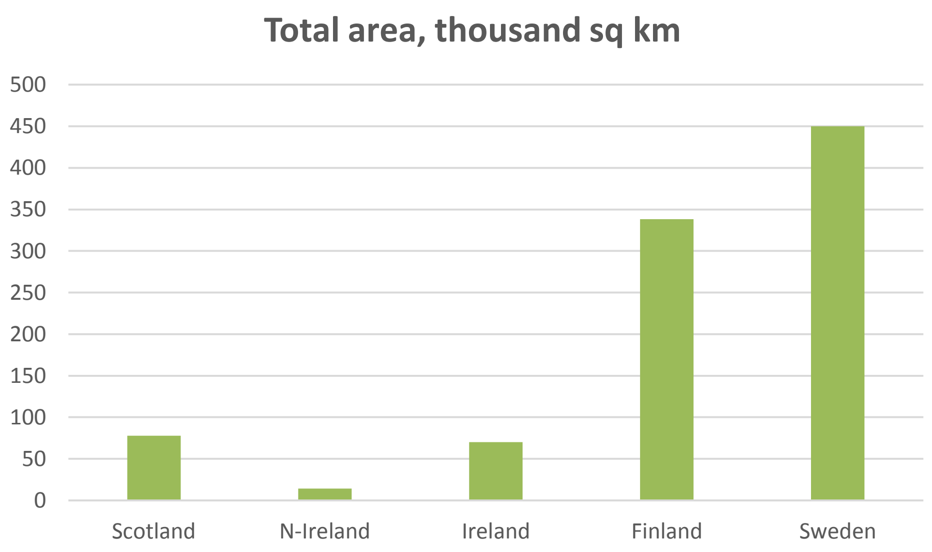


**Figure 8** Total area of the RECENT project countries

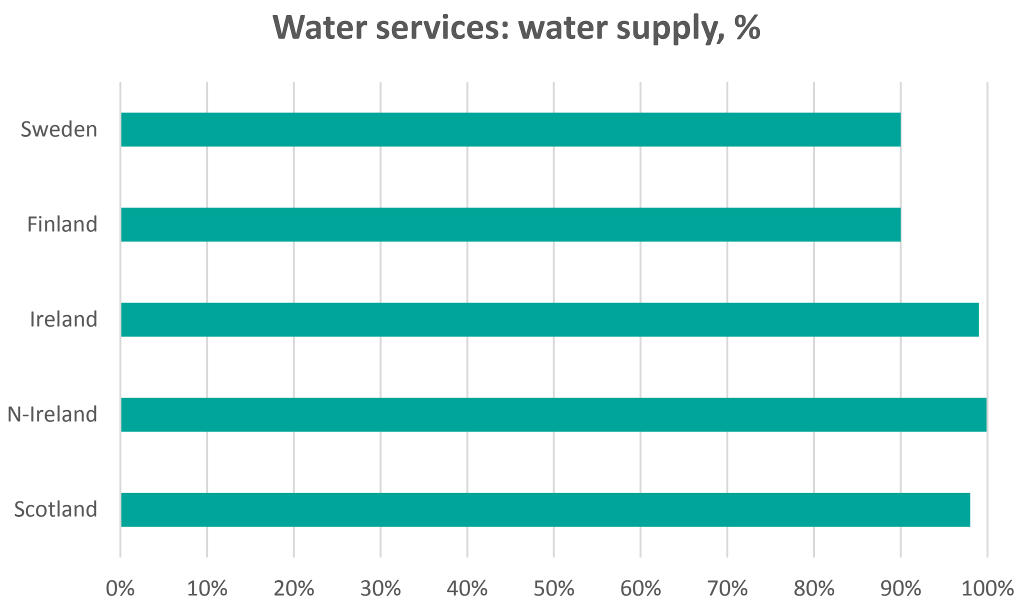


**Figure 9** Differences in water supply coverage in the RECENT countries

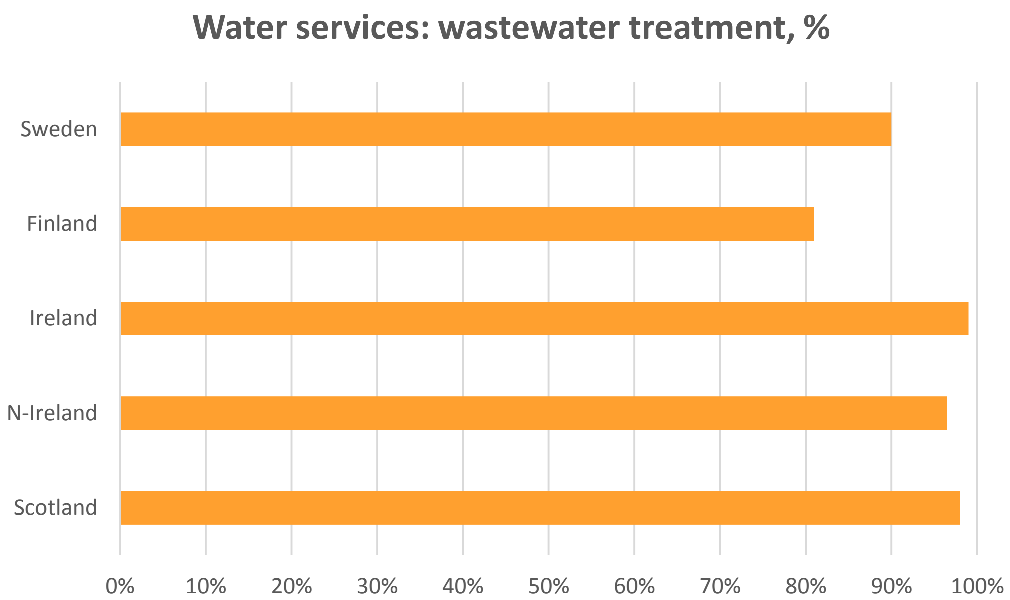


**Figure 10** Differences in wastewater treatment coverage in the RECENT countries

As can be seen from the figures, the partner countries have different territories which can be one of the primary reasons to have certain differences in approaches towards finding pilot communities and choosing pilot projects. For example, for working group of Finland or Sweden, the travel distance may be up to 4-5 hours to reach the furthest community in the project connected regions, whereas in Northern Ireland or Scotland it is located within 2 hours drive. Another aspect is queuing system in the British Isles. There is a well-developed community engagement, for instance, in Scotland and Ireland, whereas Fennoscandian partners have to start “from the scratch” their work with distant communities. It is worth mentioning that there are different initial conditions in all partner countries. Therefore, this report is of particular use.

Scotland, Northern Ireland and Ireland are in the best position within the water industry, where the coverage of water services is higher than 96%. Fennoscandian partners, due to sparse population and large lengths of the countries south-to-north, have provided their population with water services up to 90%. On a regional level: in particular, those regions included in the NPA RECENT project, the coverage of water services can be to some extent less. In these cases, community households and cooperatives come in use.

As an intermediate conclusion, all project partner countries have favourable conditions to start the project work.

# 2 ENERGY SOLUTIONS FOR THE NORTHERN PERIPHERY

There can different energy sources utilized to supply northern communities and their critical services. Water services, water supply and wastewater treatment, require certain energy supply. This report describes it and puts it in energy demand perspective. Below there are also some alternative options considered as an answer both for climate change challenges and energy security improvement.

## 2.1 Energy use in water supply and wastewater treatment

Energy is vital for water utility in order to operate and organize services for consumers. Energy is needed in water and wastewater treatment, for pumping and in the utility buildings. Due to this, water utilities consume a substantial amount of energy, especially electricity. According to Plappally, *et al*., 2011, wastewater treatment consumes approximately 7% of electricity consumption in the world. Generally, electricity consumption can constitute around 5 – 30% of the total operation costs of the utility. (Liu, *et al*., 2012)

### Energy breakdown of drinking water supply

The largest energy consumer at drinking water side is usually pumping, which can cover up to 70 – 80% of the overall electricity usage. (Liu, *et al*., 2012) Pumping of surface water into the purification plant and distribution purified water to the consumers requires significant amount of energy. However, the energy consumption of pumping and distribution of surface water can be very area specific. Among others, distances, elevation height, climate and the pipe characteristics define significantly the energy consumption of pumps. The geometry, size and friction factor of the pipe greatly affect to energy consumption of the pumping system. (Plappally, *et al*., 2011)

Pumping usually consists of larger fraction in groundwater plants due to the fact that water must be elevated from lower groundwater sources to the treatment plant. (Plappally, *et al*., 2011) The energy required for groundwater pumping increases as the elevation height increases. On the other hand, groundwater often requires less purification, resulting to decreased energy consumption at the treatment process compared to surface water plants. (Liu, *et al*., 2012)

As mentioned before, water treatment processes can also share a considerable part, around 1–10%, of the electricity use of the utility. Electricity is used for both mixing and pumping at the treatment plant, besides to possible processing and disposal of organic waste produced by purification processes. Buildings at treatment plants consume both electricity and heat (can require also cooling) for lighting and heating up spaces. Nevertheless, the energy need of buildings can be rather low, being only less than 1 per cent of the overall energy consumption. (Liu, *et al*., 2012) However, this amount could be larger in Finland and Sweden due to the cold climate.

Advanced water purification processes, such as ultra filtration, membrane filtration and reverse osmosis may provide cleaner water for water distribution with low installation and operation costs. However, these technologies may require high pressure in order to operate, or can generate a substantial pressure loss over separation surfaces. Thus, these kinds of technologies can increase the energy consumption at the treatment phase, depending on the system used before. (Pearce, 2007)

### Energy breakdown of wastewater treatment

Electricity shares usually the largest part of energy consumption at a wastewater treatment plant. The plant energy consumption depends greatly on the size and the process architecture at the plant. The energy consumption reaches its peak around midday and continues until the evening, due to the fact that more wastewater is being produced and more energy is thus needed for pumping and purifying the water. (Tchobanoglous, *et al*., 2004)

The largest proportion of energy at wastewater treatment plant is consumed in biological water treatment and drying solids and biosolids. According to Zhang, *et al*., 2012, pumping also shares a substantial part of electricity consumption at the wastewater plant. More advanced wastewater purification processes require more energy, for instance ultraviolet disinfection processes and activated sludge treatment. Figure 11 illustrates the energy breakdown of typical wastewater treatment plant having activated-sludge process. (Tchobanoglous, *et al*., 2004)

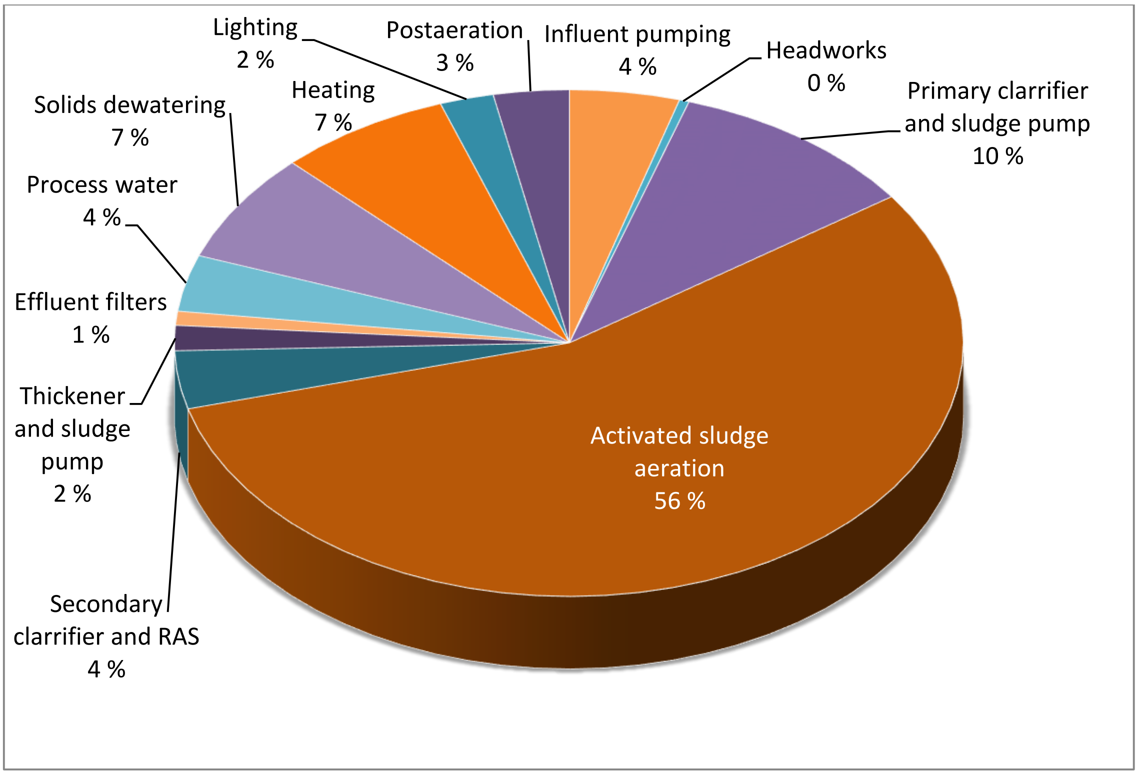


**Figure 11** Energy breakdown of wastewater treatment plant with activated-sludge treatment (Based on Tchobanoglous, et al., 2004)

As we can see from Figure 11, more than a half of energy is consumed by an aeration process. Aeration is essentially required in biological treatment phase for mixing wastewater and oxygen supply for microorganisms. (Plappally, *et al.*, 2011) Energy consumption of an aeration process depends greatly on the compressor efficiency and the raised pressure by the compressor. Efficient air supply of air is also required for microorganisms. Thus, energy-intensive turbulent flow is often involved, in which the design type of the mixing device can have a significant effect on energy consumption of mixing. (Crites, *et al.*, 1998)

Second largest part is primary clarifiers and pumping. Also the dewatering of solids shares almost one tenth of the energy consumption. (Tchobanoglous, *et al.*, 2004) However, energy required for wastewater treatment can substantially depend on the quality of wastewater. For instance, the nitrogen content of wastewater can increase the energy consumption of the aeration process. As discussed before, water pumping often shares the biggest part of energy consumption in the water cycle. However, according to Venkatesh, *et al.*, 2010, wastewater treatment can, in some cases, consume more energy than water pumping. (Venkatesh, *et al.*, 2010)

## 2.2 Renewable energy solutions in the water sector

Renewable energy solutions are often utilized to provide residential and other municipal buildings with energy supply. In water services, renewable energy technologies can produce either electricity or thermal energy, depending on the technology. Produced energy can be used for pumping and treatment processes, or heating up spaces. Installed renewable energy technologies can be grid connected or stand alone (off-grid) systems, and these technologies can produce either direct current (DC) or alternative current (AC). (Mohanraj, *et al*., 2013)

There are existing examples in the world which demonstrate possibilities of use of renewables in water services. Utilization of small-scale wind power, up to 10 kW, in groundwater pumping was proved to work in Saudi Arabia. The idea was to pump 30 000 $m^3$ of ground water annually from the depth of 50 meters by using 2,5 kW wind turbine with low costs (Rehman, *et al*., 2012). In Central Nigeria, wind power and solar photovoltaic cells were assessed in 30 $m^3$ water pumping from a borehole. It was found out that even though the initial costs of solar and wind energy systems are relatively high, the cost of water, compared to conventional petrol based system, is significantly lower when using solar and wind energy based system. (Rowley, *et al*., 2011) In the United States, several solar photovoltaic arrays were installed in remote areas in order to provide energy for water pumping. It was assessed that these systems can provide, if designed properly, enough energy for water pumping without any serious environmental impact. (Meah, *et al*., 2006)

The European Commission has forced in the Renewable Energy Directive (RED) (2009/28/EC) in 2009 in order to establish a framework for promoting the use of renewable energy in each Member State. The Directive obligates all Member States to produce 20% of the gross final consumption of energy and 10% of the final consumption of energy in the field of transportation by using renewable energy sources by 2020. The gross final consumption of energy means all energy consumed in households, industry, public sector, agriculture, fishery and forestry including losses in distribution and transmission. According to RED, each Member State should adopt a plan for using renewable energy sources, ensuring proper information, training and administrative procedures. The progress must be reported every second year. RED sets out also rules for joint projects between the member states. Furthermore, electricity grid, transmission system and energy storage should be developed to be suitable for the production and utilization of renewable energy. (2009/28/EC)

Through the RED, the European Commission compels Finland to increase the amount of renewable energy from the gross final consumption of energy to be 38% by 2020. For Sweden this value should be 50%, for Scotland – 30%, for Ireland – 16%. (BEFSCI, 2010; Ministry of Petroleum and Energy, 2012; Scottish Government, 2011) Northern Ireland has set targets for electricity and heat consumption from renewable energy sources of 40% and 10%, respectively (NSIPA, 2013). Renewable energy sources are defined by the RED are solar, wind, aero-thermal, geothermal, hydrothermal, hydropower, ocean energy, biomass, landfill gas, sewage treatment plant gas and biogas. In the case of energy extracted by heat pumps from aerothermal, geothermal or hydrothermal source, the energy produced can be considered as renewable if the amount of produced heating or cooling energy significantly exceeds the amount of primary energy input. In addition, a sustainability evaluation for biomass based energy sources must be undertaken to conclude whether a certain biomass energy production method is renewable or not. (2009/28/EC)

Currently, there are some good practices available. In this report anaerobic digestion, hydropower, wind energy, solar energy as well as aero-, hydro- and geothermal solutions (heat pumps) are considered suitable for the Northern Periphery and Arctic Region: Finland, Sweden, Scotland, Northern Ireland and Ireland. The principle of operation of these technologies has been explored in earlier theses (e.g. Kauriinoja 2009, Caló 2011 and Mikkonen 2013). Therefore, only brief explanations and general characteristics are given in this report. Depending on water asset, hydropower, solar and wind energy solutions are utilized. Pilots are described in terms of their type, energy use, water asset availability, energy production, cost of implementation of renewable energy and payback period. Location and illustration of pilot sites are also provided.

### 2.2.1 Anaerobic digestion

Anaerobic digestion is a biochemical process of organic matter conversion into flammable gas, or biogas, and digestate, occurred in the condition of oxygen absence and microorganisms' presence. These two conditions are considered as a driving force of the process. The technology is normally applied by using of airtight containers, also known as digesters. The chemical composition of generated biogas is about 30–50% carbon dioxide ($CO_2$), 50–70% methane ($CH_4$) and traces gases, mostly represented by nitrogen. A lot of various wet organic feedstocks (e.g. food waste, manure, and wastewater) are utilized to get the final product. Due to minor presence of some other chemical substances and potential threat of damage of energy conversion units, biogas usually undergoes appropriate treatment (Rutz, 2012). In addition, it can be upgraded to higher quality gas with only methane composition. Apart from biogas there is formation of digestate as an output product that can be utilized on agricultural field as soil fertilizer. (IPCC, 2011) This kind of procedure may require composting or so called thermal drying, depending strongly on the feedstock of the AD. In the case of sludge used as feedstock, the residual waste can composted or thermally dried in order to fulfill hygienic criteria and stabilize the waste, resulting to an opportunity to use residual waste as a material for land construction. (Latvala, 2009)

The biogas ranges of application are, for example, local heating, district heating or combined heat and power in small capacity plants in boilers, internal combustion engines and gas turbines. In most cases, biogas is used in combined heat and power (CHP) units, being able to generate both heat and electricity. Most of the applications generate more heat than electricity. For this purpose, CHP plants use engines such as Gas-Otto, Gas-Diesel, Gas-Pilot or other devices e.g. fuel cells and stirling motors. Furthermore, micro gas turbines can be used. (Rutz, 2012; Holm-Nielsen, *et al.*, 2008) After special treatment and compression it can be also used as a vehicular fuel. (IPCC, 2011) Typical scale of anaerobic digesters is from small-scale installations of 0,1 MW to large-scale factories of 20 MW.

