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Potentially conflicting interests between Hydropower and the European Unions Water Framework Directive

A Master Thesis in cooperation with the European Environmental Agency, Copenhagen.

Linn Melin

Division of Water Resources Engineering
Department of Building and Environmental Technology
Lund University

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Abstract

Many of the water bodies in Europe are in bad ecological condition due to anthropologic impacts. Pollution and morphological changes have had a severe impact of the water environment and flora and fauna associated with such environments. The fact that water courses often cross administrative borders within countries as well as internationally makes the water management that much more difficult.

The water framework directive (WFD) is an EU directive created in order to protect and improve the water status of the water bodies within the member state countries. Since hydropower production is one activity that has negative environmental impact on the water courses, the regulation imposed by the WFD will have consequences for the hydropower industry. Hydropower causes fragmentation of the water course and an altered hydro regime, which seriously impacts the environment.

Although hydropower has major negative environmental impacts, it provides Europe with 70% of its renewable energy. 10 % of all the electricity is generated from hydropower, which is by far the most important renewable source. Since hydropower is such an important source of renewable electricity and the fact that hydropower has the important ability to store energy, makes it inevitable in the European energy mix even though it causes serious environmental impacts.

Possible conflicts arise between producing renewable electricity from hydropower and conserving the water courses. The WFD provides tools in order to solve the conflicts and to ensure good ecological status in the water bodies. The hydropower industry is concerned about the increased costs of e.g. providing mitigation measures at the hydropower installations and issues regarding the residual flow.

Sweden is not planning any new HP installations and the view towards HP development is rather negative. Austria and Scotland plan a future expansion of the HP industry, although in the case of Scotland mainly a development of small-sale hydropower.

Is appears that it is possible to carefully develop HP, with sufficient mitigation measures in place, without conflicting with the objectives of the WFD. It is unlikely that small-scale HP will play a prominent role in reaching the renewable energy targets on a European level. But small-scale HP can, however, play a role at locations where large-scale HP is not suitable.

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1. Introduction

1.1 Background

Water resources are of great value – they are the source of life, they provide important habitats for animals and plants and they are crucial for many human activities. But many of the water resources in Europe have been negatively altered, polluted and are far from the natural water environment they once were. The degradation of lakes and rivers has had serious effects on water bodies and pristine water environments are becoming fewer. In order to protect and improve the water bodies within the European Union, the Water Framework Directive (WFD) was introduced in order to improve the status and to prevent deterioration of the surface, coastal and groundwater in the EU.

Meanwhile, the issue of climate change and the reduction of CO_2 emissions are more central than ever. At the same time the world is highly dependent on energy in order for society and our economy to function and develop. The conventional fuels such as coal and oil have been for a long time, and still are, a crucial energy source in most economies in the world. These fuels have many negative impacts on the environment and one such problem is the CO_2 emissions that contribute to climate change. The facts that fossil fuel causes climate change and are a finite resource are reasons why renewable energy sources are required.

Renewable energy sources such as bio-fuels, wind power, photovoltaic and hydropower (HP), can be constructed and operated in a way that causes only marginal emissions of carbon dioxide. They also have the advantage of causing less pollution of e.g. sulphur and nitrogen oxides.

When it comes to HP, it is an old technique of utilising the water to generate energy. The earliest hydropower plants (HPP) utilised the energy of the water for mechanical energy, e.g. to turn a mill wheel. Today HP is mainly used to produce electricity. In countries with favourable conditions, e.g. in the alpine region and Scandinavia, HP has been an important factor for the industrial development of the country and plays an important role today in providing the country with electricity.

There are many benefits with HP – it is first of all renewable and causes none or very little pollution and with its long lifespan the electricity produced is relatively cheap. If the water is stored in dams, the electricity generation can be timed with demand peaks throughout the day as well as over the year. But over the last few decades the negative impacts of HP on the surrounding environment have been highlighted.