AD processes (reactors) can be distinguished according to the temperature into psychrophilic (T < 25°C), mesophilic (25°C < T < 45°C) and thermophilic (45°C < T < 70°C). Reactors can be also categorized into wet and dry reactors and batch, semi-batch and continuous reactors. Main rector parameters affecting to the biogas yield are the retention time of the feedstock in the reactor and the temperature in the reactor. In most of the cases, thermophilic reactor has the highest biogas yield and lowest retention time. Co-digestion of wastewater sludge and bio waste by using a thermophilic reactor can increase the biogas yield around 45-50% compared to mesophilic reactor. (Cavinato, *at al.*, 2012) Thermophilic reactors often have other advantage being able to destroy pathogenic bacteria. Other central factors affecting to the biogas yield in the reactor are pH-number and properties of feedstock, such as solid matter content, organic matter content and homogeneity of feedstock. (Seadi, *at el.*, 2008)

Sludge from wastewater treatment plants contains substantial amount of water. (Lo, *et al.*, 2012) The most significant part of the sludge is organic matter and is thus well suited for AD, especially for wet reactor if the sludge is not being dried. At wastewater treatment plants, the AD processes are not only used for generating biogas, but also for stabilizing the sludge and reducing the amount of the final waste. For these purposes, the thermophilic process is most commonly used because its advantages described above. (Latvala, 2009; Frijns, *et al.*, 2011)

AD includes various unit processes in order to operate appropriately. The investment costs of AD plant with full equipment can be rather high. In addition, maintenance is needed frequently. According to Seadi, *et al.*, 2008, the payback period for anaerobic digestion can be more than 20 years. From environmental point of view, anaerobic digestion can substantially decrease $CO_2$ emissions originating from the wastewater treatment plant. (Shahabadi, *et al.*, 2009) In future, anaerobic digestion research will focus strongly on reducing investment costs of the system. In this way, payback period can be also reduced. (Holm-Nielsen, *et al*., 2008)

**Good practices of biogas generation**

In Finland, in 2011, there were around twenty municipal and industrial anaerobic digestion facilities with biogas production from wastewater sludge. The total energy production through the biogas utilization was about 145 GWh. (Bionova, 2009; Kauriinoja, 2010; Rintala, *et al*., 2012). One of the plants that treats wastewater sludge and produces biogas is located in Vampula. The biogas production plant uses municipal sludge and organic waste as a feedstock for anaerobic digestion. As a result, 8 000 MWh of power and 9 000 MWh of heat is produced on an annual basis. (Vambio, 2014) Other biogas production plants based on wastewater treatment facilities are situated in Espoo and Turku (Biovakka, 2009; Rintala, *et al*., 2012). In Turku, biogas is utilized with production of heat and power. The amount of generated power is 4 MW. The heat is used in district heating. (Biovakka, 2009) In Jyväskylä, electricity is produced after anaerobic digestion process from biogas by using a 157 kW motor. Produced electricity is sent to compressors supplying air for aeration process. Similarly, in Tampere, produced biogas is converted into electricity and thermal energy. Produced electricity, afterwards, is used as additional energy at the wastewater treatment plant. (Latvala, 2009) By 2015, 0,2 TWh of energy can be potentially produced via utilization of sewage sludge in anaerobic digestion in Finland (Rintala, *et al*., 2012). In Kemi wastewater treatment plant, there was an estimation work done on potential energy utilization contained in wastewater. The plant consumes about 835 000 kWh of electricity and 775 000 kWh of heat on an annual basis. By implementing anaerobic digestion, one fourth of electricity needs and around half of heat demand can be covered. In connection with this, corresponding reduction of $CO_2$ is also possible. The potential emissions reduction constitutes one third of $CO_2$ emissions in 2012. (Mikkonen, *et al.*, 2013a)

In Scotland, there are also anaerobic digesters applied in wastewater treatment works. (Scottish Water, 2014a) In Aberdeen, there is a wastewater treatment plant operated by Scottish Water. It treats sewage from 350 000 people. Some sludge is imported from adjacent areas. There are two 4 000 $m^3$ anaerobic digesters which produce biogas and fertilizer. The biogas is sent to co-generation facility and converted into heat and power. The amount of produced electricity is 1 MW per year. (Cambi, 2007) Another wastewater treatment plant of Scottish Water that produces biogas is located in Edinburgh. There are six digesters of 2 500 $m^3$. Biogas is utilized to generate steam and 2,5 MW/year of electricity. As a by-product, fertilizer is produced. (Cambi, 2013) Some Scottish Water biogas production facilities are based on co-digestion and use not only sewage sludge but also food waste as feedstocks (Scottish Water, 2014a).

In Ireland, there are examples of utilization of anaerobic digestion technology at wastewater treatment works. A Dublin plant has three digesters to treat sewage sludge and produce 45 000 $m^3$ of biogas per year. As a result of biogas-to-energy conversion steam, 4 MW of electricity and biofertilizer are produced annually. (Cambi, 2009)

### 2.2.2 Solar photovoltaic and thermal technologies

**Solar photovoltaic solution**

Solar cells, also called as solar photovoltaic devices, are gaining more attention in the field of renewable energy technology. Cell prices are predicted to get lower and the efficiency higher in future. Being able to generate emission free energy from irradiation coming from an abundant energy source, from the Sun, solar cells can be considerable technology for electricity generation. Solar energy is converted into electricity using photovoltaic (PV) cells. A group of these cells can be mounted together into a solar panel. The PV cells are made out of layers of semiconductor material such as silicon. When sunlight shines on the semiconductor a negative charge is created on one side of the surface and a positive charge on the other. This creates a voltage. The two sides of the cell are connected to a load and as the current flows from one side to the other, electricity is generated. (IPCC, 2011) Solar cells are available at various scales from watt scale to hundreds of kilowatts. The amount of power produced by a cell is rated by watt peak ($W_p$) under standard testing conditions with incident power density of 1000 $W/m^2$, air mass of 1,5 and temperature of 25°C. (Nelson, 2004) Usually, solar panels have power production values of 20 to 500 $W_p$ (Mikkonen, 2013).

The amount and properties of incoming solar radiation are affecting significantly to the power production of a cell. Indeed, solar radiation flux varies greatly seasonally and daily due to the movement of the Earth. For example, during summer time the amount of irradiation is greater compared to winter period, resulting to slightly lower annual solar radiation in higher latitudes. Due to these variations, declination angle of the Earth, latitude and hour angle must be taken into account when evaluating the amount of solar irradiation. In addition, weather conditions have an influence to the direction of the radiation by scattering, reflecting and absorbing solar radiation in the atmosphere. Furthermore, the cell can be installed by having a certain slope and azimuth angle, affecting thus the final amount of reached solar radiation at a given moment. However, Figure 12 below illustrates the sum of yearly irradiation on optimally inclined south oriented solar cell in Europe. As Figure 12 illustrates, the yearly sum of solar irradiation is around 1000 $kWh/m^2$, being a considerable amount of energy. However, only a part of this can be converted to electricity. (Sørensen, 2011) The most used solar cells are based on silicon (Si), an abundant material on the Earth's crust. Si-based solar cells are designed to have either monocrystalline or polycrystalline structure. The main advantage of these two designs is relatively high efficiency, but the limiting factor is usually the price of the Si-based cell, being rather high. Hence, there are several technologies existing and under development requiring less material compared to Si-based solar cells. These thin film solar cells tend to have lower efficiency, but considerably lower price. Thin film solar cells include amorphous silicon, cadmium telluride (CdTe), copper indium diselenide ($CuInSe_2$) and organic solar cells. (Bhubaneswari, *et al.*, 2010)

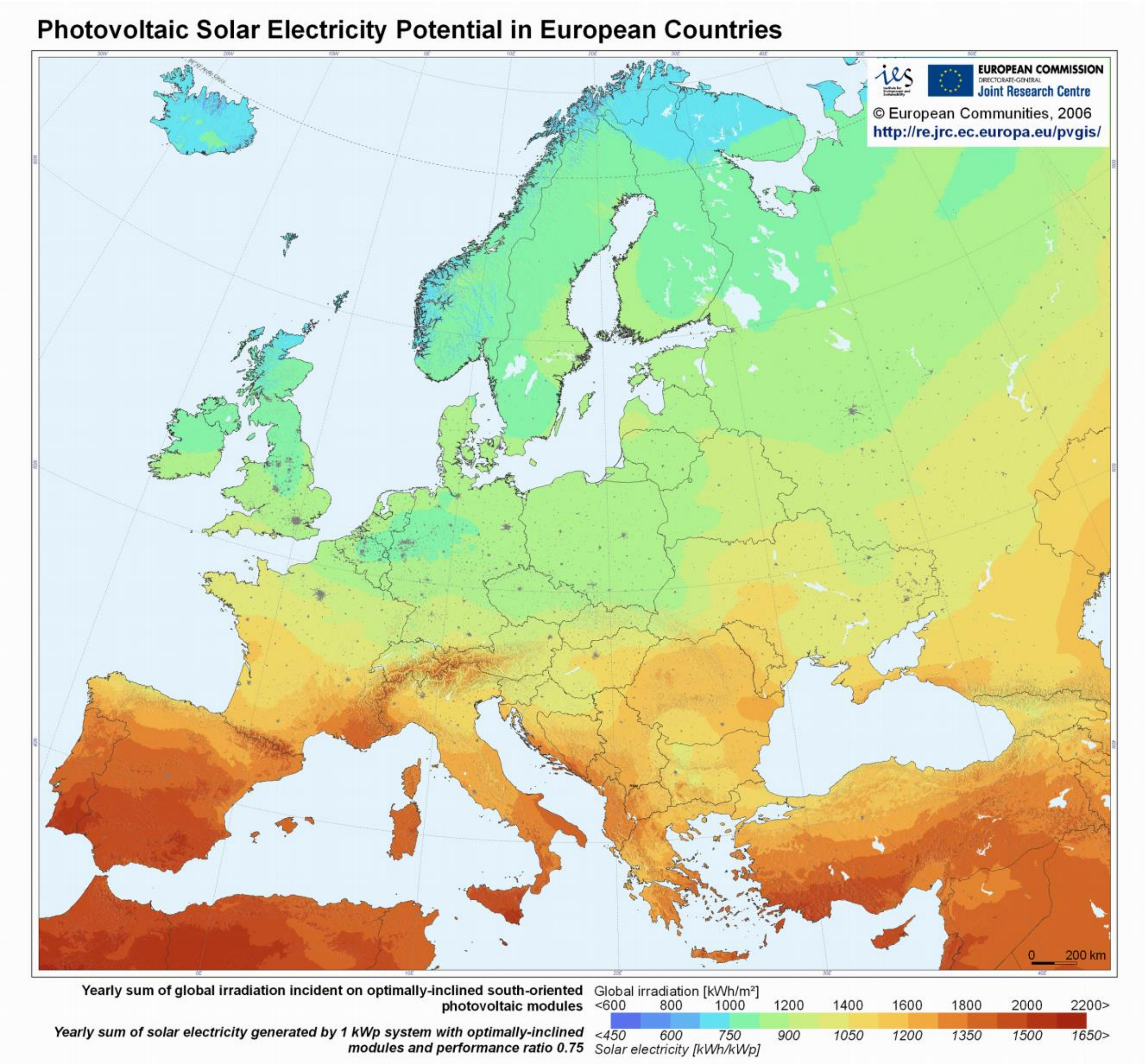


**Figure 12** Yearly sum of global irradiance in Europe (JRC a, 2006)

The efficiency of the solar cell is affected by numerous factors, such as the cell materials and the structure of the cell. Different materials are having specific physical properties, such as band gap values, photon absorption spectrum and recombination rate. Ventilation is required in the cell in order to keep the temperature at acceptable level. Indeed, the cell efficiency tends to decrease when the cell temperature increases. Thus, the structure and placement of the cell can also affect to the power conversion efficiency of the cell. In addition, the overall efficiency of the system must be considered, including inverter losses and losses in cables and storage. Shading formed by obstructions can significantly affect to the final power yield of the solar cells system. (Nelson, 2004)

The main investment cost of a solar cell system is the cell module, including the actual cell. Depending on the installation, mounting structure, inverter and other accessories must be added to the investment costs. Decreasing prices and system costs of PV modules is predicted to make solar cell technology more viable in future. The lifetime of conventional silicon based cell is usually 20-25 years or more. After this timeframe, the cell efficiency tends to decrease. The payback time depends strongly on the latitude, technology and the manner of installation, but is usually around 10-20 years. Produced electricity can be used for conventional electric applications, but also for water pumping. (SEAI, 2010; Gopal, *et al.*, 2012)

**Solar thermal solution**

Solar thermal energy provides an option for generating energy for heating purposes. Conventionally, solar thermal collectors can be used for providing space heating or heating up hot water. Thermal energy can be used also for heating up processes. Basically, four major systems can be distinguished:

- Flat plate collectors;
- Evacuated tube collectors;
- Concentrating collectors;
- Solar air collectors.

From these types of collectors, flat plate and evacuated tube collectors are most commercialized and used technologies. (Gajbert, 2008) A solar thermal collector consists of glazing, absorber material and insulating material. A glazing is installed on the top of the collector, having high transmittance values for short wave radiation and low transmittance values for long wave radiation for preventing the radiative heat loss from the collector. The glazing prevents also from heat losses from inside of the collector. The absorber material has been designed to have suitable properties for reaching high absorptance for incoming short wave radiation. In most cases, insulation material is installed at the bottom of the collector in order to prevent from conductive heat loss. (ASHRAE, 2008)

In conventional applications, heat is absorbed by the collector and being transferred then into a working fluid. Working fluid is then exchanging heat to a storage tank or to a heat transferer. In active systems, fluid is circulated by a pump, whilst passive systems operate by utilizing gravity forces and the density differences of the working fluid. The performance of the collector depends greatly on the amount of incoming radiation, collector area, tilt angle, orientation and overall efficiency of the system. (Gajbert, 2008) The produced thermal energy can be directly used for domestic hot water production, or, alternatively, stored in thermal energy storage. From the storage, thermal energy can be discharged according to demand. (Tian, *et al*., 2012)

A typical one square meter sized solar thermal collector installed in Finland produces around 250-400 kWh of energy during one year (Motiva, 2013). The lifetime of a solar thermal collector is around 20-25 years. Initial investment costs can be rather high, but maintenance and running costs are not as high as in some other renewable energy technologies. Payback period for solar thermal systems is between 5-15 years. (ESTIF, 2003)

**Good practices of solar energy utilization**

Solar panel installations are set on Scottish Water assets to generate power (Scottish Water, 2014a). There are six solar panels are installed as an *in situ* water asset utilization. Each solar panel produces annually 0,2 GWh of electricity. This supplies water treatment works with up to one fourth of their electricity demand. There are solar panels embedded on the roof of buildings as it is at Carron Valley (North Lanarkshire), Balmore (Glasgow), Blairlinnans (West Dunbartonshire); as well as installed on the ground of the Scottish Water land assets as it is at Mannofield (Aberdeen), Spey Valley (Aviemore) and Forehill (Peterhead). (Scottish Water, 2014b)

## 2.4 Wind energy

Wind energy can provide renewable electricity for water utilities. At the operation phase, wind energy is considered as emission free in terms of $CO_2$. However, noise, electro-magnetic radiation and glitter emissions are often involved. The installed nominal power capacity can vary between 75 kW and 3,6 MW. The installation can be done either off-shore or on-shore. (Turkia, *et al*., 2011)

A wind mill consists mainly of a foundation, tower, rotor, drive train and nacelle. In addition, a certain amount of automation and electric equipment, such as gear box and yaw system (controls the orientation of the mill) is needed, especially in larger scale wind mills. Mechanical energy is produced when wind flows through the rotor disc and part of the kinetic energy of the wind is extracted by the rotor blades. This energy is further transferred to electricity in a generator. Direct electric current must be converted into alternating current by using an inverter. Electricity can be then supplied to the grid. (Burton, *et al*., 2001)

The performance of the wind mill depends greatly on wind velocities and the amount of the wind within a given time interval. The energy in the wind is proportional to the cube of the wind velocity. Wind mills are not producing electricity all the time due to the fact that wind speed varies annually, monthly, daily and in every second. However, the typical cut-in speed (when wind mills start to produce usable electricity) varies between 3 and 5 m/s. In addition, due to the safety issues and the design of the mill, cut-out speed shutting down the mill is around 20-25 m/s. The maximum power is generated by the wind mill during the rated wind speed, which in many mills lies between 10-25 m/s. At lower wind speeds, the wind mill power output decreases. Figure 13 below illustrates a power curve of WinWinD 1 MW (WWD-1) wind mill with the rotor diameter of 60 m. (Manwell, *et al*., 2009; Herbert, *et al*., 2005)

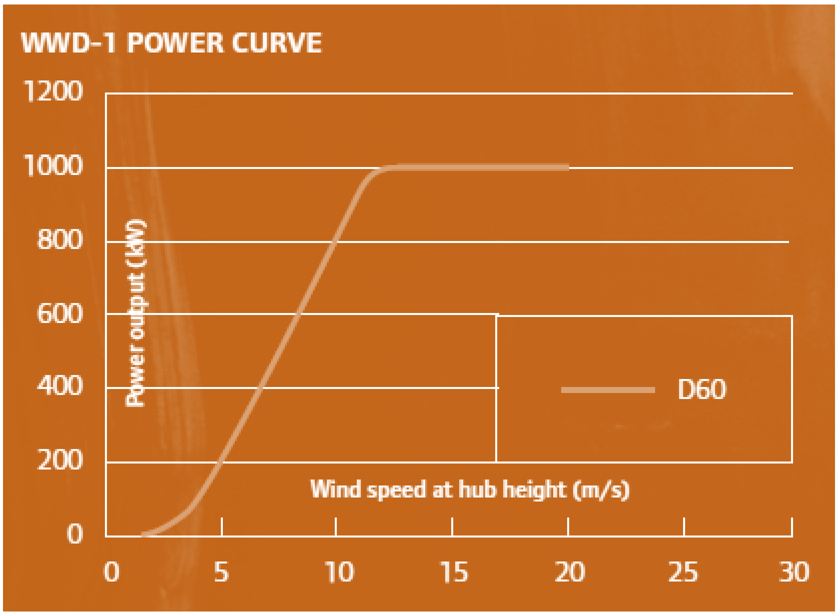


**Figure 13** Power curve of WinWinD WWD-1 wind mill (WinWinD, 2013)

The usual lifetime of a windmill is around 20 years. The cost of the system depends significantly on the technology and the installation (off-shore). However, the maintenance costs are evaluated to be around 1,5-3% of the initial cost of the turbine (Burton, *et al*., 2001). The payback period depends also greatly on the wind conditions on the site. The payback period of wind mills is roughly around 10-15 years. (Energysolve, 2013)

### Good practices of wind energy utilization

Wind mill installations are growing rapidly in Finland. The target for 2020 set by Finnish government is to produce 6 TWh with wind power, meaning installed power capacity of 2000 MW (Ympäristöministeriö c, 2012).