The HPP's substantially changes the river environment. The installations destroy habitats and decrease the number of species and severely alter the river morphology. The type and size of the plant will give different impacts. Many of the large scale installations have storage reservoirs, created by damming the river and flooding the area upstream of the generator. The flooded area impacts the people, the vegetation and the animals in the area. The dried flood bed downstream of the dam drastically deteriorates the living environment for all the species living in and around the river, causing river fragmentation and obstacles for fish migration. The many negative impacts on the local environment have caused people to react and over time the regulation regarding HP has became increasingly focused on mitigating the environmental impacts.

It is crucial to protect the valuable water environments and make sure that development takes place in the most suitable locations, with the right mitigation measures taken. The water framework directive (WFD) introduces an integrated approach to the management of surface water, ground water and coastal water. The WFD covers all aspects of the waters – the chemical, the biological and the morphological status. Since HP installations change the ecological status of rivers through morphological alterations, indirectly affecting the chemical and biological status, it is an activity that would be affected by the regulation imposed by the WFD.

HP is the most important renewable energy contributor in Europe – 10 % of the total electricity generation in Europe comes from HP. More stringent environmental regulation could increase the electricity price and lower the production. But, HP has serious negative impact on the environment. Dense population and high level of industrialisation of Europe has resulted in many rivers being in poor condition leaving few pristine rivers remaining.

The WFD offers tools to protect the status of water bodies and prevent deterioration. The river basin management plan is an instrument which helps striking the right balance between the two interests, where potential conflicts may arise – between renewable energy production and environmental conservation. Clearly we need to be economical with the limited natural resources at hand and only utilise water resources when it is sustainable in order to maintain our water environment for future generations.

1.2 Objectives

The objective of the thesis is to highlight and evaluate the potential conflicting interests between hydropower and the WFD in Europe. The thesis aims to do so by answering the following questions:

- What are the main potential conflicts? How do they differ between the three countries in the thesis?
- How would it be possible to maintain and develop HP without interfering with the WFD goal of good ecological status/potential? Or is it possible at all?
- How do the benefits and environmental impacts differ between small scale and large scale HP?
- What role could small-scale hydropower (SHP) play in reaching the European goals of renewable energy?

1.3 Method

Firstly, the theoretical background of HP and the WFD is studied through scientific articles and information from authorities as well as from other stakeholders.

The existing arguments for and against HP used by different stakeholders such as; NGO's, governmental institutions and the industry, is studied on a European level. This is done by studying stakeholder documents as well as getting in contact with stakeholders in Austria, Scotland and Sweden in order to understand their views of HP development and the WFD.

Three different countries are selected, Austria, Scotland (as a part of the UK) and Sweden, with the objective to see if the situation regarding HP differs, what players that dominate and where this leads the development of HP. Further on, three case studies in the countries above will be carried out in order to give a real life example that illustrates the present situation for HP.

The River basin management plans (RBMP) of Austria, Scotland and Sweden will be evaluated regarding HP and hydro morphological alterations in order to understand the magnitude of the environmental deterioration caused by HP. The RBMP's are also evaluated regarding measures and suggestions of how to improve the water environment as well as how to deal with the impacts of HP.

The stakeholders are contacted in order to qualitatively gather information through interviews via e-mail or over the telephone. This is done with the purpose of finding out what arguments are put forward, the stakeholder's standpoint regarding HP and the WFD and their predictions for the future.

1.4 Limitations

Given the timescale of the thesis, 20 weeks, far from all the aspects regarding the WFD and HP in Europe could be taken into consideration. The focus has been to portray an overview of the present situation and to understand the view of the stakeholders and their opinions.

The geographical limitation of the thesis is the European Union, but only three regions will be specifically studied; Sweden, Austria and Scotland. The reason for choosing Scotland and not the UK, is that Scotland independently manages its own water management, that there is a separate environmental protection agency (SEPA) for Scotland and that the potential for HP differs quite a lot between Scotland and other parts of the UK. The choice of countries is not entirely representative, since no countries in e.g. southern or eastern Europe are included. The main reason is that many of the national documents are only available in the original language, making it difficult to study these countries.