Part of land resources of Scottish Water are used to produce wind energy. There are about sixty large-scale and ten small-scale wind turbines built. (Scottish Water, 2014a) Wind energy is utilized at Touch in Stirling water treatment works. The annual electricity production is about 300 MWh. (McConnell, 2011) Near Stornoway on the Isle of Lewis, there is also a wind turbine at wastewater treatment works (CIWEM, 2013). Six wind turbines are installed at water treatment works at Broadford on the Isle of Skye and on Rassay. The turbines produce power enough to supply up to 50% of the works demand. (Evance Wind, 2013)

## 2.5 Hydropower

Hydropower technology has been a conventional electricity conversion method for long time. The scale of hydropower varies from hundreds of kilowatts to tens of megawatts. In the area of EU, small-scale hydropower comprises plants having nominal output less than 10 MW, whilst large-scale plants exceed the limit of 10 MW. (Pienvesivoimayhdistys ry, 2009)

The basic operation method of a hydro power plant is that water having high elevation is discharged to the lower elevation level. In many cases, separate reservoirs can be constructed for storing water. The potential energy of high elevation changes to the kinetic energy of water as water is discharged towards the turbine locating at the lower elevation level. The kinetic energy is then used to rotate the turbine in order to generate mechanical energy.

The mechanical efficiency of a hydraulic turbine varies between 60% and 90% depending on the design of the turbine. The turbine efficiency tends to decrease when the turbine size decreases. Most used hydraulic turbine types can be distinguished into Pelton, Turgo and Cross flow turbines. (Paish, 2002) In addition to a turbine, hydropower plants may require the construction of reservoirs, dams, transformers etc. Advantages of hydro power include very robust operation of the system, long life time, high efficiency and little maintenance. Furthermore, hydropower has been considered rather emission free energy production technology. Still, especially in larger scale, hydropower may have some negative impacts on aquatic biology and environment. (Pienvesivoimayhdistys ry, 2009)

Hydropower can be classified in large scale and small scale installations. Large-scale installations have capacity of more than 100 kW, small scale – 0-100 kW. The small scale plants consist of micro-hydro power units of the capacity between 5 and 100 kW, and pico-hydro power units having the scale less than 5 kW. Such systems do not necessarily require any kind of reservoir, as larger scale hydro power plants often do. Small-scale hydro power plants can also operate at lower discharge rates. In this way, impacts on the aquatic environment can be minimized. At the same time, small-scale hydro turbines can be installed in various resorts having also lower effective pressure head over the turbine. (Williamson, *et al*., 2011) Large scale hydropower plants have relatively long lifetime, often at least 50 years. Since the plant is often generating electricity continuously with relatively high efficiency, payback period can be approximately between 10 and 20 years despite of high investment cost. Hydropower plants tend to have also rather low maintenance and operation costs. (Paish, 2002)

**Good practices of hydropower utilization**

In Scotland, hydropower schemes are mostly of small scale (HI energy, 2010; McKenzie, 2007). At present, there are ten of them in operation in Scottish Water. (Scottish Water, 2014a) Hydropower is utilized at water and wastewater treatment works at Turret in Perthshire, Lintrathen and Tannadice Angus and Castle Moffat East Lothian. Moreover, the works function in a self-sufficient manner due to the water asset utilization. (McArdle, 2013) In the water works of Castle Moffat, there is in-pipe micro-hydro turbine installed to produce power (Global Water Research Coalition, 2010). At Glencorse in Edinburgh, water treatment plant has a gravity-fed facility with hydro turbine. It generates power and satisfies two thirds of the plant power demand. (O'Fee, 2014) As a whole, it is likely that the role of hydropower in Scotland will increase in the years to come. The reason for this is the developing Hydro Nation initiative (Scottish Government, 2012).

As a recent example of community hydropower development, Sunart Community Renewables, Lochaber, Scotland – raised funds by selling community shares in the amount of 985 000 euros. The energy improvement project includes utilization of unused community critical infrastructure asset, in particular, an unused dam of Scottish Water. The community has purchased it from the water services provider and is planning to produce 425 kWh on an annual basis. (Community Shares Scotland, 2015)

## 2.6 Heat recovery from wastewater

Wastewater coming from domestic, industrial and other sources contains always a certain amount of heat, which could be recovered. (Frijns, *et al*., 2011) According to Intelligent Energy 2007, this energy potential is often unused due to the lack of information, meaning that heat is being rejected to the environment. Thus, heat recovery from wastewater could provide a considerable option for generating renewable energy on the site of a water utility. (Intelligent Energy, 2007)

As mentioned before, the temperature of wastewater can vary at a given time interval. Wastewater temperature can also decrease between producing and treatment positions. Principally, the heat is lost in the piping system. According to Sallanko, 2006, the temperature decrease of wastewater in a sewage pipe in Finland was 0,16 – 0,27 °C in the beginning of the pipe and 0,02 – 0,10 °C in the final part of the pipe. The research made by Sallanko concluded that the temperature of wastewater decrease 0,12 – 0,17 °C/h. According to Tekes, 2013, the temperature of wastewater at the beginning of the sewage pipe is 20 – 30 °C and can be anywhere between 5 up to 23 degrees at the wastewater treatment plant. (Sallanko, 2006; Tekes, 2013)

Heat can be recovered at several different points at the wastewater system. First of all, heat recovery system can be situated immediately after wastewater is being produced. On the other hand, a heat recovery system can be installed in a sewer or at the wastewater treatment plant, as illustrated in Figure 14.

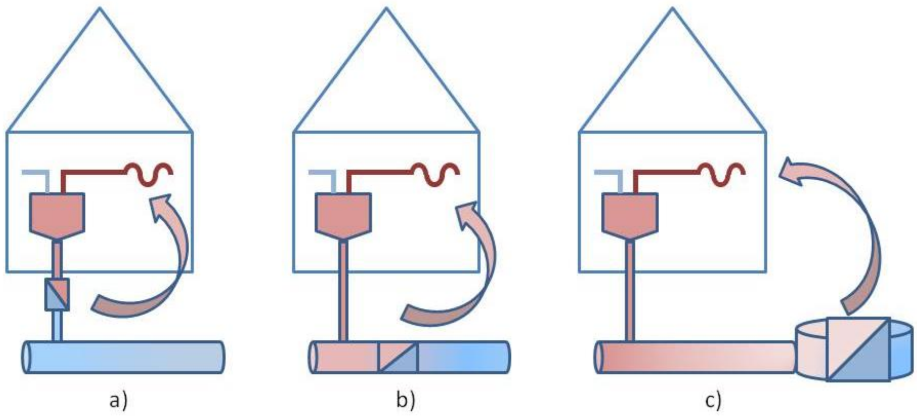


**Figure 14** Options for placing a heat recovery system from wastewater:

a) inside a building, b) in a sewage pipe and c) at the wastewater treatment plant (based on EAWAG, 2013)

Heat can be recovered from wastewater by using either a heat recovery system or a heat pump. Principally, the heat recovery system is a heat exchanger allowing wastewater to flow through the system and transferring heat from warmer wastewater to colder fluid flowing in the heat exchanger. This kind of system is conventionally installed in a building or in a sewer system. For wastewater heat recovery from a wastewater treatment plant, heat pumps tend to be more efficient, even though the investment costs of heat pump systems are considerably higher compared to heat recovery systems. In heat pump systems, heat is recovered by a heat exchanger from wastewater (evaporator) and brought to a compressor raising the pressure and temperature of working fluid. Heat is being transferred out in a condenser. The heat rejection includes usually a phase change from gas to liquid. The circle is closed by an expansion valve decreasing the pressure and temperature of the working fluid. In most of the cases, heat energy output is considerably higher compared to the electricity consumption of the compressor. On the other words it means that the coefficient of performance (COP) is having higher values. Furthermore, heat pump systems can operate other way around, producing cooling energy. (Meggers, *et al*., 2010)

The temperature decrease of wastewater due to the heat recovery can affect to water treatment processes, especially if heat is being recovered before these processes. According to Wanner *et al*., 2005, even 1°C decrease in temperature can decrease the operation efficiency of nitrification by 10%. The decreased amount of wastewater entering the wastewater treatment process can also affect negatively to other biological or bio-chemical processes. (Wanner, *et al*., 2005; Tekes, 2013)

It is possible to utilize recovered heat from wastewater in order to warm up building interiors or hot usage water, or in processes, such as anaerobic digestion and sludge drying. Heat can be also exchanged into a district heating system. As mentioned earlier, the heat pump system can produce also cooling energy, especially during warmer seasons, increasing thus the overall annual efficiency of the system. (Tekes, 2013)

Small-scale heat recovery plants installed in Finland are having the scale from around 100 kW to 1 MW. Bigger scale plants are operating from 20 to up to 90 MW. The amount of produced cooling energy is usually slightly lower compared to the amount of heating energy. Because of the organic content of wastewater, both heat energy system and heat pump technology require maintenance and protection from the fouling of the heat exchanger surfaces. (Tekes, 2013)

The payback period of the installed system varies significantly depending on the installed technology, scale and operating conditions, to mention some. Nevertheless, some installations in Finland are aimed to have payback period of 2-3 years. (Tekes, 2013)

**Good practices of heat recovery utilization**

Thermal energy is utilized via heat recovery from wastewater to heat up building spaces at wastewater treatment plants in Finland. In Lapua, a 120 kW heat pump recovers energy from wastewater for heating utilization. The investment of 45 000 euros has a payback period of 2-3 years (Mikkonen, *et al.*, 2013b). Similarly, a heat pump system is used for space heating at a wastewater treatment plant in Vaasa and Helsinki. (Heinonen, 2013; Tekes, 2013) In Savonlinna, at wastewater treatment plant that utilizes accelerating composting unit to produce compost has also heat recovery embedded in the technological scheme (Green Net Finland, 2008).

In Sweden, there is the largest heat recovery from wastewater in the world. It utilizes energy contained in wastewater that has temperature within range of 7-22 $^{0}$C. By producing more than 1 200 GWh of thermal energy on an annual basis, the wastewater treatment plant provides heat to around 95 000 households. (Mikkonen, *et al.*, 2013b)

## 2.7 Challenges of renewable energy generation

Energy conversion from renewable energy sources may be uneven. For instance, solar photovoltaic system may not be able to provide enough electricity during a cloudy day, night time or winter season. Similar uncertainty can be found with solar thermal systems, wind mills and hydropower. In case of anaerobic digestion, the amount of feedstock can also vary seasonally. In addition, heat recovery from wastewater may have seasonal variety in the temperature of wastewater at the wastewater treatment plant. (Twidell, *et al.*, 2006)

Another problem can occur during a situation, when energy consumption is low at the end-use phase, but energy production is excessive. The situation can be also vice versa, as it can be for example during winter period with solar energy. Peak consumption hours occur during certain periods during the day. Thus, these energy peaks should be able to be satisfied, or preferably, removed or at least lowered. Examples of the key solutions for balancing the uneven production and consumption of energy are energy hybrid systems, energy storage and smart grids. (Twidell, *et al.*, 2006)

Hybrid systems can include integrated technologies, for instance simultaneous wind power and solar photovoltaic power generation. In this way, energy can be produced more reliably. For instance, even though it is not windy, sufficient amount of solar radiation may be available. The aim is to secure the energy conversion making it more reliable. (Sørensen, 2011)

Energy storage plays an important role in securing the supply of energy and promoting renewable energy sources. Produced excess energy can be stored in storage when not needed, and utilized when energy demand is growing. Energy storage can enable also the moving of energy in some other form, such fuel. Energy storages can be distinguished to electrical, thermal, mechanical, chemical and biological storage. (Twidell, *et al.*, 2006)

Thermal energy can be stored into a thermal storage. Materials with suitable thermodynamic properties are utilized to capture the produced heat. For example, water is often used due to its high specific heat capacity. For instance, solar thermal collectors often use water tanks as thermal storage. Phase change materials, salt hydrate etc. can be also used in order store not only sensible heat, but also latent heat. (Sørensen, 2011)

Batteries are conventional devices for storing electricity. The lead acid battery is the most conventional type of battery. Also other materials and compounds can be used. Batteries can be utilized to store generated power from wind mills, photovoltaic, anaerobic digestion and hydropower. It is also possible to store electricity or heat into chemical compounds. As chemical reactions are endo- or exothermic, stored energy can be further utilized by burning fuel, for instance. One example of this kind of storage is hydrogen storage, in which electricity can be stored into hydrogen bounds by using electrolysis. When energy demand increases on the load side, energy carried by hydrogen can be used in a fuel cell producing electricity and heat. (Twidell, *et al*., 2006)

Mechanical storage can store mechanical energy, such as rotation energy or pumped energy. Typical mechanical energy storage can be found in the relation of hydropower plants, where energy of water in a reservoir is stored as potential energy due to the elevation. Mechanical energy can be also stored into flywheels and compressed air storage. Energy from mechanical storage can be further converted into electricity or heat, depending on the type of the storage. (Twidell, *et al*., 2006)

Nowadays, energy supply is mainly organized by larger centralized energy suppliers. Energy is transmitted from the centralized plant to the end-user, consumer. In this kind of one-way communication system, the user does not have much freedom to affect to energy supply. In addition, the current electrical network does not necessarily support renewable energy systems in a level it should support. Thus, conventional electric network has started to undergo several development actions in order to achieve a network, in which two way communication and liberalization of energy markets are possible. This kind of network utilizing information technologies and high degree of automation is also called as smart grid. (European Commission, 2006)

Smart grid enables energy distribution, storage and supply as well as communication between centralized and decentralized energy systems and consumers. The network communicates in real-time within these systems. In this kind of model, the consumer is not only consuming energy, but can also produce it and sell it back to the grid. By combining possibilities of energy storage, decentralized supply and two-way communication, small-scale renewable energy conversion technologies can be supported better. Smart grid can significantly improve the reliability of the grid, while being also very cost-effective. (European Commission, 2006)

Barriers for renewable energy technologies can be also non-technical. For instance, financial and economic support may not be always included. Renewable energy sources often tend to have high investment costs, which may affect to the decision of installation. In addition, the lack of awareness of renewable technology and behavioral barriers can take place. It is also possible, that national policy is not supporting some certain renewable energy technology. (Sudhakar, *et al*., 2003)

## 2.8 Energy efficiency solutions

Energy efficiency improvements usually stand for measures related to decreasing energy consumption by an object, which can be a building, a process, a device or a service. Among possible energy efficient solutions for buildings can be those leading to their less heating, cooling and electrical energy consumption. This results not only in environmental benefits but also economic savings which can be of use for a company or municipal organization. (Martinkauppi, 2010) In cold climates, heating contributes to nearly half of the total energy consumption of buildings. Heating is required to maintain healthy and comfortable indoor conditions as well as producing warm water for showers, washing. Heat is produced by heating systems (e.g. furnace and electric radiator), solar radiation, occupants and heat losses from appliances. Heating systems may require wood, oil or gas or district heating. (Martinkauppi, 2010) During warmer periods, cooling energy is needed to cool down the building interior in order to maintain an adequate building climate. Especially in southern countries, cooling energy comprises the largest portion of energy consumption in buildings. (Bauer, *et al*., 2010) An essential part of building energy consumption is electricity. Electricity is needed in some heating systems in order to produce heat, run control systems, but also in domestic appliances and lighting. Lighting is consuming a substantial amount of electricity, especially during darker periods and in municipal buildings, such as offices. Many of our daily routines, such as cooking, watching TV and charging batteries require electricity. Electricity consumption in the building sector can form almost 50 % of total electricity consumption. Electricity and district heating is often generated using fossil fuels, such as coal, oil and natural gas. It must be taken into account that production of electricity for energy efficient and green buildings should be done by using renewable resources. (Bauer, *et al*., 2010) Ventilation and air conditioning requires also energy in order to operate and provide adequate indoor air quality (IAQ) to building interiors. Air conditioning usually provides cooling or heating energy and distributes it with an appropriate fresh air flow. In addition, humidity and contaminant levels can be controlled by ventilation systems. (Kreider, 2001) In colder climates, energy consumption reaches its peak in winter time when substantial amounts of heat and electricity are needed because of darkness and coldness. Daily peaks in households occur during mornings and evenings, when people are active (and generally at home). In offices, peak hours usually occur during day time, when people are working and both lighting and ventilation is needed. (Energy Priorities, 2012; LBL, 2016)

Energy efficiency improvements in buildings is a sum of many actions. As a result, apart from saving energy, buildings should provide an adequate indoor air quality, taking also into consideration occupancy requirements. In many cases, to maximize advantages, an optimum between energy efficient technologies and solutions must be found. As an example, a large south-facing window can maximize the amount of daylight and bring heat to interiors, but can also increase heat loss during winter time. Figure 15 illustrates the issues to be considered when working with energy efficiency in buildings. It is to be mentioned that using renewable energy sources are an essential part of the improvements.

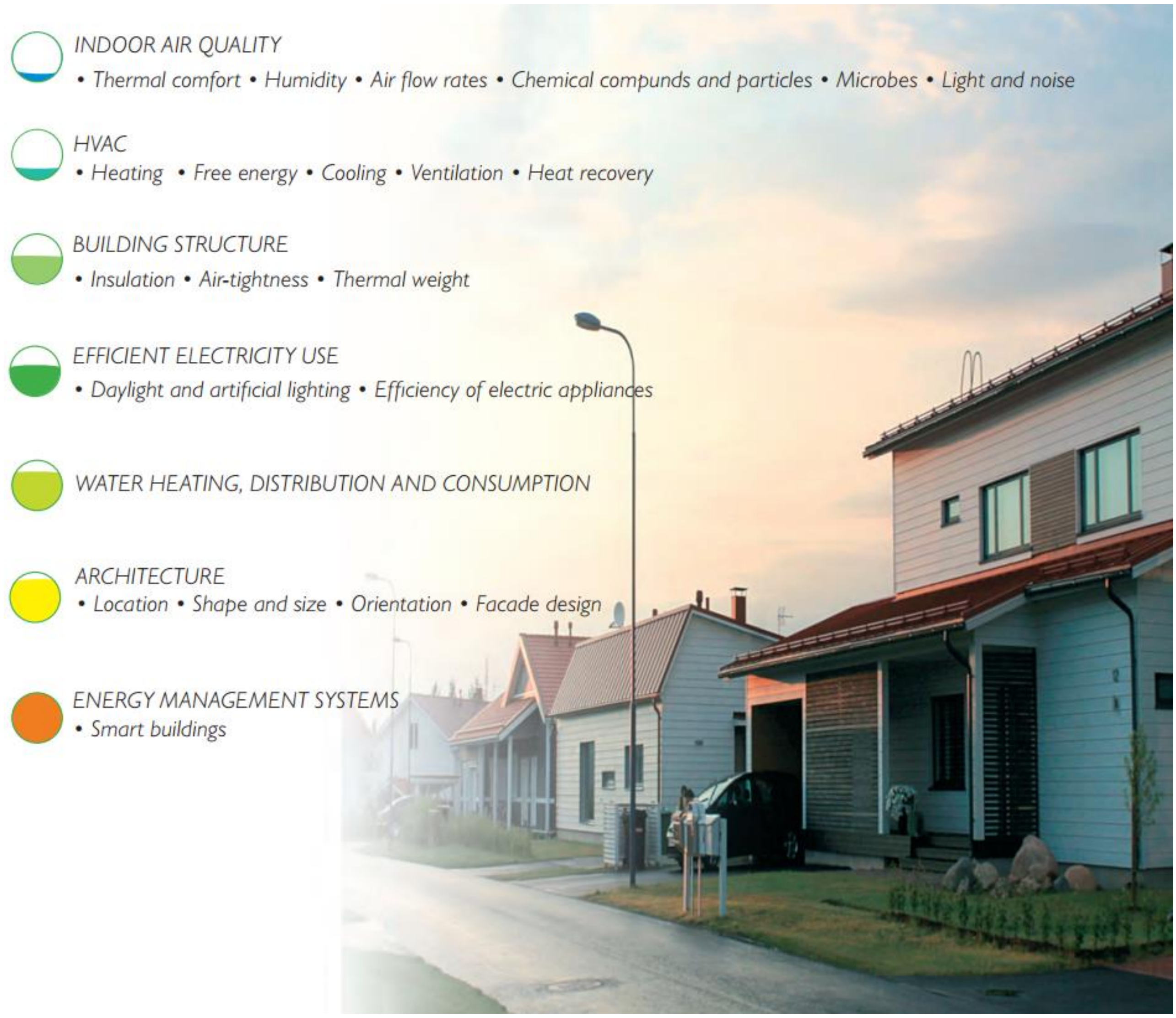


**Figure 15** Energy efficiency in buildings: examples of measures

### 2.8.1 Location

Climate conditions vary substantially in different regions, hence the location plays an important role when designing energy efficient buildings (EeBs) and is always involved in the design process of new houses. In building design, it is important to take into account regional and local climatic conditions as well as microclimate. In addition, topography, landscape, surrounding buildings and vegetation are important factors defining the site for the building. (CIBSE, 2004) The main climatic conditions to be considered at the building site are outside temperature and humidity levels, local wind conditions, the amount of solar radiation and seasonal and daily fluctuations in weather. The climatic conditions and outside temperature are decisive in insulation levels are also affecting HVAC systems. Moreover, the topography, vegetation and the existence of surrounding buildings can contribute to local wind conditions, solar radiation, shading and air pollution. The utilization of local resources can bring many advantages such as passive use of solar energy or generating electricity from the wind. (Bauer, *et al*., 2010)

### 2.8.2 Architecture

Architectural design is an essential tool towards EeBs. The shape of the building affects energy efficiency in many ways. Compact shape in buildings leads to decreased heat losses through building envelope and decreased exposure to weather due to the decreased ratio of building surface area and floor area, as presented in Figure 16. Especially in colder climates, compact shape saves heat energy significantly during winter and can offer better solutions also for organizing HVAC systems (fewer ducts etc.). (CIBSE 2004; Bauer, *et al*., 2010)


**Figure 16** More compact shape (a) is usually more energy efficient choice than more complex shape (b)

The orientation of building is also a part of the building design. The design should allow the incoming solar radiation from south (free energy), bringing both heat and light, resulting in a decreased need for artificial lighting and heating during colder periods. Thus, south oriented windows, having a larger glaze area, can be very beneficial. North facing windows often contribute to heat losses and are exposed to cold winds, so adequate insulation and size of these windows play very important role. On the other hand, during summer, solar radiation can heat up the building considerably. Thus, the design should take into account passive methods in order to prevent excess heating of the building and thus minimize the use of cooling energy. Such passive methods include e.g. eaves, sun blinds and vegetation. Deciduous vegetation can be utilized to maximize solar gains during winter, while minimizing it during summer. (Bauer, *et al*., 2010; Motiva, 2008)

Apart from the orientation of the windows, the amount and size of the windows have to be optimized by design because windows conduct substantial amount of heat, but also allow solar radiation to enter the building, heating the building during colder periods and increasing the amount of daylight. In many countries, regulations can limit the size and amount of glazed areas. It is also more energy efficient to have one larger window than many small ones in the same wall. (Motiva, 2008; CIBSE, 2004)

Generally, the northern facade of the building is exposed mostly to cold winds and rain. Due to this, the building should be covered and sheltered by using e.g. vegetation and other buildings, or by placing the building in south facing hill, if possible. In addition, placements of rooms can also be an issue in EeBs. As a rule, spaces requiring less heating (bedrooms, storages etc.) should be oriented north, while areas requiring more heating (living rooms, offices) should be oriented south. (Bauer, *et al*., 2010)

Electricity consumption in buildings can be reduced by carefully designing the placement and amount of artificial lights, while maximizing the amount of daylight. Artificial lighting should be used only when there is not enough daylight available. In addition, the design should consider the possibility to utilize reflected daylight from light surfaces. (Bauer, *et al*., 2010)

### 2.8.3 Building envelope

The building envelope forms the boundary between building interiors and exteriors. Usually, the building envelope consists of walls, floor, roof, windows and doors. The building structure can also consist of atria. For energy efficiency in buildings, the envelope plays an important role in terms of for heat losses and moisture transfer. The building envelope inside the building is in touch with indoor conditions (temperature, moisture, pressure etc.) and outside the envelope is exposed to outdoor conditions (solar radiation, wind, rain, low temperature etc.), so identifying these factors is essential to take in to account when designing an EeB envelope. When it comes to heat losses, one has to remember that heat can be lost through convection and radiation, not only conduction. (Hagentoft, 2001)

Heat losses through the building envelope can be prevented by using adequate insulation, where the most important factors are the U-value of building structure, the total area of building envelope and temperature differences between building interiors and exteriors. Also air leakages through the building envelope can significantly contribute to heat losses and the indoor air quality of the building.

***Insulation.*** Insulation of the building envelope and structures is necessary in order to avoid heat loss and excessive consumption of heating energy during cold periods, and transfer of heat into the building during cooling. Therefore, the thermal resistance of the building envelope should be maximized. Adequate insulation of building structures can also decrease draught, add to the thermal comfort and improve the IAQ in buildings. Especially in cold climates, heat tends to transfer from building interiors to building exteriors due to temperature differences, so insulation is mandatory. (Seppänen, 2001)

*Walls, roof and floor.* Walls, roof and floor form the largest area of the building envelope. When designing the insulation for building walls and roof, indoor and outdoor temperatures must be considered. In the case of the floor, the heat conductivity of soil must be taken into account, which varies between different soil types. Heat conductivity through the floor structure is usually largest in corner areas, because of the distance between the floor and the outside air is the smallest. (Turner & Doty, 2007)

Heat transfer through the building envelope is greatly affected by the thickness and physical properties of insulation materials. Usually, increasing porosity in materials increases the amount of air in the material (heat conductivity of air is 0,026 W/mK), which leads to decreased heat conductivity. (Seppänen, 2001)

The water content in materials increases heat transfer substantially. First of all, water conducts heat very efficiently and, secondly, water conveys heat in the material. This is especially true with porous materials. In cold climate, humidity levels in buildings are often higher inside than outside. Therefore, it is essential to install a vapor barrier. Generally, the vapor barrier is installed as near the warm building surface as possible. (Binggeli, 2003)

Further important factors affecting heat transfer in insulators are temperature and material density. Gas with high heat resistance can be added in porous materials in order to increase the heat resistance. (Seppänen, 2001)

The common insulation materials in buildings include mineral wood, polystyrene, polyurethane, light concrete and wood fiber slabs. Factors affecting the decision regarding insulate materials are heat conductivity, price, weight, chemical and mechanical permanence, safety, air tightness, humidity resistance and fire resistance. Some general values of heat conductivity of insulators are presented in Table 1. (Seppänen & Seppänen, 2004)

**Table 1** Heat conductivity of some insulation materials (Seppänen & Seppänen 2004)

| Material | λ (W/mK) |
| --- | --- |
| MINERAL WOOL | 0,041 - 0,045 |
| POLYSTYRENE | 0,041 - 0,055 |
| POLYURETHANE | 0,030 |
| CONCRETE | 1,7 |
| BRICK | 0,6 - 0,7 |
| WOOD (PINE, SPRUCE) | 0,12 |

Insulation should be evenly distributed in the building envelope. In many cases, changes in the building structure or change in building composition can lead to increased local heat conductivity. These kinds of areas are called thermal bridges. Such places include e.g. corners, metal studs and structure beams. Thermal bridges should be avoided because of increased heat conductivity but also because of decreased local surface temperature. Decreased surface temperature of the structure due to better heat conductivity can contribute to the condensation of moisture, leading to several problems (e.g. formation of mold and increased draught). Thus, special attention must be paid to insulating these areas. (Turner & Doty, 2007; Seppänen & Seppänen, 2004)

***Windows***. The amount, size and properties of windows affect greatly the heat loss in buildings. Therefore, careful design of windows must be done. Heat losses through windows can be decreased by increasing the thickness of the window, installing more than one glazed layers and letting air gaps between the layers (or some insulation gas). The use of shutters and blind shades also affect the heat conductivity of windows. It is also considerable that window frames and other structures can conduct substantial amount of heat, especially in older buildings. (Seppänen & Seppänen, 2004)

Energy efficient windows should also have a coating, which allows the entering of short-wave solar radiation in to the building. In proportion, glazed area should be designed so that it absorbs and reflects long wave radiation from building interiors, decreasing the overall heat loss through windows. Heat loss through window frames must be also taken into account. (Turner & Doty, 2007)

***Doors***. Doors are also included in the building envelope, and thus heat losses through door slab, door window and door frames will also have to be taken into account when defining the total heat loss through building envelope. (Seppänen, 2001)

In Finland, the insulation of buildings is well regulated. There are regulations for upper limits in different parts of buildings. In warm spaces (T ≥ 17 °C), the U-value of windows is not allowed to exceed 1,8 W/m$^2$K, and 0,6 W/m$^2$K in other structures. For colder spaces (T ≤17 °C) the upper limit for U-value in windows is 2,8 W/m$^2$K. Usually, the insulation in Finnish buildings is much more energy efficient, especially in new buildings. (Ympäristöministeriö, 2010)

***Air tightness.*** Air tightness (infiltration) in buildings describes the movement of air in the building structures. Air can flow from the building interiors to outside and the other way around, depending on the existing pressure and temperature between inside and outside air. Other factors affecting to air tightness (and air leakage coefficient q, describing air tightness) are the properties of building envelope materials and wind conditions. Cracks in building materials contribute to the movement of air through the building structure. (Bauer, *et al*., 2010)

Air leakages from building interiors contribute to heat losses through the building envelope. In hot seasons, warm air can flow from the building exteriors to interiors, leading to increasing energy requirement for cooling. Moreover, the air moving through the building envelope can also lead to moisture problems and transfer of contaminants to building interiors. Therefore, it is important to seal building structures properly. (Turner & Doty, 2007)

Heat losses are lower in air tight buildings and usually contribute to a better IAQ. However, when the building is very air tight and insulated well, some problems with moisture can occur in critical areas of the building such as the thermal bridges. For this reason, and adequate ventilation system (usually a heat recovery system) is recommended in order to remove excess moisture and avoid problems with mold. The ventilation system also maintains a slightly smaller pressure in building interiors than outside, avoiding the driving of moisture into the structures, and preventing the excess movement of air from outside to inside. It is also necessary to install an air barrier, to block out excess movement of unwanted air. In Finland, the air leakage coefficient can have the value of 4 m$^3$/m$^2$h at most. (Ympäristöministeriö, 2012)

***Thermal weight and special insulation materials.*** The building envelope can store heat from outside (free energy) and from inside. By controlling the mass and heat capacity of the building structure, we can affect the thermal weight of the building. For example thermally “heavy” building structure can store free energy (such as solar energy) during warm summer day and release it in building interiors during colder night. Therefore, savings in heat energy consumption during nights can be obtained. Appropriate materials for thermally heavy building envelope include e.g. concrete, brick, stone and tile. (Turner & Doty, 2007)

Some light transmitting insulation materials can also be used in order to increase the amount of absorbed heat. In colder climates, these kinds of materials are more likely to be used in outer walls, where solar radiation transmit the material, absorbing then in thermally heavy material. In addition, there are also insulation materials that can allow a certain amount of air leakage. In this case, the structure exchanges heat between conducting heat and heat carried by the leakage air. By doing this, the heat flux through inner or outer envelope structures can be controlled. Some phase change materials are also available. (Seppänen, 2001)

### 2.8.4 Heating, ventilation and air conditioning

The main purpose of heating, ventilation and air conditioning system (HVAC-system) is to provide adequate indoor conditions for occupants. Such conditions include e.g. maintaining appropriate temperature (cooling and heating) and humidity levels, removal of harmful compounds and distribution of fresh air. In order to maintain these basic needs in the building, energy must be used. One must keep in mind that an energy efficient HVAC system can consume less energy, while providing better indoor air quality (IAQ) and improving the quality of life. In many cases, HVAC systems can be characterized as active or passive systems. Active systems include all the “technical” or mechanical solutions, and passive systems include non-mechanical solutions. Furthermore, HVAC systems can be distinguished to centralized and decentralized units.

***Heating***. Heating is necessity for buildings in order to maintain an appropriate temperature in the building interior. Heating can form a major portion of energy consumption in the building sector and it is also contributing substantially to emissions associated with buildings. A large proportion of heat is produced by using fossil fuels (such as natural gas, charcoal and oil) in the building or as a district heat, which should be replaced by renewable energy sources.

The total heat demand of buildings is determined by heat losses through building envelope, heat conduction to the soil, heating demand of ventilation system, heating demand of air leakages and heating demand of water. When evaluating the entire heat production of the building, heat loads from occupants, electric devices and lighting must also be taken into account. Especially in densely occupied buildings, heating load from humans can also be relatively high. This free heat should be utilized as efficiently as possible. (Seppänen, 2001)

In Finland, most of the heat for buildings is produced by district heating facilities. Compared to boilers in buildings, these kinds of larger heat production facilities have some advantages such as better efficiency and controllability of the equipment and cheaper raw-material costs. Moreover, air pollution is not necessarily generated in the building area. District heating facilities also use large amounts of fossil fuels, such as coal, natural gas, oil and peat. (Seppänen & Seppänen, 2004)

Boilers, furnaces and fireplaces are also commonly used in buildings in order to produce heat. Due to the high heating values and low volume requirement of oil, coal and natural gas, these fuels are often most used. Still, apart from the environmental impact, the prices of fossil fuels are increasing, which are restricting the use of these fuels. (Turner & Doty, 2007) More preferable fuels are wood, biogas, pellets and other biofuels. Disadvantages of these fuels are the usually higher price, lower heating values and larger volume requirements. However, in many cases, these combustion based fuels can release enough heat for building. To make the heating system more energy efficient, there are systems available that can recover heat from flue gases and transfer the heat for example to water. In addition, the use of pellets can offer a viable choice for replacing wood or fossil fuels due to their high energy density and low price, storage volume and low emissions. (Hirsilinna, 2012)

Furnaces and fireplaces can act as thermally heavy heat storage, heating the surrounding air through convection and radiation. On the other hand, heat from the heat source can be used in order to heat up water, which can be further distributed to heat releasing systems, such as radiators. It is possible to use air or water as a distribution media, but water is still the most common media used due to its great heat transfer properties. (Seppänen & Seppänen, 2004)

Warm water is commonly released by different kinds of radiators and convectors. A common radiator type is a panel radiator, which is usually placed under a window to avoid draught. However, in many cases, a more energy efficient solution can be realized by using floor distribution system, which has larger heat transfer area and removes the problem of cold floor surfaces. The distribution system can also be installed in the ceiling. However, the furniture and carpets can block heat effectively from floor radiant system, decreasing the efficiency of the floor heating system. (Seppänen, 2001)

Space heating can also be produced by using electricity, and the produced heat can be further transferred to water. It is also possible to have electric resistance heating in the radiators. Such systems responds quickly to temperature changes in rooms. In addition, lower-priced electricity during the night can be used in electric heating applications by storing the produced heat. Nevertheless, electric heating is not the most efficient and cheapest way of heat production. (Turner & Doty, 2007)

There are also other sustainable and efficient systems for heating in buildings. Heat pumps can produce heat with low electricity use reliably over the year. Other systems include active solar thermal collectors and biomass-based heat resources. (Awbi, 2008)

Passive use of solar irradiation is common in buildings. Direct gain heating is one option, where windows are used to allow the incoming short wave irradiation to enter the room, while reflecting back most of the long wave radiation (heat). Windows are usually oriented to south in order to maximize heat gains. There are many factors affecting to the amount of gained heat, such as window area, heat losses through window and absorptance of the room surfaces. Excess heat gains can be prevented by installing solar shading system. Despite the potential heat losses during winter, window size should be optimized in order to maximize direct solar gains and minimize heat conduction through window. (Duffie & Beckman, 2006)

Solar radiation can be used passively by absorbing incoming radiation to building structures. Collector-storage walls or solar walls can absorb solar radiation and transfer the absorbed heat in to rooms by radiation and convection and radiation. In many cases, these kinds of structures have a special insulation material, which allows the incoming radiation to enter the absorbing structure. Between these structures there can be a glaze and the gap between glazing and the absorbing structure can be vented or unvented. Moreover, if vented, ventilation can be forced or natural. Heated air can be distributed to rooms which are colder (shadow side rooms). However, thermally heavy building structure can store heat and release it during e.g. nights when it is colder. Steep and dark colored roof structure can absorb bigger amounts of solar energy than light colored gentle roof slope. (Duffie & Beckman, 2006)

There are also window structures that operate like collector-storage systems. In these applications, e.g. blind shade between glazes absorbs heat, which can be further leaded to rooms. Moreover, sunspaces, which are separate glazed areas in buildings, can utilize solar radiation passively. Heat can be stored in structures (e.g. floor and walls) and direct gains can be generated. In addition, hybrid systems, which use solar radiation actively and passively, can be used. (Duffie & Beckman, 2006)

***Cooling***. In colder climates, inside air temperatures can raise substantially during summer, affecting to comfort of occupants. Thus, cooling energy must be provided. The cooling system applied depends on the amount of removable heat load. During sunny summer days, it is important to minimize the heat production in buildings. This can be done by using solar shading system in front of windows, which block solar radiation effectively. The size of west and east oriented windows can be minimized to avoid excessive heat gains. In high buildings, warm air can be ventilated outside through an air gap at the ceiling. (Bauer; Mösle & Schwarz, 2010)

Good insulation and appropriate air-tightness of building envelope prevents heat transfer from outside to building interiors. Moreover, heavier thermal mass can absorb heat and release it later during cooler periods, e.g. during nights. It is also important to place devices producing unwanted excess heat in separate rooms. (Seppänen & Seppänen, Rakennusten sisäilmasto ja LVI-tekniikka, 2004)

If these passive methods described above cannot be used to provide enough cooling energy, active cooling takes place. In many cases, cooled air is distributed by an air conditioning system, where a separate cooling coil produces cold air. On the other hand, heat recovery system can recover cooling energy and lead it back to the building. However, auxiliary cooling systems with cooling coils use electricity, which increases the overall energy consumption of the building, and should thus be avoided as much as possible. (Kreider, 2001)

If outside air is warm and dry, an evaporative cooling system can be used. Evaporative cools down the incoming warm and dry supply air by transferring heat in to water droplets. In addition, mist air feels cooler. Moreover, absorption refrigeration and desiccant cooling system can provide low temperatures to building interiors. (Binggeli, 2003)

Heat pumps and other refrigeration cycle devices can provide efficient cooling energy for buildings. These devices can use building interiors as a heat source and release heat to a heat sink (i.e. air, ground or water). In addition, ground can be used as a pre-cooler for cooling systems. For instance, during summer, the temperature of the ground in certain depth can be much cooler than the temperature of air and topsoil. With rather small electric input for heat pump compressor and fans, lot of cooling energy can be provided. (Awbi, 2008)

***Air conditioning and ventilation***. Ventilation is necessary in every building in order to maintain appropriate indoor air quality and occupant comfort. Ventilation removes such as odor, pollen, hazardous contaminants and moisture from the building. With air conditioning system, also adequate temperature and fresh air can be brought to the building. There are several different ventilation systems available, but this text concentrates only on the most energy efficient ones, which are used in colder climates.