Regarding the stakeholders, no local stakeholders such as farmers or local fishing organisations were included in the study. This would be an interesting aspect, however, the thesis has rather focused on larger stakeholders such as the hydropower industry and regulators.

The thesis will not evaluate all the potential conflicts between HP and the WFD, rather provide an overview of the larger and most common potential conflicts that can occur.

1.5 List of Abbreviations

EU – European Union
EPA – Environmental Protection Agency
HMWB – heavily modified water body
HP – Hydropower
HPP – Hydropower plant
LHP – large scale hydropower
NGO – Non-governmental organisation
RBMP – River basin management plan
SEPA – Scottish environmental protection agency
SHP – small scale hydropower
WFD – Water framework directive

2. Hydropower

2.1 Energy contributor

Hydropower is by far the single most important renewable electricity source in Europe at present, contributing with 70 % of the renewable electricity production. In 2008 the electricity generated from HP in EU-27[1] contributed with 10 % of the total electricity production which corresponds to 106 GW of installed capacity (European Commission SETIS, 2010). Worldwide, HP represents 87% of the renewable energy production. Globally, there is still a lot of unused potential, about two thirds are left to develop. In Europe however it is estimated that half of all the suitable locations for HP have already been developed. HP is a mature technology, but there is still a lot of interest especially in small-scale hydropower (SHP), upgrades of existing plants and to some extent large-scale HP. (World Energy Council, 2007)

HP is utilising the hydrological cycle in order to generate electricity. Since the cycle is driven by the sun, the same water molecules are circulated and that there is no depletion of any resource, the utilisation of water as an energy source is renewable. The primary energy form is potential, it is elevation differences of the water that in turn transforms into kinetic energy when the turbines are being rotated. The potential energy might be increased by manmade storage reservoirs or by constructing the turbines underground. Storage reservoirs have the advantage of transforming the potential energy of the stored water into kinetic energy at a given time, thus the dependence of the natural runoff in the river decreases. (Sørensen, 2000, p 274)

How well an area is suited for HP production initially depends mainly on two factors; precipitation and elevation differences. This is a very simplified assumption, rather than precipitation, it is the runoff in the rivers that is interesting and the runoff does not only depend on the precipitation, but also factors including, evaporation and transpiration, vegetation and soil characteristics. In addition to hydrological factors, the feasibility of HP depends on grid capacity, environmental concerns and political decisions etc. (ibid, p. 275)

HP produces energy at very low production costs. This is due to the long effective lifespan of the plant as well as low maintenance and operating costs. Compared to other energy sources, renewable and non-renewable, HP has a very high thermal efficiency, i.e. the electricity generated is not too far from the maximum theoretical output normally it is just below 95 % (Svensk energi, 2002). The economical disadvantage of a HP installation is that it is associated with high investment costs and long return periods. There are also long lead times for the realisation of a project, of course depending on the country. The high investment cost and the often quite complicated and long process of realising project are some of the reasons why very few HP installation are being commissioned. This is especially true for many parts of Europe,

[1] EU-27: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom.

where many of the most suitable locations for HP have already been developed. (Lehner et al. 2005)

2.2 Different types of hydropower installations

There are several different technical solutions in order to utilise water for power generation. The main technical difference between the types of installations is if the water is collected in a reservoir or if the water is running freely through the turbines. There are also installations where water can be pumped from a lower to a higher reservoir as a method of storing electricity. It is common to distinguish between small and large installations as well. The most common SHP is run-of-the-river installations, while LHP are normally operated with a storage reservoir or as pumped hydro – although this is not necessarily the case.