***Heat recovery***. Nowadays heat (or energy) recovery system is default in almost every new building in Finland. Heat recovery removes warm and contaminated air from the building interior, transferring heat to the fresh and colder air from outside. The filtered fresh air is introduced to building interior. Thus, heat it not released outside – it is recovered, leading to better energy efficiency of the building. Heat recovery system can also work opposite, bringing cooling energy to building (recovery of cooling energy). Heat recovery units can also transfer moisture, leading to controlled healthy moisture levels in building. The control of moisture levels is important especially in highly EeBs, where moisture can condense on thermal bridges. (Awbi, 2008)

When using heat recovery system, one must ensure that the building envelope is airtight enough and there are no air leakages in ducts, so that heat is not lost through the structures and the heat recovery system can work as efficiently as possible. Additional heating and cooling coils can be also added in order to heat or cool down the supply air, but this kind of procedure consumes extra energy. Energy efficiency can be increased by constructing preheating unit, which transfers heat to from e.g. ground to supply air. (Kreider, 2001)

***Natural ventilation and hybrid solutions***. Natural ventilation can be used in some cases in order to ventilate rooms. Natural ventilation can be organized e.g. through windows or ceiling openings. However, window based natural ventilation is not enough in colder climates, where heating is needed most of the time. In addition, simultaneous use of window and mechanical ventilation system is usually inefficient. Hence, window ventilation can be used when a mechanical ventilation system is turned off. However, window ventilation can bring impurities, cold air and moisture into the building, leading unhealthier and unaccepted indoor air. (Kreider, 2001)

Natural ventilation includes also convective ventilation, in which warm stale air raises towards ceilings where it is removed and fresh outdoor air infiltrates from lower building levels. Besides natural forces, fans can be also used. Convective ventilation can be used especially in high buildings. In the end, heat can be recycled back to the building. However, this kind of system must be designed very carefully, especially in colder climates, because of heat losses through infiltration areas and too cold air intake. (Binggeli, 2003)

Some hybrid solutions, such as integrated heat pump with heat recovery system, can lead to better energy efficiency of the system. Switching between natural and mechanical ventilation can also lead to energy savings, especially in bigger buildings, where heat loads e.g. from people are really high. (Awbi, 2008)

When designing energy efficient HVAC system for buildings, the air distribution system must be considered as a part of energy calculation. At first, ducts can have a certain amount of heat loss when distributing the air. Secondly, air is distributed by fans, which are consuming electricity. The electricity demand for fans depends on the fan efficiency, the properties of the duct (friction, length, area, shape, the amount of other equipment etc.), operation time and required flow rate (i.e. pressure difference). Turning off the ventilation when is not needed saves a lot of electricity, especially in office buildings. On the other hand, fans produce some heat while operating, which have to be taken into account. (Seppänen & Seppänen, Rakennusten sisäilmasto ja LVI-tekniikka, 2004)

HVAC systems require also a measurement and control system, which consumes electricity. In addition, some air conditioning systems have heating and/or cooling coil or preheaters, which can run by using electricity. These kinds of actions consume more energy, obviously. Energy losses through the ventilation unit must be also evaluated. In addition, heating demand of ventilation air must be included in to energy demand calculations. Correct sizing of HVAC system have also crucial role in the energy efficient design. (Ympäristöministeriö, Rakennuksen energiankulutuksen ja lämmitytehontarpeen laskenta, 2007)

The optimal use of HVAC system increase also energy efficiency. HVAC system should provide sufficient conditions for occupants. Minimum or “just enough” –principle works in many cases. Following issues are essential to remember when designing HVAC system:

- Do not ventilate with full power when a room is not occupied
- Avoid excess heating and cooling
- Provide just enough ventilation air
- Do not use simultaneous heating and cooling, if possible

***Water heating and distribution***. Buildings consume significant amounts of water every day. In colder climates, approximately 40 – 50 % of water is consumed as warm water. Thus, substantial amount of energy is needed in order to produce warm water for building and occupant purposes. This is especially true with residential buildings, swimming halls and sport centers, where warm water is for e.g. in showers, washing machines and cleaning. Usually taking care of personal hygiene shares the biggest part of warm water consumption. In office buildings, water heating can share smaller part of total energy consumption. (Seppänen, Rakennuksen lämmistys, 2001)

Heat is often transferred from district heating system to warm domestic water. As presented before, water can be also heated by using boilers or electricity. Today, water heating should be more efficient and renewable energy sources should be used in water heating. Thus, water heating can be assisted by using solar thermal collectors, heat pumps (air-to-water, ground-to-water or water-to water) or combination of solar thermal collectors and heat pump. It is also possible to utilize heat from wastewater streams. Recovering heat from wastewater is more economical in bigger municipal buildings, such as swimming pools. (Awbi, 2008)

Water heating and distribution should be as efficient as possible. Factors affecting to the efficiency of water heating include heat losses through heat production system, pipes, valves and other equipment. In addition, pressure losses in pipes should not be too big. Otherwise excess electricity is needed in pumps etc. One has to always remember that water consumption should be also minimized by changing habits and having efficient water nozzles and domestic appliances, besides lowering the temperature of the hot water. Energy demand of water systems can be also decreased by utilizing grey water in toilets and gathering rain water and leading those to e.g. vegetable garden, if possible. (Bauer; Mösle & Schwarz, 2010)

The temperature of the domestic hot water should be high enough (between 55 - 65 °C) in order to avoid harmful growth of bacteria (especially *Legionella pneumophila*). On the other hand, lower water temperature e.g. in pipes and storages prevent from excessive heat losses through surfaces. Thus, lowest possible temperature should be used. Placing the water storage tank in warm room prevents also from heat losses. (Seppänen, Rakennuksen lämmistys, 2001)

### 2.8.5 Electricity and control systems in buildings

***Electricity and lighting***. Buildings consume substantial amount of electricity annually. Electricity is needed in lighting, HVAC systems, electric appliances and other equipment, such as lifts and escalators. Increasing electricity price and pollution from electricity production is pushing towards savings in electricity consumption. Thus, careful electrical and lighting design must be undertaken when designing EeBs.

Lighting can share a big part of electricity consumption of buildings. More energy efficient lighting does not only save electricity, but it can also contribute to the quality of light and productivity of workers in buildings. Usually, daylight should be utilized as much as possible. South facing windows and obstruction free courtyard decrease the need of artificial lighting. Utilizing daylight can be seen one of the most effective and cheapest method to reduce electricity consumption of lighting. The quality of daylight is also comfortable. However, the optimization between windows gaining daylight and preventing from heat losses must be done. (Bauer; Mösle & Schwarz, 2010)

By using light colors inside the building, the reflectance of daylight can be improved. At the same time, daylight can be distributed better to interiors. In addition, the amount of daylight can be utilized by using toplights and skylights. These solutions provide excellent amounts of daylight, especially if south oriented. At the same time, the effect of glare can be reduced. (Binggeli, 2003)

When artificial lighting is needed, the electricity consumption can be decreased by increasing the lamp efficiency. Decreasing the amount of luminaries can cut down the electricity consumption. Artificial lighting should be used only when needed and where needed. This is especially true in hospitals and offices, besides rooms where special tasks have to be done. Allocating light where it is mostly needed can save energy. In addition, there are several lighting control systems available, such as time clocks, photocells and occupancy sensors. These control systems can turn of lights when not needed, leading to substantial electricity savings. (Turner & Doty, 2007)

HVAC system can form 40 to 50 % of total electricity consumption in buildings. However, efficient HVAC system brings other advantages. Electricity in HVAC systems can be decreased by shutting down ventilation when is not needed and using passive cooling or heating methods. (Kreider, 2001)

Domestic appliances consume some energy, and attention should be paid on energy efficiency of these devices. In addition, other devices, such as lifts and escalators require electricity. Electricity can be saved also by decreasing the amount of these devices and using them only when needed. (CIBSE, 2004)

***Energy management and control systems***. Control and automatic systems are advantageous when making an energy sparing building. These systems, besides optimal energy use, enable also safe, economical and appropriate operation of target device or system and lead to optimized indoor air conditions. As a result, building can be more energy efficient by being implemented with “smarter” technology.

Smart electric power management system (EPMS) ensures safe and reliable power quality, when bringing economic advantages and reduced energy consumption. Based on measured and monitored power consumption, power quality (i.e. outages, surges and sags, for instance) and event alarms, the power management system can suggest or initiate schemes for reducing power consumption. The system can also respond to power demand during peak consumption hours by defining power saving schemes, such as reducing power consumption of HVAC system and lighting or using electricity production systems on site. During peak consumption hours, the price of electricity can be more expensive. Thus, the system can bring substantial economic benefits. (Sinopoli, 2010)

Smart meters measuring power consumption in detail are essential part of EPMS. By providing real-time data about the amount of consumed power and information about consumption time and seasons, smart meters enable customers to monitor and control power consumption and evaluate schemes to improve energy efficiency, while minimizing power costs. EPMS can also have submetering devices monitoring power distribution in different areas in buildings. By submetering, customers can follow real-time power consumption in specific areas, and control then e.g. power consumption. In addition, smart power strips can decrease the electricity consumption of devices being shut down or having standby mode. (Sinopoli, 2010)

The ultimate goal of EPMS would be storing electricity and running devices during night, when electricity is usually cheaper. Electricity could be stored e.g. in batteries communicating with other domestic appliances and even with an electric car. Furthermore, EPMS can have different power usage settings for energy savings, such as holiday scheduling, yearly scheduling, night time settings, hot water reset and so on. The advantage of EPMS is that it can use wireless digital control. (Turner & Doty, 2007)

Lighting control system can include several control methods available decreasing the electricity consumption of lighting. At first, scheduling (or time clocking) can be used, in which the device holds light on, turning them off after a certain period of time. Other option is occupancy sensors, which recognize if the room is occupied or not, and controls then the lighting. Usually the occupancy sensors sense e.g. body heat, movement, sound or combination of these, putting then lights on. (Sinopoli, 2010)

Photoelectric devices can control the amount of artificial lighting, when daylight is available. Thus, the device turns lights off when daylight is at large. Automatic blinds, for instance, can be also possible to prevent excessive passive solar heating. Furthermore, dimmers can be used in order to cut energy use of lamps. Dimmers can be especially useful when there is some supplementary lighting required besides daylight or during the day time, when electricity demand is at peak. (Sinopoli, 2010)

HVAC control systems can also use this kind of sensors controlling the operation of the system. For example, if occupancy sensor is not sensing any people in the building, ventilation is put off. On the other hand, occupancy sensors can measure the amount of occupants in the building, controlling thus the operation rate HVAC system. Real time monitoring enables an appropriate control of temperature, humidity, pressure and airflow levels. To avoid overlapping in heating and cooling, a dead band thermostat can be used. This device shut HVAC off, having a clear difference between cooling and heating. (Turner & Doty, 2007)

### 2.8.6 Renewable energy in buildings

Most of buildings nowadays use fossil fuels in order to produce heat. Furthermore, electricity is brought from the outside source of the building in many cases. Raising environmental concern, increasing energy prices and tighten regulations are pushing us towards renewable energy in buildings. The use of renewable energy sources, when realizing the application or combination of applications appropriately, can bring substantial economic and environmental advantage. This chapter presents the most common renewable energy sources in building applications.

As mentioned in earlier chapters, building sector consumes a substantial part of total energy. Especially, the main part of heat is consumed in buildings. In addition, buildings can use even 50 % of total electricity supplied. At the moment, prices of electricity are raising, pushing us towards energy savings in buildings. Furthermore, production of electricity is one of the main contributors to environmental hazards, such as climate change. Thus, the use of renewable energy sources should be used more, also in buildings. Figure 17 presents electricity production by source in Finland and Figure 18 describes some common renewable energy sources, which can be integrated in buildings. (Tilastokeskus, 2008)

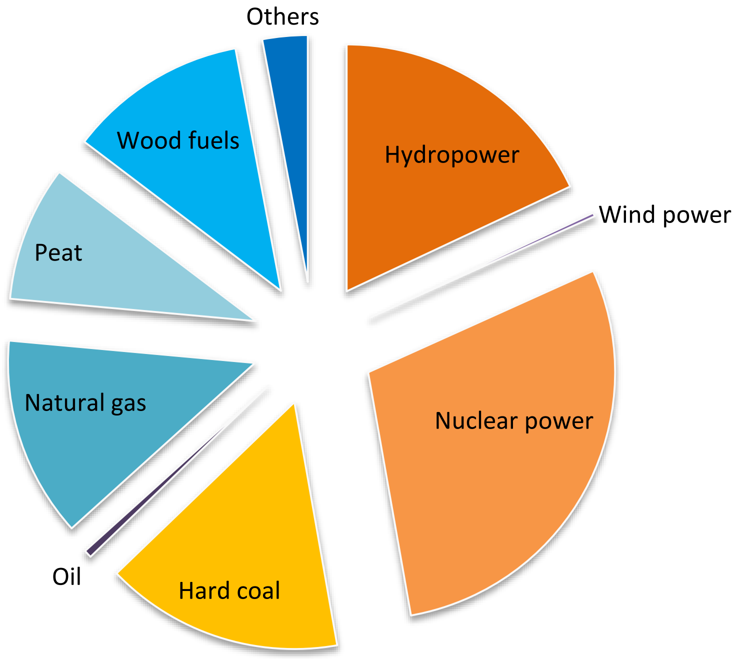


**Figure 17** Supply of electricity by energy source in Finland 2007 (Tilastokeskus, 2008)

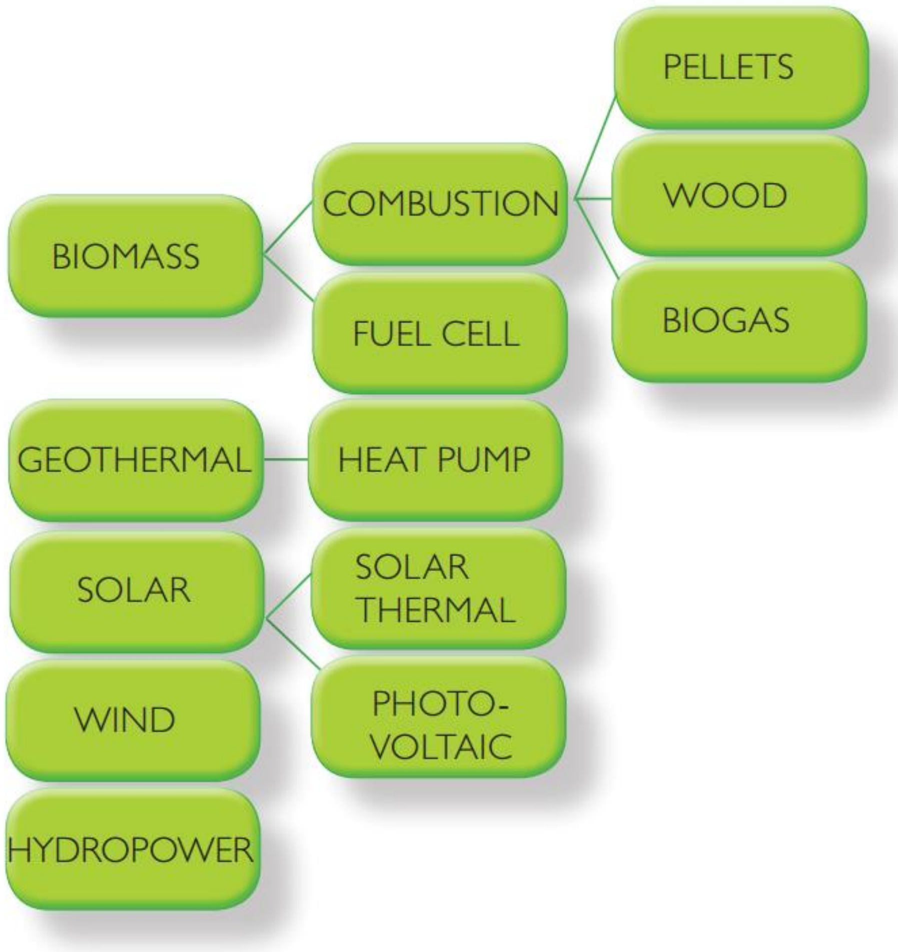


**Figure 18** Common renewable energy sources in buildings

***Biomass energy***. Biomass can be used in order to produce heat or electricity. The most conventional biomass based fuel that is used in buildings is wood. Through combustion processes in furnace, wood can produce sufficient amount of heat for space heating, water heating and e.g. cooking. Wood based combustion is still recommended in small and medium scale buildings and especially in seasonally occupied buildings as a heat source. Recently, more energy dense, tubular shaped pellets can be used instead of wood in furnaces. The advantages of modern pellet systems, besides higher energy density, are easier storability, automatic fuel supply and controlled combustion conditions. (Twidell & Weir, 2006)

Some buildings produce heat by using natural gas and other fossil fuels. It is possible to replace these gaseous fuels by biogas produced from anaerobic digestion or syngas produced from gasification process. Liquid fuels can include ethanol, biodiesel and bio-oil. These fuels can be combusted and used to heat up boiler, for instance. (Twidell & Weir, 2006)

Especially in future, fuel cells can have a great potential in buildings because these devices have multi-scale options and rather good efficiency. Fuel cells can utilize e.g. hydrogen, methane and carbohydrates as an energy source. It is possible to produce both electricity and heat through fuel cells. (Twidell & Weir, 2006)

In residential areas, bigger CHP plants can produce electricity and heat for surrounding buildings. These kinds of plants can include combustion, gasification, pyrolysis and anaerobic digestion plants. (Twidell & Weir, 2006)

***Geothermal energy***. Geothermal sources include air, water and ground. In building applications, geothermal applications can generally provide heating and cooling. Nowadays, heating and cooling is provided extensively in different climates with devices called heat pumps. In heat pumps, a refrigerant flows in pipes (usually closed loop) and extracts energy from a low energy system (air, ground or water) and brings heat for a high energy system (building) by work done by a compressor. (Kreider, 2001)

Conventional heat pump uses air as a heat source. More advanced water-source heat pumps can extract heat from lakes, rivers and sea. It is also possible to pump ground water from the ground to a heat exchanger unit, where heat is transferred and ground water is led back to the source. (Awbi, 2008)

Ground-source heat pumps use soil or bedrock as a heat sink and source. Heat collection or rejection system in the case of ground-source heat pump can be vertical or horizontal. Horizontal piping requires more space, which can be problem in urban areas. On the other hand, vertical installation (U-pipes) can be rather expensive. It is also possible to install energy piles in construction auger piles when in new buildings to avoid excessive costs. (Awbi, 2008)

Heat pump applications can provide space heating during winter and cooling energy during summer. Water heating is also possible by using these applications. In some cases, solar thermal collectors can be integrated to heat pumps in order to enhance water heating. Heat from wastewater can be also utilized by using heat pumps. (Seppänen, Rakennuksen lämmistys, 2001)

***Solar energy***. Utilization of solar energy passively is very common in buildings. Active use of solar radiation can be distinguished to solar thermal collectors and solar photovoltaic cells (PV). In colder climates, the biggest restrictive factors for the use of solar energy is dark winter time, when solar radiation is at minimum and electricity and heat demand are at maximum. Other restrictive factors affecting the energy production of active solar energy are e.g. daily variations in the amounts of irradiation (day – night), weather conditions, rather low efficiency and presence of pollution. However, solar energy can bring sufficient amount of energy during summer. (Duffie & Beckman, 2006)

Solar cells can convert incoming photons from the Sun into electricity. The efficiency of a certain cell usually varies generally between 10 – 20 % and cells can be placed on the roofs, walls and other building structures. Solar cells have become popular in buildings in southern countries, but increasing attention is gained also in northern areas. Still, the main restrictive factors for the use of solar cells are low efficiency, high price and lack of solar radiation during winter. Direct current from solar cells can be utilized for example in water pumps, but usually DC is converted to AC, which is suitable for domestic appliances. (Luque & Hegedus, 2003)

Solar thermal collectors absorb solar irradiation with dark colored absorption surface and transfer the absorbed heat to fluid, which is flowing through the collector. Heat transferred to the fluid can be used in order to heat up the usage water or circulated in water circulating space heating system, such as floor radiator. In colder climates, solar thermal collectors can provide auxiliary heating for building space and water. (Duffie & Beckman, 2006)

Solar thermal collectors can be distinguished to direct or indirect systems. In direct system, water flows through the collector and water is heated up. In indirect system, a fluid (usually freezing resistant fluid) flows through the collector and releases absorbed heat in to water in a separate heat exchanger. Furthermore, solar thermal collectors can be divided to pump assisted active systems and passive systems based on gravity and density forces. (Duffie & Beckman, 2006)

In active solar energy applications, it is important to consider the roof area of building. The bigger the area is, larger amount of solar radiation can be utilized. (Bauer; Mösle & Schwarz, 2010)

***Wind energy***. Wind energy can be used when there are sufficient wind conditions. Usually, the economic operation of wind mills requires wind velocities up to 4 m/s, which cannot be met in every building area. Especially, in urban areas, other buildings can block wind efficiently. One of the main disadvantages of wind turbine application is that it is not always windy, leading to unreliable production of electricity. (Manwell; McGowan & Rogers, 2009)

With sufficient wind conditions, wind power can provide auxiliary electricity for building applications. There are several different wind mill sizes available on the market. Some special applications where wind mills can be used, besides conventional electricity production, are, for instance, water pumps and ice making (cooling storage). (Manwell; McGowan & Rogers, 2009)

### 2.8.7 Energy storage

In order to save energy and enable the use of renewable energy in buildings, energy storage is often involved. By using energy storages, free energy can be also stored. In addition, it is possible to use energy from energy storages during peak consumption hours, when the price of electricity can be higher. Generally, energy storages can be distinguished to thermal, chemical, electrical and mechanical storage. Biological storage is an option, but it is not discussed in this context.

***Thermal storage***. Thermal storage is often integrated to building structure. As discussed in earlier chapters, building's thermal mass can store heat passively from solar radiation. With high mass and great heat capacity, the structure can store heat during a day and release it during cooler night periods. This kind of procedure saves cooling energy during day and heating energy during night time. (Duffie & Beckman, 2006)

Hot water (or other liquid) storage with sufficient insulation can used as thermal storage over weeks or even few months. Tanks can be placed above or under the ground. For instance, heat generated by solar thermal collector can be further stored in this kind of system. Water storages can be also used as cold water storage. In addition, phase changing materials having e.g. higher melting points than water can be also possible heat/cold storages, such as Gauber's salt ($Na_2SO_4 \cdot H_2O$). Energy can be also stored in ice storage utilizing the latent heat of phase change in order to get cooling energy in warmer periods. (Twidell & Weir, 2006)

***Chemical storage***. Chemical storage provides an option where electricity or heat can be stored in chemical bonds of compounds. These compounds can be further broken down in exothermic reactions, such as combustion, in order to produce heat. One option for chemical energy storage is hydrogen ($H_2$). Hydrogen can be produced from water by using electrolysis. Thus, direct current from renewable energy resources in buildings could be stored in hydrogen molecules that can be stored and burned or used in fuel cells. (Twidell & Weir, 2006)

***Electrical storage***. Electricity is conventionally stored in batteries. In buildings, batteries can be charged with e.g. renewable electricity from solar cell or wind mill, or cheaper electricity from the grid can be stored during nighttime. Electricity can be used during peak consumption hours. Electric cars can also work as electric battery storage. (Twidell & Weir, 2006)

***Mechanical storage***. Mechanical storage systems have usually bigger scale and are more expensive solutions. However, bigger commercial buildings can use mechanical storages in some cases. First of all, water can be pumped in to higher water reservoirs by using electrical pumps. During immediate demand or peak consumption hours, or when electricity is not produced from renewable sources, water can be led out from reservoirs in order to run a turbine and produce electricity. Mechanical storage systems can include also flywheels and compressed air storages. (Twidell & Weir, 2006)

## 2.9 Summary

There are several renewable energy technologies available and the feasibility of each technology must be evaluated separately according to the surrounding conditions and the need of energy at the load side. Table 2 summarizes general scales and payback periods of renewable energy technologies. Values are general, and payback periods may vary strongly depending on ambient conditions and the system architecture.

**Table 2** Typical scales and payback periods of renewable energy technologies

| | **Scale** | **Payback period, years** |
|---|---|---|
| **WIND POWER:** | *0,1 – 3,6 MW* | *10 – 20* |
| **SOLAR THERMAL:** | *250 – 400 kWh/m$^2$/year* | *5 – 15* |
| **SOLAR PHOTOVOLTAIC:** | *20 – 50 $W_p$* | *10 – 20* |
| **HYDROPOWER:** | *0,1 - > 100 MW* | *10 – 15* |
| **ANAEROBIC DIGESTION:** | *0,1 - > 20 MW* | *10 – 25* |
| **HEAT RECOVERY FROM WASTEWATER:** | *0.1 – 90 MW* | *2 – 10* |

The scale of solar photovoltaic cell is expressed as watt peak ($W_p$) rated under standard testing conditions. The amount of energy production in solar photovoltaic technology depends greatly on the installed area of the cells and the amount installed cells. The power production of solar thermal collectors and PV cells can be increased significantly by having a control system, in which the cell/collector follows the direction of the Sun. In this way, the cell/collector can be oriented ideally towards the sun dynamically. (Nelson, 2004)

Concerning implementation of the considered technologies, the Northern Periphery Region is gradually including more renewable energy sources in energy supply for the water industry. Hydropower, solar and wind energy are applied in Scotland, Northern Ireland and Ireland. Anaerobic digestion is common for Finnish, Scottish and Irish water service sector. Heat recovery is employed in Finland and Sweden.

As a whole, water assets are the most utilized for renewable energy generation in Scotland and Ireland. These countries have the highest number of water-energy projects. Northern Ireland can be second place in this sense. In Finland, heat pumps and anaerobic digestion are used. But the scale of implementation of hydropower, solar and wind energy is negligible and there is still unutilized potential. In Sweden, there is high expertise of wastewater heat recovery. In Ireland, there is a list of pilot projects in terms of renewable energy implementation. The prioritized renewable energy technologies are wind energy, solar PV energy and hydropower. (MayoCoCo, 2014) As regards the Scottish water industry, there are also numerous water-energy projects utilizing such renewable energy solutions as anaerobic digestion, solar, wind energy and hydropower. One of the key reasons of broad renewable energy development in Scotland is that Scottish Water is one of the largest energy consumers in the country and aims to become an energy self-sufficient entity. In this context, the water assets such as land, water and community resources are in the focus of attention. There are quite many renewable energy initiatives applied and now Scottish Water produces about 7% of their total energy consumption. (Scottish Water, 2014a) The objectives are to export energy to the national grid, support the Renewable Energy Directive targets in the country and produce up to 5% via the Scottish Water asset utilization (McArdle, 2013; O'Fee, 2014). In total, Scottish Water has approximately 285 $km^2$ of land area. High land areas possess hydropower energy potential. Land areas can be also used for wind energy production. Scottish Water reservoirs can be converted into dams to generate hydropower. High-pressure water pipelines of the water infrastructure can be supplied with small in-pipe turbines to produce micro-hydropower. (O'Fee, 2014) Some of the renewable energy potential in the water sector is already utilized now. However, there are still unused opportunities for water asset utilization.

There is a list of working technologies which can be successfully utilized within the RECENT project.

# 3 FINANCIAL TOOLS FOR SUPPORT OF ENERGY SOLUTIONS IMPLEMENTATION

## 3.1 Scotland

In Scotland, (as well as in Wales and England), a water company as a producer of renewable energy has access to the following financial support instruments:

- Loan;
- Feed-in tariff;
- Quota system (Renewables obligation);
- Other economic mechanisms (e.g. crowdfunding).

***Loans for renewable energy producers***

Loans have been available for renewable energy producers since 2013; however, they apply only to the solar energy. This campaign was launched as part of the British Green Deal (Qualifying Energy Improvements) Order 2012. The Green Deal consists of 45 different measures to improve energy efficiency in buildings, including solar energy. Figure 19 illustrates the loan scheme. (Tallat-Kelpšaitė, 2013)

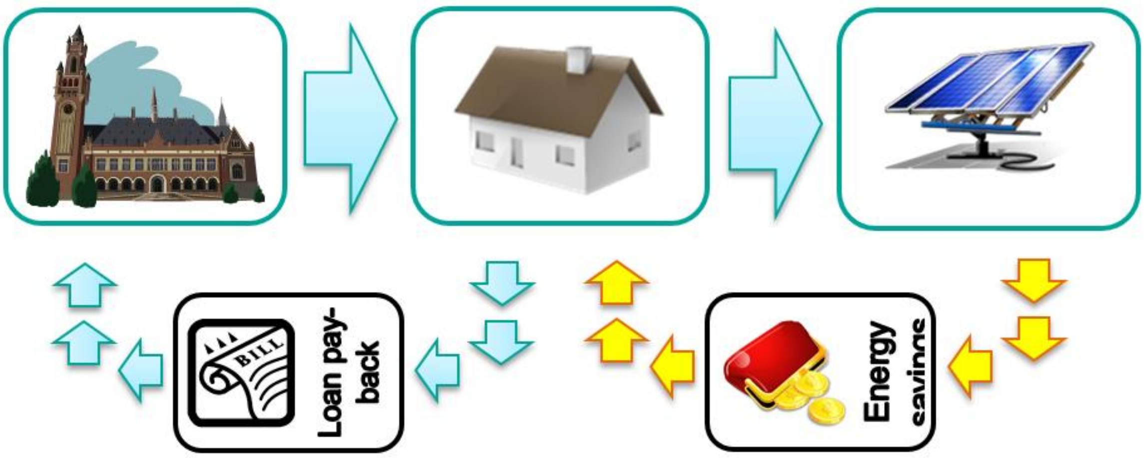


**Figure 19** The scheme of loans for solar energy in Scotland

The targeted parties are property owners, both business and private. The idea is to reduce the need to buy energy and create savings through solar installation. The loans can be paid in two possible ways. The first option is to repay it during the lifetime of the solar panel investment, whereas the second option is to pay it back during a certain repayment period specified in the Green Deal. The specified period can be 25 years at maximum. To receive the loan with the purpose of solar energy production, a property owner should address the Green Deal Oversight and Registration Body, which is the main competent authority. In the Green Deal Oversight and Registration Body, the property owner should be in contact with a Green Deal Assessor. The Green Deal Assessor is responsible for assessing the potential and applicability of solar energy technology on the property. The Green Deal Assessor produces a Green Deal Advice Report on the feasibility of solar energy solution, which contains also recommendations about potential energy-efficiency measures to be taken. Furthermore, the report contains estimates of potential savings from a financial point of view, if all the recommendations are implemented. After this, the property owner should find an appropriate Green Deal Provider to implement the recommendations. The Green Deal Provider is an entity that will receive the loan. Then the property owner and the Green Deal Provider sign a Green Deal Plan, which is a contract between them. The contract states the amount of the loan, that it should be repaid by the property owner to the Green Deal provider and the period of repayment. When this step is completed, the Green Deal Provider should find a Green Deal installer, who is in charge of solar panels installation. After finishing all the installations and implementations, the loan should be paid back by the property owner to the Green Deal Provider via electricity bills. The loan is supposed to be lower than the actual savings incurred by the implemented solar energy solution or any other stated energy efficiency measure. The latter is the so-called “Golden Rule” of the Green Deal. The source of funding originates from the Green Deal Finance Company created by the government. (Tallat-Kelpšaitė, 2013)

***Feed-in tariff system in Scotland***

The feed-in tariff system has been available since 2010 and is applicable for such renewable energy solutions as hydropower, anaerobic digestion, solar photovoltaic energy and wind energy. The main limitation is that the capacity of the technologies has to be fewer than 5 MW. The aim is to support the implementation of renewable energy technologies by making production of renewable energy financially viable for the producers. This extra support helps them to enter the energy market easier and receive guaranteed pay-back of their investments. The general scheme of the feed-in tariff in Scotland is presented in Figure 20 The entitled parties are renewable energy producers. With the help of the feed-in tariff, they are able to sell electricity to energy markets under the actual production cost, but still cover their own costs. This mechanism lowers the barriers of entry to the energy markets for potential renewable energy technologies. (Tallat-Kelpšaitė, 2013) In order to become a feed-in tariff support holder, a renewable energy producer first needs to know what is the planned capacity of the proposed energy installation. If it is less than 50 kW, renewable energy producer has to inform the electricity supplier about the energy installation.

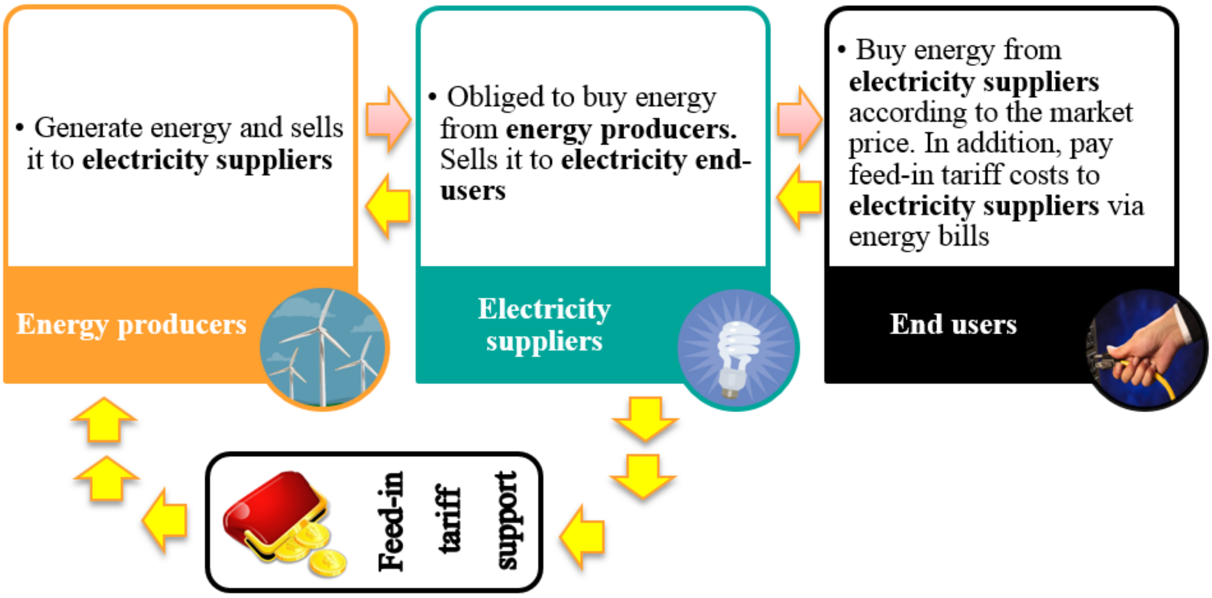


**Figure 20** The scheme of feed-in-tariff in Scotland

The electricity supplier then registers the installation in the Central Feed-in Tariff Register. If the renewable energy producer generates more than 50 kW, then the application for feed-in tariff support has to be directed to the competent authority, which is the Gas and Electricity Markets Authority (Ofgem). At Ofgem the application goes through an accreditation process. For some technologies, there is a preliminary accreditation available, e.g. for anaerobic digestion, solar energy and wind energy with the capacity of more than 50 kW. After all the requirements are met, the accreditation is issued, the energy installation is connected to the grid, and the renewable energy producer can receive the feed-in tariff support. The support is paid by the electricity supplier, or feed-in tariff licensee, that must purchase it from the energy producers. The feed-in tariff licensees are obliged to take part in the feed-in tariff system and buy electricity from renewable energy producers. Small electricity suppliers covering fewer than 250 000 households can participate in the feed-in tariff support on a voluntary basis. In turn, electricity suppliers include the feed-in tariff payments in energy bills that are paid by electricity end users. (Tallat-Kelpšaitė, 2013)

Ofgem also has a levelisation fund, which was created to ensure that all the costs for feed-in tariff licensees are in balance. The levelisation fund is formed by payments paid by the licensees, and is used to redistribute finances between electricity suppliers. In case the fund is in deficit, the licensees need to cover this with additional payments. (Tallat-Kelpšaitė, 2013)

The levels of feed-in tariff support are decided on annual basis by Ofgem, in collaboration with the Secretary of State for energy. The common trend is that small-scale wind energy along with hydropower production receives more support per produced kWh. In large-scale renewable energy production, the priority is given to solar energy and anaerobic digestion. (Tallat-Kelpšaitė, 2013)

The conditions of the system are as follows (Tallat-Kelpšaitė, 2013):

- For solar energy (up to 250 kW) there are three feed-in tariff support levels: lower, middle and higher. To get the higher feed-in tariff, solar panel installations (up to 250 kW) must have an Energy Performance Certificate of Level D or higher. Those installations, which do not meet this requirement, can receive only the lower feed-in tariff. The installations with 25 or more solar panels receive the middle feed-in tariff that is considered a multi-installation tariff;
- The rates of feed-in tariff for solar panel installations decrease every 3 months since November 2012;
- The period of guaranteed feed-in tariff support is 20 years at maximum;
- Renewable energy installations supported by the quota system are not eligible for feed-in tariff.