There are several different turbines that can be used in order to generate electricity from water. The type of turbine employed normally depends on the head of the water, i.e. the vertical distance between the water surface up- and downstream of the turbine. The higher the head, the larger the energy output and different technical solutions are required in order to achieve maximum efficiency. For HP installations with low head the Kaplan turbine is suitable, for medium head the Francis turbine is suitable and for high-head installations the Pelton turbine is used. There are variations of these too, but the types of turbines will not be in focus in this chapter, rather the overall design of different HP installations. (British Hydro Association, 2010)

2.2.1 Run-of-the-river

This type of HP installation utilises the natural flow of a water course in order to generate electricity. The installation is constructed in the water course, where the water is led through the turbines, as illustrated in Figure 1. In the run-of-the-river installations the head is low; which means less potential energy. The run-of-the-river installation continuously generates electricity and the generation is depending on the water flow of the river. Therefore the electricity generation from this type of installations varies with e.g. seasonal variations of the water flow. (Energie Wasser Bern, 2010)

Run-of-the-river HPP can be of various capacities, from very small installations in streams to larger installations in rivers. This type of installation has no possibility to store any water. On the other hand run-of-the-river installations require much less area than hydro with storage reservoir and pumped hydro and the environmental impacts are considered much smaller. The flow regime of the river is not considerably altered, thus major problems of hydro peaking do not exist.

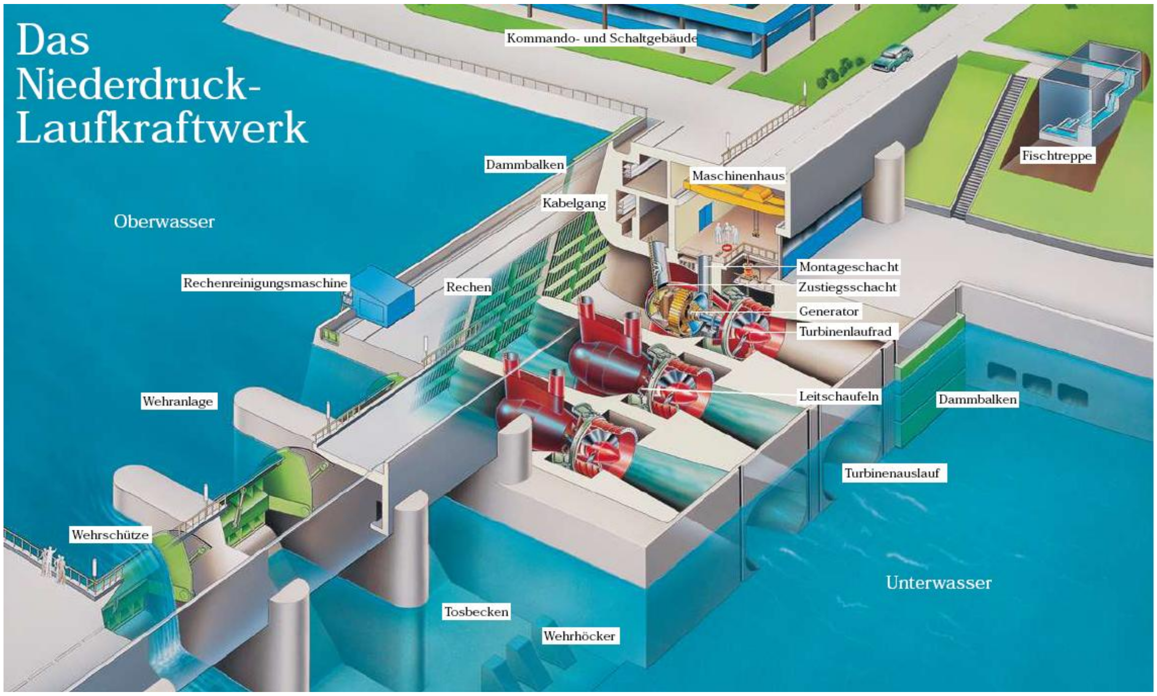

Figure 1. Schematic image of a run-of-the-river HPP. (Source: Energie Wasser Bern, 2010)

2.2.2 Hydro with Storage reservoir

HP installation with a storage reservoir is constructed in such a way that a water course is being blocked. This will flood the area upstream of the weir and create a dam. The area downstream of the weir, i.e. the river course, will be largely dry. From the storage reservoir the water can be directed to the turbines through a penstock or pipeline, either above or below the ground surface, see Figure 2.