***Renewables Obligation***

The Renewables Obligation, or quota system, in Scotland, is to oblige electricity suppliers to produce and sell renewable energy. Within the quota system, an electricity supplier needs to buy Renewables Obligation Certificates to present them to Ofgem. The difference between the Scottish quota system and the feed-in tariff is the capacity of renewable energy. In the Renewables Obligation, preference is given to higher generation capacities, those more than 5 MW. However, also 50 kW to 5 MW capacities can be supported. An energy producer, whose production capacity is between 50 kW and 5 MW, can choose between the feed-in tariff or quota system. (Tallat-Kelpšaitė, 2013) The scheme of the quota system in Scotland is represented in Figure 21. According to the quota scheme, electricity suppliers should verify that they met their obliged proportion of renewable energy supply by presenting Renewables Obligation Certificates, or Green Certificates. A Green Certificate is awarded for every MWh of electricity generated by the energy producer and respectively received by the electricity supplier. The names of the green certificates are different in Scotland and Northern Ireland but the general scheme is the same. To get the Green Certificate, the electricity supplier needs to buy it from the competent authority, Ofgem. The purchase should be done within a certain period during the obligation year: from April of the previous calendar year to March of the next calendar year.

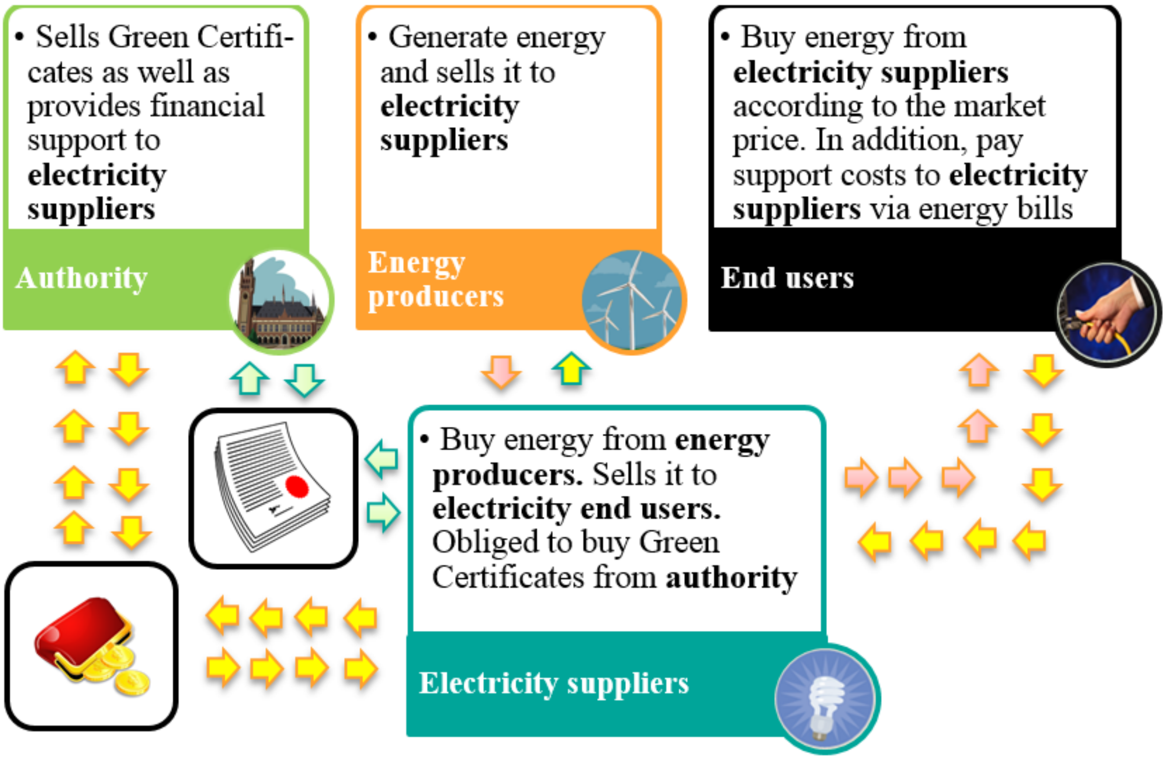


**Figure 21** The scheme of the quota system in Scotland

All the obligation payments for the Green Certificates are collected into a special fund. When all electricity suppliers have made the payments, the financial support is distributed among the electricity suppliers. If the electricity supplier did not buy obligated proportion of the Green Certificates by September, apart from the price of the Green Certificate, there is special penalty of 5% interest per day of the price of the Green Certificate that should be covered by the end of October. In case of shortfall (e.g. due to failure of one electricity supplier to meet an obligation) in the fund, electricity suppliers need to make additional payments. The sources of funding are electricity end users through payments of energy bills. (Tallat-Kelpšaitė, 2013)

Under the quota system, support can be provided to onshore and offshore wind energy, solar photovoltaic energy, geothermal energy, anaerobic digestion, hydropower and bioenergy based on solid biofuels. The quota obligation for electricity suppliers in Scotland and Northern Ireland is presented in Table 3. The conditions of funding are as follows (Tallat-Kelpšaitė, 2013):

- The installations completed before 1990 without further renovation, offshore wind mills older than 20 years and large-scale hydropower plants (>20 MW) launched before 2002 are not eligible for the quota system;
- The renewable energy installations supported by the feed-in tariff are ineligible for the quota system;

- The period of the financial support under the quota scheme is 20 years;
- Applications delivered after 2017 are not considered.

**Table 3** Quota system in Scotland and Northern Ireland (based on Tallat-Kelpšaitė, 2013)

| **Obligation period** | **Quota obligation coefficient** (proportion of renewable energy) | |
|---|---|---|
| | **Scotland** | **Northern Ireland** |
| **APRIL, 2009 – MARCH, 2010** | 0,097 | 0,035 |
| **APRIL, 2010 – MARCH, 2011** | 0,104 | 0,040 |
| **APRIL, 2011 – MARCH, 2012** | 0,114 | 0,050 |
| **APRIL, 2012 – MARCH, 2013** | 0,158 | 0,081 |
| **APRIL, 2013 – MARCH, 2014** | 0,206 | 0,097 |
| **APRIL, 2014 – MARCH, 2015** | 0,244 | 0,107 |
| **APRIL, 2015 – MARCH, 2016** | 0,154 | 0,063 |

***Crowdfunding***

The concept of crowdfunding is usually referred to internet based platforms, where different parties (e.g. individuals, organizations, institutions, companies, public authorities) can support a project of a company or individual, who is seeking extra funding. With the help of this funding, the planned project can be completed and the parties, who have invested in it, can benefit from its realization. Crowdfunding has been used in funding of software development, cultural projects, etc., and has been implemented quite recently also in renewable energy projects. In the UK for instance, crowdfunding is still in tis beginning phase and is rapidly increasing its popularity. One of these was the installation of hydropower generator in the Osney Lock Hydro project, which gathered via crowdfunding about 665 000 euro for installation of a hydropower generator. Another example is in the Gen Community project, which raised approximately 555 000 euro for implementation of solar panels in Newport. The largest amount of financial support gathered so far in renewable energy projects within the Abundance Generation project is around 7 308 000 euro. (NFI, 2013; ANRG, 2014)

## 3.2 Northern Ireland

In Northern Ireland, the following financial support mechanisms can be used in the implementation of renewable energy technologies (Tallat-Kelpšaitė, 2013):

- Loan;
- Quota system (Renewable obligation); and
- Tax regulation mechanisms;
- Other economic mechanisms such as crowdfunding

The crowdfunding system has already been described for Scotland. This section discusses only the loan, the quota system and tax regulations.

***Loan***

The loan support in Northern Ireland is represented by the free loan scheme. The principle is similar to that of Scottish. However, there are some small differences. The loans in Northern Ireland are available for any business, which intends to invest in energy efficient, low carbon and environment friendly technologies. The free loan scheme is available to projects that include such technological solutions as air conditioning, heating control, recovery of heat, building insulation, energy-efficient lighting and renewable energy, for example solar energy. The only exemption to the free loan scheme are the public organizations, which are not eligible for this scheme. The size of the loan, which the organizations can apply for, depends on the amount of carbon dioxide savings achieved through the implementated investment. For every annual 1 500 kg of carbon dioxide saving an interest free loan for 1 200 euros can be granted. Invest Northern Ireland, which is in charge of these loans, can grant loans from around 3 700 to 491 500 euros and invest in renewable energy investments. The loan scheme is used in the whole Northern Ireland, and for example in 2012 Invest Northern Ireland granted interest free loans for over 6 145 500 euros. As a rule, the loans should be paid back within 4 years after receiving the loan. (Carbon Trust, 2014a; Carbon Trust, 2014b)

***Quota system***

The quota system under the Renewables Obligation in Northern Ireland is similar to the quota system in Scotland. The general scheme is illustrated in Figure 22.
The key players are (DETI, 2013):

- The Gas and Electricity Markets Authority (Ofgem) in collaboration with the Northern Ireland Authority for Utility Regulator, as an authority;
- Renewable energy producer;

- Traders and brokers;
- Electricity supplier; and
- Electricity end users.

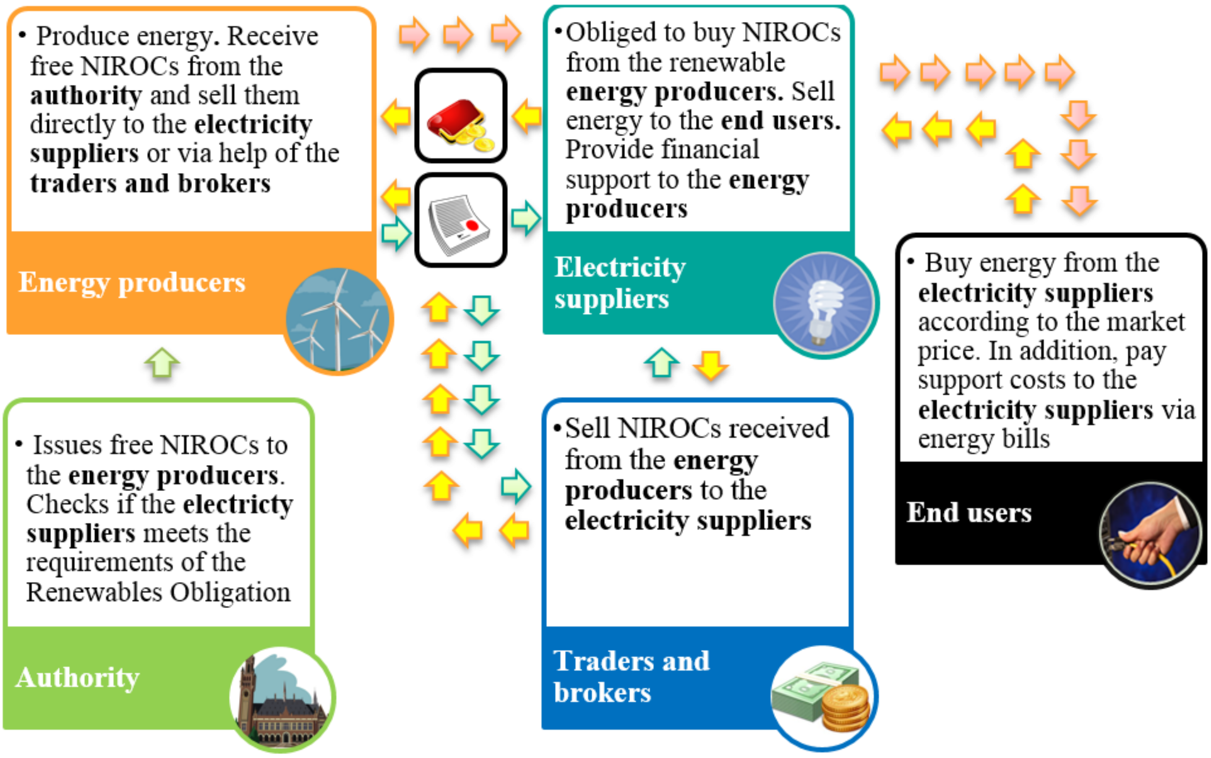


**Figure 22** The scheme of quota system used in Northern Ireland

According to the Renewables Obligation, the electricity supplier must provide the end users with a certain amount of electricity (i.e. quota) from renewable energy sources. Suppliers have to verify this to the authorities by purchasing Green Certificates. The Green Certificates are also known as Northern Ireland Renewables Obligation Certificates (NIROC). The NIROCs can be bought either directly from the energy producer or from the traders and brokers. As in Scotland, every megawatt of power, which has been produced from renewables, is worth one certificate. The organization responsible for issuing these Green Certificates is the authority (Ofgem). The NIROCs are provided to the energy producer on free of charge basis. The renewable energy producer shall apply for accreditation from Ofgem; once this has been done, then financial support can be granted to the applicant. The certificates make the renewable energy investments more viable by closing the gap between higher energy production prices of renewable energy technologies and the lower prices of energy in the markets. The financial support comes directly from the electricity supplier. The source of funding of the quota system originates from electricity end users through payments for energy bills. (DETI, 2013)

If the electricity supplier cannot present the authority with sufficient Green Certificates to meet the Renewables Obligation, then the so-called “buy-out” fee is used in Northern Ireland. The electricity supplier can pay “buy-out” fee, which is a direct alternative to the Green Certificate. If the electricity supplier, for instance, does not have access to the renewable energy producer, they can comply with the Renewables Obligation by paying the charge. It also works as a combination of the two. The electricity supplier can purchase the NIROCs and pay the “buy-out” fee. When the obligation period is over and all the obligations (NIROCs or “buy-out” fees) have been met, the “buy-out” fees are redistributed among the electricity suppliers. The redistribution is done according to the proportion of the NIROCs that the electricity suppliers have at the end of the obligation period. For instance, those suppliers, who have the highest amount of NIROCs, get the highest financial support in the form of the redistributed finances. Currently, Northern Ireland does not meet the Renewable Obligation set for it, which has led to the use of “buy-out” fees, which are consequently redistributed among the electricity suppliers. Due to this fact, NIROCs have a certain value on the energy market. The latter condition plays a motivating role for renewable energy developers to make appropriate investments. (DETI, 2013)

The quota system provides support for the following renewable energy technologies: wind energy, solar photovoltaic energy, anaerobic digestion, hydropower and bioenergy based on solid biofuels. (DETI, 2013)

There are some limitations, which restrict quota scheme. These are the following ones (DETI, 2013):

- The Green Certificates are valid only for one Obligation Period;
- The applications energy producers should apply for it by the end of 2017;
- The maximum period of the financial support is 20 years or until 2037.

***Tax regulation mechanisms***

There are two types of the tax regulation mechanisms (Tallat-Kelpšaitė, 2013):

a) *Climate Change Levy*. This is a tax created for greenhouse gas reduction and climate change mitigation. It is applied energy, which has been generated from sources of energy considered as non-renewable. It applies to both industrial and commercial electricity end users as well as households. Coal, gas, liquefied petroleum gas are referred as the traditional, non-renewable energy sources. The Climate Change Levy (CCL) is charged from electricity suppliers. The renewable electricity suppliers are supported in this case by being excluded from the Climate Change Levy obligation. The electricity end users as electricity suppliers include the CCL costs in the energy bills, which means that the end users pay for it in the end. To prove that an energy producer generates renewable energy, they have to hold a special license. The competent authority, Her Majesty's (HM) Revenue and Customs, is responsible for issuing the licenses. To receive the license, the electricity supplier should enter into an agreement with the electricity end user, which states that a certain portion of energy originates from renewable sources. The other way to achieve this is through a Levy Exemption Certificate (LEC) which means that the electricity supplier provides the electricity end users with renewable energy. The amount of renewable energy provided is related to one LEC. LECs are issued on a monthly basis by an appropriate regulatory authority. In case an electricity supplier owns a LEC, it gives the supplier the right to receive the license. Once the electricity supplier has either of the options, HM Revenue and Customs can issue the license to free an electricity producer from the Climate Change Levy. In 2013 the CCL was 0,00633 euro per kWh

b) *Carbon Price Floor*. This is a tax with a main objective to increase the use of renewable energy sources in electricity production. Non-renewable energy producers are charged the Carbon Price Floor (CPF) tax. Main renewable energy technologies supported by the tax mechanisms, which free them from the described taxes, are solar energy, geothermal energy, bioenergy based on solid biofuels, wind energy, hydropower and anaerobic digestion. The competent authority is HM Revenue and Customs.

## 3.3 Ireland

Water companies as renewable energy producers can be supported by the Irish government through tax relief scheme (Maroulis, 2013).

***Tax relief scheme***

The tax relief scheme has been used as a financial support for renewable energy implementation also in Ireland since 1999. There are several renewable energy sources that can be supported under the tax relief scheme: e.g. solar energy, hydropower, ocean, tidal and wave energy, wind energy, and bioenergy. The responsible authority for the tax relief application process is the Irish Revenue Commissioners. A company, which is going to implement a renewable energy production investment on behalf of the energy producer, can apply for the tax relief. Thus, there are two key players: the investment company and the renewable energy producer. The renewable energy producer must get approval from the DCENR for the renewable energy production technology and obtain an appropriate certificate. Then the renewable energy producer must be certified by the Revenue Commissioners to meet all the legislative requirements. Afterwards, the two players, must enter into an agreement about the terms of investment. In the end, the investment company applies for the tax relief to the Irish

Revenue Commissioners that makes the final decision. The tax relief support cannot be more than 50% of the investment cost of the renewable energy project, or 9 525 000 euros. The funding is paid from the state budget. (Revenue, 2014; Maroulis, 2013)

## 3.4 Finland

Financial support for renewable energy implementation is provided by the Finnish Energy Authority and the Ministry of Employment and Economy. The two key categories of financial support are subsidies and the feed-in tariff.