One of the main differences between run-of-the-river HPP's and HPP's with a storage reservoir is the ability to store energy and the ability of meeting electricity demands. Both types of plants produce electricity, but only the HPP with a storage reservoir has the possibility of storing energy. The great advantage of this is that the energy can be used at a certain point of time which is suitable for the energy demand. The run-of-the-river continuously generates electricity and the generation is depending on the present water flow in the river.

The principle of a hydropower installation with a storage reservoir is displayed in Figure 2. The head of the water is the vertical distance from the water surface of the upper reservoir to the water surface in the lower reservoir; the larger the head the more energy can be generated. The intake grid stops debris and larger animals from entering the turbines. The penstock, or other technical solutions, leads the water from the reservoir to the turbine. The penstock can be of various lengths and sometimes below the ground surface to create a larger head. The rotating motion of the turbine is being transformed to electricity by the generator. The Electricity can then be used for whatever purpose; normally the larger scale installations deliver electricity directly to the grid. (Tennessee Valley Authority, 2010)

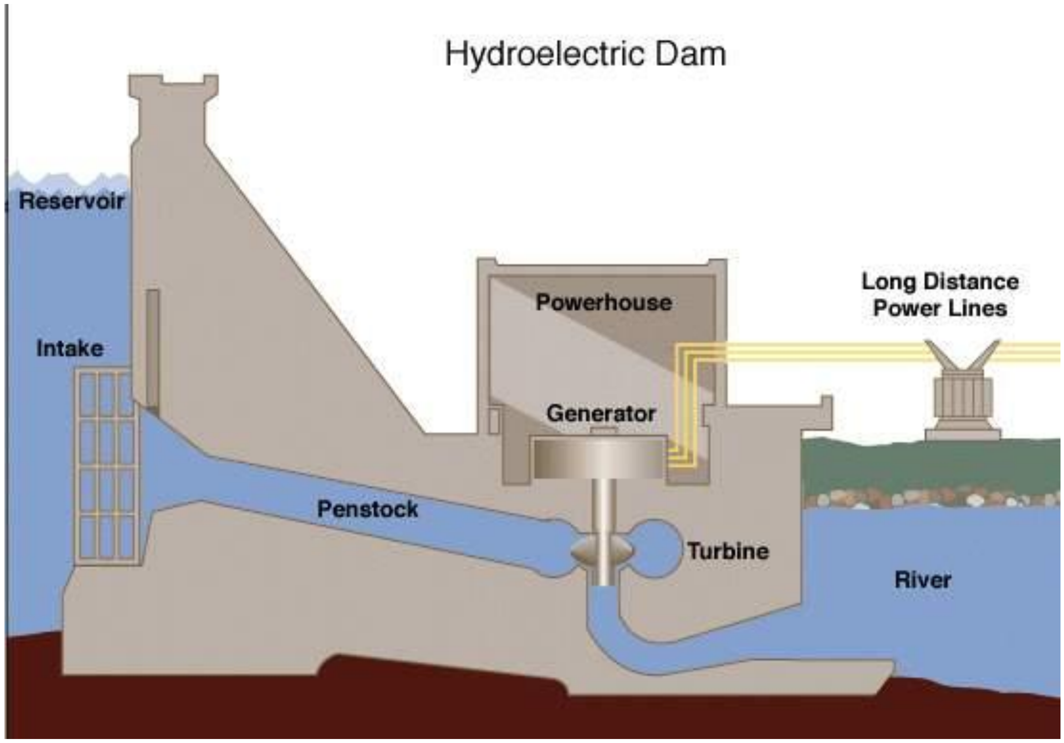

Figure 2: Schematic image of a hydroelectric dam with a storage reservoir (Source: Tennessee Valley Authority, 2010)

2.2.3 Pumped Hydro

Pumped HPP's utilise two water reservoirs, located at different altitudes, se Figure 3. In order to generate electricity, the pumped hydro operates much like a storage HPP; water is released and diverted from the upper reservoir and electricity is produced at turbines located at a lower elevation. The water is then released into the lower reservoir.

When there is high demand for electricity, e.g. during peak hours, electricity is being produced in order to satisfy the demand and to balance the electricity system. When there is a surplus of electricity on the grid, e.g. at off-peak hours or when other forms of electricity are being excessively produced, water can be pumped from the lower reservoir to the upper. Pumping the water from lower to higher altitude requires energy and the energy used will be the surplus electricity from the grid. (Electricity storage association, 2009)

This is one of the few conventionally accessible methods of storing energy (other methods include various types of batteries, compressed air etc.).

Figure 3 displays an example of a pumped hydropower plant. Elevation difference is necessary to create a head, this is why normally mountainous or hilly regions are favourable locations.

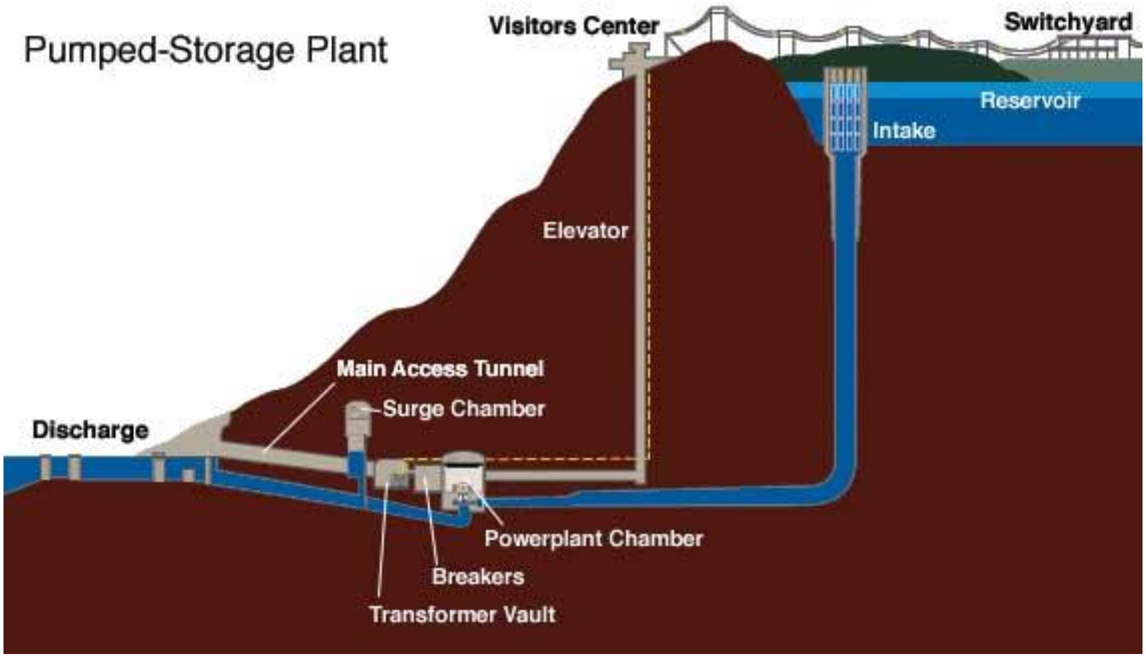

Figure 3: Schematic image of a pumped hydro plant. (Source: Tennessee Valley Authority, 2010)

2.3 The regulating role of hydropower

In order for an electrical grid to operate, the frequency must be held constant at all times, only very small fluctuations are allowed. In order to maintain a constant frequency, the input and output of electricity must be balanced. (Svensk Energi, 2002)