***Subsidy***

Subsidies, or energy aid, for implementing renewable energy can cover up to 15-30% of investment cost. Energy aid is also applicable for research projects dealing with renewable energy solutions. The extent of support varies depending on the renewable energy technologies. In Finland, support is provided for solar photovoltaic and solar thermal, anaerobic digestion, bioenergy, wind power, geothermal energy, heat recovery from wastewater and small-scale hydropower. In addition, if a project is aiming at improving energy efficiency and decreasing environmental impacts from the energy sector, it can also be eligible for support. These investments are expected to implement state-of-the-art technologies. If a research and development (R&D) project intends to implement a new technology, the financial support can be up to 40% of total costs. Private companies, municipalities or organization are all eligible applicants. The applications for subsidies are sent to regional Centres for Economic Development, Transport and the Environment (ELY Centres). The ELY Centres are in charge of funding decisions for renewable energy projects with a budget up to 250 000 euros and for research projects or implementation of new technologies – up to 5 000 000 euros. In case the budget is higher, the decisions are made by the Ministry of Employment and Economy. The received energy aid is paid either in several parts or at once depending on the decision of the competent authority. The only limitation for the subsidy holder is that at least 25% of the total project cost should come from non-state financial sources. Subsidies cannot be given to farms, households, co-operatives and construction projects that already have been granted state aid. If a project is done in collaboration with several organizations, the subsidy is given to the lead partner of the project. All the subsidies are paid by the Ministry of Employment and the Economy, which is the main responsible authority, and provide from the state budget. (Mikkonen, 2013; Brückmann, 2013)

***Feed-in tariff***

The feed-in tariff (FIT) support became available in Finland in 2010. In 2012 about 100 million euros were provided to subsidize renewable energy. The concept of FIT is illustrated in Figure 23. In general, FIT makes it profitable for a renewable power producer to be present on the energy market with the help of financial support from the government. This support is meant to cover the difference between the average energy market price and the target price. Currently, the target price in Finland is 83,5 €/MWh.

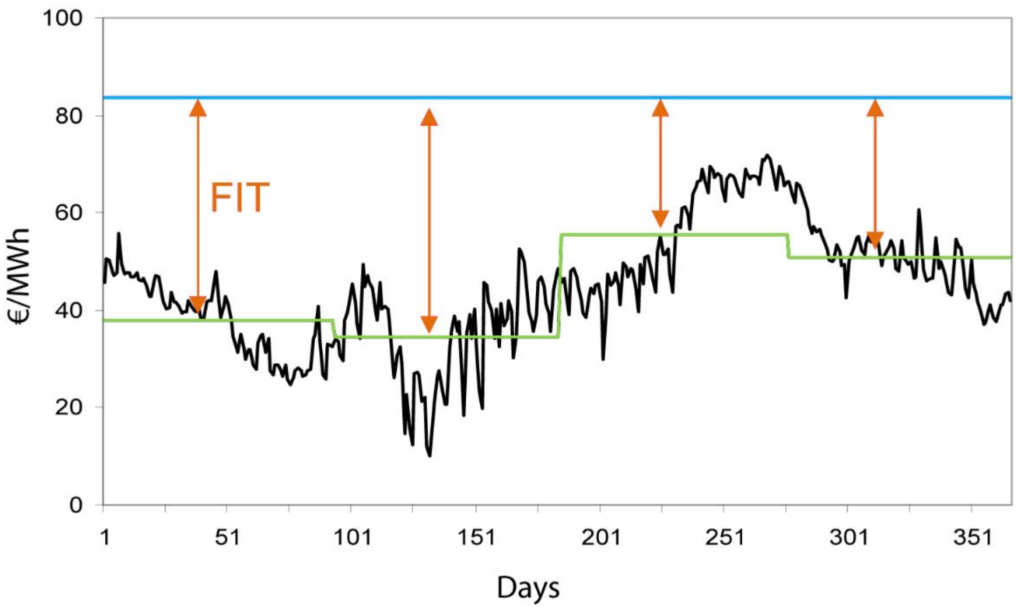


**Figure 23** Schematic representation of feed-in tariff (FIT) support in Finland.
The blue line represents the target price, the black line the daily power market price fluctuation and the green line the three months average of power market price. The amount of feed-in tariff is represented by the red arrows.

As illustrated in Figure 23, the energy market price varies daily (black line). FIT is the difference between the target price and the average of last three months' market price. If, for example, a biogas plant can sell for the energy market for an average of 38 € per MWh, the Finnish government will support bioenergy production by paying the biogas plant an extra 45,5 € per MWh. (MEE, 2013b; Brückmann, 2013) This financial support can relate to different renewable energy sources; however, in focus are especially energy production from wood chips or wood fuels and anaerobic digestion, as shown in Table 4. In addition, if a bioenergy or biogas production utility generates also heat, they are allocated extra 20 and 50 €/MWh, as an extra benefit. (Brückmann, 2013)

**Table 4** Amount of feed-in tariff support for renewable energy solutions in Finland (based on Brückmann, 2013).

| Energy type | Feed-in tariff €/MWh | Extra benefits €/MWh |
|---|---|---|
| **SOLID BIOFUEL** | 83,5 | 20 |
| **ANAEROBIC DIGESTION** | 83,5 | 50 |

The application process starts when energy producer with an already constructed plant informs the Finnish Energy Authority about the intention to start energy production. The energy producer provides the authority with all the technical specifications of the facility. The exception is a wood chips energy production plant, which can start operation and then apply for the feed-in tariff support. If all the formal requirements are met, the Energy Authority decides about the allocation of financial support. The allocation criteria are as follows (Brückmann, 2013):

- The feed-in support holder should be based in Finnish territory or in Finnish waters, and connected to the electricity grid;
- All the technical and economic requirements related to energy production should be met;
- No previous grants or state support;
- The energy utility should be entirely constructed from new parts;
- Minimal capacity requirements:
    a) For wind energy – at least 500 kVA,
    b) For anaerobic digestion (AD) and bioenergy based on solid biofuel – at least 100 kVA;
- The energy efficiency of AD and bioenergy must be at least 50%;
- There should be both heat and power production with AD;
- If the average energy market price for the last three months is lower than 30 €/MWh, according to the Finnish regulations, the target price should be lowered to 30 €;
- The feed-in tariff is applicable only until a production limit is achieved, which is:
    a) 2 500 MVA for Wind energy;
    b) 19 MVA for AD
    c) 150 MVA for bioenergy based on solid biofuels

The Ministry of Employment and the Economy (MEE) and the Energy Authority are in charge of feed-in tariff support decisions. The MEE, as the main competent authority, is responsible for management, supervision and assessments, whereas the EA deals with practical legal matters and payments of the tariffs and the bonuses. The maximum period a company can receive the support is 12 years. The feed-in tariff is funded from the state budget (Brückmann, 2013).

## 3.5 Sweden

In Sweden, there are the following support schemes available:

- Quota system;
- Subsidy;
- Tax regulation mechanisms.

***Quota system***

If a water company is interested to implement renewable energy technology as an on-site installation, the Swedish authorities can help the company through "Electricity certificates within the quota obligation program". This quota program was established to support the development of renewable energy market in Sweden. The parties under the quota obligation system are electricity suppliers and electricity consumers. The program is based on electricity certificates, which are tradable in the electricity certificates market and function as medium of renewable energy exchange between producers and consumers. Under the program, energy producers are interested to sell the renewable energy certificates, whereas consumers are obliged by the government to buy them in certain proportion or quota. (Pobłocka, 2013) The scheme of the quota program is illustrated in Figure 24.

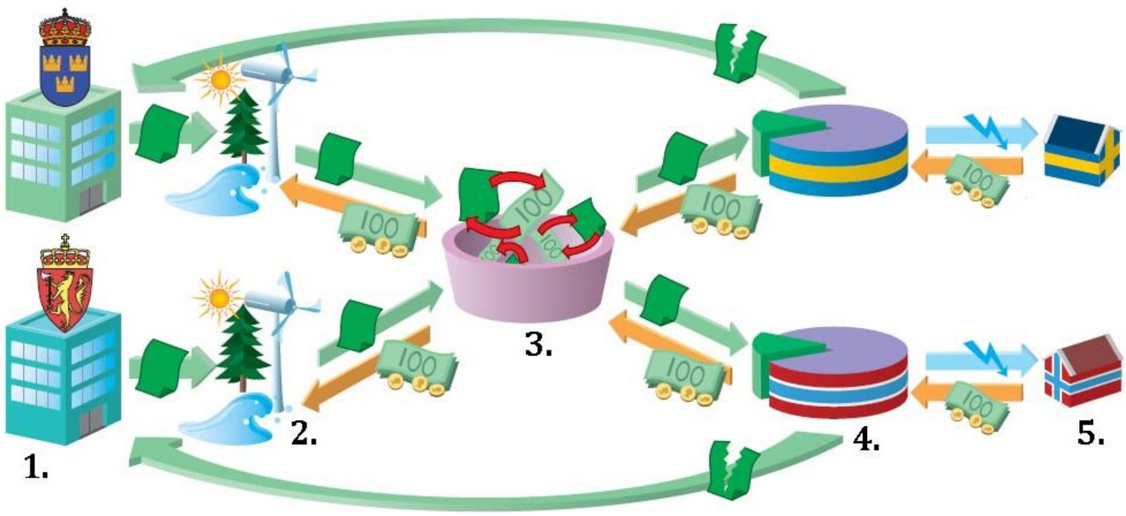


**Figure 24** The scheme of joint quota system for electricity market in Sweden and Norway (NVE, 2012)
Key stakeholders: 1) authorities, 2) energy producers, 3) certificates market, 4) quota obligation, and 5) consumers

The quota system originates from 2003. Since 2012 the electricity certificate market has been carried out as a Swedish-Norwegian collaboration. The main objective of the energy market union is to meet the requirements of the Europe 2020 strategy and the Renewable Energy Directive. Among the mutual advantages for Sweden and Norway are more efficient use of renewable resources, more participants on the energy market, good financial support for renewable energy technologies and more cost-efficient renewable energy production. (NVE, 2012) The quota system applies to all renewable energy solutions: wind, wave, solar, geothermal, hydropower, anaerobic digestion as well as bioenergy. As Figure 24 illustrates, the electricity certificate flow is directed towards electricity end users and the financial support toward the energy producers. The main source of funding is electricity end-users.

The authorities responsible for electricity certificates in Sweden are the Swedish Energy Agency, which is in charge of the monitoring of the quota system, and the Swedish transmission grid operator Svenska Kraftnät. Svenska Kraftnät registers the electricity certificates and supports renewable energy production. Each electricity certificate is worth 1 MWh of production. If for instance a water company would generate 5 MWh of saleable power, they would receive five electricity certificates (or green certificates). (Pobłocka, 2013, 2014) The water company would also have the right to sell the certificates to energy consumers on the electricity certificate market. The market is open for Swedish and Norwegian electricity consumers. Energy consumers are obliged to buy certificates by law; they must have a certain proportion of electricity usage originating from renewable sources. The quota program is set by the Electricity Certificate Act and the yearly quota obligation coefficients are seen from Table 5. (Pobłocka, 2014)

**Table 5** Quota obligation values in Sweden between 2012-2035. (Based on Pobłocka, 2014).

| **Obligation year** | **Quota obligation coefficient** (proportion of renewable energy) |
|---|---|
| 2012 (first year) | 0,179 |
| 2016 | 0,144 |
| 2020 | 0,195 |
| 2026 | 0,137 |
| 2030 | 0,076 |
| 2035 (last year) | 0,008 |

The maximum value of quota obligation is set for the year 2020, which is 0,195; after which it decreases. The peak corresponds with the 2020 Strategy. Based on this quota obligation, in 2020, for instance, at least 19,5% of the total energy consumption of the end users must be covered by renewable sources. To meet this goal, energy users must buy electricity certificates sold by renewable energy producers. As the energy price with the renewable energy certificates is higher than the regular price of energy, this makes the system attractive for renewable energy producers. (Pobłocka, 2014)

The certificates expire at the end of the year and the consumers need to buy new ones to meet the quota obligation. This creates continuous demand. Failure to meet the quota will result in a fine, which is 150% of the electricity certificates yearly average price. (Pobłocka, 2014) The price for electricity certificates is included in the customer's electricity invoice and they pay only for their actual consumption. The system is easy to use for the end-user. For companies to be involved, the conditions are the following (Pobłocka, 2014):

- Renewable energy production should be built within licensing terms;
- Renewable energy production was started after 2009. The exception is hydropower plants: there are certain restrictions and additional tax regulation mechanism – higher tax rates to prevent opening more hydropower stations;
- Renewable energy producers that would begin to function after 2020 are not eligible;
- The assignment period is 15 years. However, if company has been present on the energy market before 2012, the years of presence shall be deducted from the assignment period. For instance, if Swedish wind park was launched in 2010, the assignment period is 13 years;
- If a renewable energy producer has received previously government state grants, which have not been repaid before 2012, then this producer is not eligible for the quota program.

***Subsidy***

This support scheme is only available for solar photovoltaic installations, which are completed by the end of 2016, December, 31$^{st}$.

The conditions of funding are as follows (Pobłocka, 2014):

- Subsidy of 30 per cent for companies and up to 20 percent to others, on the basis of the eligible installation costs. The maximum per PV system is 1.2 million SEK and the eligible costs may not exceed 37 000 SEK plus VAT per installed kilowatt electric peak power;
- It is also possible to seek a tax deduction for photovoltaic installation (on the cost of labor ) , but you cannot have both . At the moment the deduction is 50 % of labour cost but may reduce to 30 percent of the government's proposal goes through;

- The subsidy is limited and will only be given as long as there is money left . The total budget for Swedish subsidies, 2009-2016, is app. 22,65 million euro.

***Tax regulation mechanisms***

There are two working tax regulation mechanisms in Sweden:

a.) *Reduced real estate tax*. For owners of land where a wind energy solution is implemented, there is a tax payment reduction.

b.) *Energy tax reduction*. In Sweden, all electricity producers and suppliers are levied to pay a tax on the electricity consumption. Wind energy generators, which are non-commercial producers are freed from this tax.

c.) *Rot-support scheme*. Starting from January 2015, wind energy and hydropower solutions are supported in Sweden by tax reduction for excessive electricity generation fed into the grid. The annual tax reduction maximum in this case is approximately 2000 euro. The tax credit available for renewable energy producers is 60 cents per kWh of the electricity fed into the grid. The tax reduction is achieved by the income tax return once a year. If an electricity producer purchases 15 000 kWh/year, while feeding the grid with 20 000 kWh/year, the producer does not receive a tax subsidy for an extra 5 000 kWh produced. To be counted as a micro-producer and be able to claim the tax subvention, the fuse in the connection point cannot exceed 100 ampere.

A producer, who sends the surplus/excessive electricity to the network, can also sell this to the owner of the grid or electricity selling company. Different network owners offer different level of compensation, but usually it is between 1 to 5 eurocents per kWh. If energy producer is selling electricity, it should be registered as VAT holder and pay the VAT of 25%.

## Summary

Renewable energy technologies are becoming more and more popular in northern and sparsely populated areas of Europe. Wind power, hydropower, bioenergy produced through anaerobic digestion, solar energy and other renewable energy generation technologies are all commonly desired and used in the discussed countries. However, depending on local geographical conditions and policies, there is often preference toward certain technological solutions. For example, Sweden has utilized hydropower to a great extent, and has no support towards building more hydropower installations, whereas wind energy is supported in the country. Finland supports bioenergy, as one example. Partners from the UK have favourable geographical conditions and are supportive towards all technological solutions, including, for example, small-scale hydropower, anaerobic digestion and solar energy.

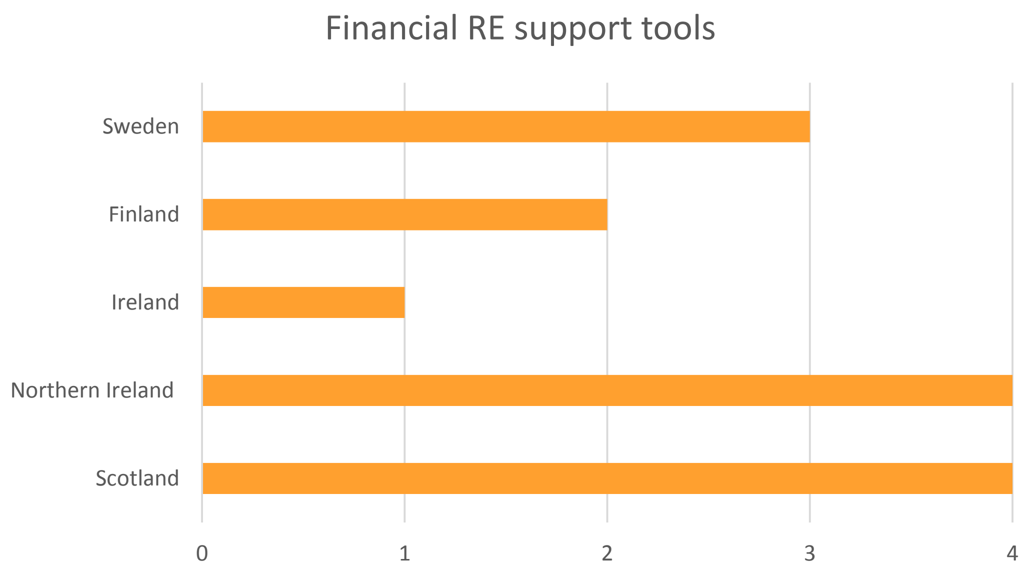


**Figure 25** Financial tools for renewable energy support in the RECENT partner countries

What is common for almost all the renewable energy technologies in all of the discussed countries, is that all of them need initial support in order to enter the energy markets in earnest. Figure 25 shows the number of available funding tools in Scotland, Northern Ireland, Ireland, Finland and Sweden. Some of these mechanisms are repeated in several countries and have same names: e.g. feed-in tariff in Finland, Scotland, Ireland. However, there are also mechanisms used only in Fennoscandia or only in the British Isles, such as subsidies and loans respectively. The number of economic mechanisms for renewable energy support is highest in Scotland and Northern Ireland: four; while in Ireland the number is lowest: one. Sweden and Finland have three and two working mechanisms to support implementation of renewable energy solutions.

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## RECENT PROJECT DESCRIPTION

RECENT is a three-year project of the Northern Periphery and Arctic Programme, which provides a service for small-scale rural communities to improve their energy profile through the utilization of renewable energy and energy efficiency solutions. The project is led by the International Resources and Recycling Institute in Scotland, and is realized in partnership with Action Renewables in Northern-Ireland, Mayo County Council and Clár-ICH in Ireland, University of Oulu in Finland and Jokkmokk municipality in Sweden.

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UNIVERSITY of OULU OULUN YLIOPISTO

Action Renewables the future of energy, today

Northern Periphery and Arctic Programme 2014–2020

EUROPEAN UNION Investing in your future European Regional Development Fund