In connection with other types of renewable energy sources, primarily wind and photovoltaic, the HP with water reservoirs can play the regulatory role provided that the energy sources are connected to the same grid. Wind and photovoltaic electricity generation have the characteristics of being weather dependant, which makes it difficult to time the produced electricity with the demand. Therefore these types of energy sources require a regulator in order to balance input and output of electricity on the grid and maintain the right frequency. HP is very suitable as a regulator since it has good energy storage capacity and compared to other renewable energy sources there are not many large scale alternatives for storing electricity. Yet another advantage with HP is the very short start-up time usually around 0.5 – 3 minutes, making the timing of supply and demand very efficient. The frequency of the grid and the balance between produced and consumed electricity can be well balanced with HP in the system. (Sørensen, 2000, p. 553)

Using HP as an energy regulator for another energy source could mean either that the HP is operated at lower levels when there is production from the complimentary energy source or, when there is an electricity surplus on the grid, that water is pumped back up to the reservoir. This requires a different turbine installation, so that the water can both be pumped upwards and released for power production at the same location (ibid). In order to use HP as a regulator a reservoir storage is required in connection to the HPP, this will have large impacts on the surrounding environment. This also means that small-scale HP does not have the possibility to contribute as a storage supply since small-scale HP normally is constructed as run-of-the-river installations without dams or pumping facilities.

2.4 Large-scale hydropower

There is no clear definition of large-scale and small-scale HP installations. The most common definition is that large-scale HP has a capacity above 10 MW[2]. This is also the definition that will be used, unless stated otherwise, in this thesis. The large-scale HPP's can be either run-of-the-river installations, hydro with storage reservoirs or pumped hydro.

The total amount of installed HP capacity in EU is about 106 GW, not including the pumped hydro storage capacity. The large-scale HP installation covers 90 % of this capacity and about 10 % of the capacity is from small-scale HP. (European Commission SETIS, 2010)

The reservoir storage installations can retain water and therefore energy for a longer period of time. An artificial reservoir will normally be constructed in connection with such an installation in order to store the water of the river. The storage of water enables a steady generation of electricity which to a certain point is independent of the short-term flow of the river. The reservoir installation will normally cause a dry river bed or at least a river bed with much less water than what naturally occurs. (Leher et.al.2005)

2.5 Small-scale hydropower

As mentioned above, there is no clear definition for small-scale HP. There is also different terminology used, e.g. micro-hydro, mini-hydro. Normally the installations below 10 MW are referred to as small-scale, but the definition differs between different countries and organisations. However the definition of 10 MW is accepted by the European small hydro association, ESHA, as well as by the European Commission. (Lins, 2005)

The leading countries, in terms of most installed SHP capacity in EU-27[3], are Italy, France, Spain, Germany, Austria and Sweden. In EU-27 there are today over 21 000 SHP installations that have an installed capacity of in total 13 000 MW (although the European renewable energy council estimates the installed capacity slightly lower, to 12 000 MW). In an average year, the SHP installations produce around 41 000 GWh. The reason for slightly different figures regarding SHP capacity is probably connected to the fact that the definition of SHP can differ between countries and organisations. (ESHA, 2004 (a))

The small-scale HP installations are almost always run-of-the-river installations, which causes a smaller impact on the water environment than the larger installations with a water reservoir.

[2] Generally accepted and used by the European Commission and ESHA. In Sweden the definition of small scale is normally below 1.5 MW. (Lins et. al, 2005)

[3] EU-27: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and the United Kingdom.

The electricity output from SHP is relatively small. In Austria the SHP only contributes with 10 % of the total amount of electricity produced from HP. In Sweden, the contribution of SHP is even smaller. 700 large-scale installations contribute with approximately 62.5 TWh/year while about 1200 small-scale installations contribute with only approximately 1.5 TWh/year. Although each one of the large-scale HP installations causes greater environmental impacts than the SHP – there are much fewer and they produce considerably more electricity.

The electricity contribution of the SHP might be rather small, but there are other benefits of the SHP as well. In Scotland, for instance, factors such as rural employment are seen as one benefit of SHP development. (Forrest et al, 2009)

In many European countries most of the SHP potential has already been harnessed. The exploitation ratio is rather high, for EU-15[4] it is 82 %. However, ESHA estimates that a further 2 100 MW of capacity can be made available through upgrading existing SHP schemes as well as reopening closed plants. With environmental constraints the estimated capacity would be 1 100 MW. Regarding new SHP plants it is estimated that the remaining potential, with economical and environmental constraints taken into consideration, is 6 700 MW. The total economical and environmental available potential for SHP in Europe adds up to 7 800 MW. The SHP installations represent around 7 % of the total European HP electricity production. (Leckscheidt et al., 2003)

2.6 Environmental Impacts by hydropower

All HP installations will inevitably have a negative impact on the surrounding environment. The magnitude of the impact will mainly depend on the type of installation, the size, the design and operation. There are also different types of impact associated with different installations and the different stages of the construction and operational phases. The impacts will also differ with geographical location and the types of habitats. The impacts associated with dams will not apply to the run-of-the-river HPP's.

This chapter aims at presenting the main environmental impacts associated with HP installations. HP installations cause several changes in the environment, direct and indirect. There are some impacts, primarily indirect ones that will not be covered in this chapter – simply because they are quite site specific. Rather this chapter aims to give an overview of the most prevalent impact in connection to HP installations.

2.6.1 Biodiversity and change of habitats

The biodiversity is negatively affected by the HP installations and of the flow regulations. From a European perspective, it is rare that species are made completely extinct when a HP installation is constructed, but they are reduced in numbers. The reason that they are not extinct is primarily that species normally have strong populations in other rivers that are protected from

[4] EU-15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.

HP exploitation. Rivers in temperate regions have fewer endemic species than for example tropical rivers and are therefore less vulnerable to developments (Jansson, 2006). However, in Austria long-distance migratory fish do no longer exist which is largely due to the number of obstacles in the river system causing river fragmentation. (Lebensministerium Austria, 2009)

Regarding the run-of-the-river HPP's (although this is a serious problem at all types of HP installations), the main concern is normally the up- and down-stream migration of fish and other fauna connected to the water environment. The HP will, unless there are measures taken, be a definitive obstacle for the water fauna and isolate animals and plants living in and around the river.

Migratory fish are blocked from their spawning grounds when a HP is constructed, unless there are measures taken to enhance the migration. For migratory fish, both the upstream and the downstream migration are affected by a HP installation. Grown individuals of anadromous fish species like salmon and trout migrate up the rivers to the spawning grounds. The downstream migration contains both the returning grown individuals as well as the smolt. HP blocks the upstream migration of fish. If there are mitigation measures, such as fish ladders, this might improve the situation but still delay the fish or make it more vulnerable for predators. It is mainly during the downstream migration when the fish risks dying or getting injured by passing through the turbines, falling over weirs or getting damaged by other constructions. (Degerman, 2008)

A HP installation with a water reservoir causes flooding of an area upstream of the installation. The flooded area, i.e. the dam, will have impacts with certain characteristics. The flooded area means loss of habitat meaning animals and plants of that area will be largely affected. Especially larger animals can move in order to avoid drowning, but might die or be reduced in number due to the loss of habitat. Plants in the flooded area will be drowned, although there have been attempts in some cases to relocate plants. The new reservoir that replaces the former river environment offers a new habitat, but in general the new habitat has a much lower biodiversity. Studied areas in Sweden and Canada has shown that the riparian areas surrounding a storage reservoir decreased by 84% regarding degree of coverage and with 34% regarding number of species, compared to the natural river or a natural lake. (Jansson, 2006)

Migratory fish, like salmon, make an important contribution to the nutrient balance of the upstream forests. Salmon can migrate far upstream in order to spawn and the salmon that gets eaten by predators and for other reasons does not makes it back to the sea contributes with a valuable import of phosphorous and nitrogen. In boreal forests, where the nutrient levels normally are low, the salmon makes a significant contribution to the nutrient balance and the growth of riparian forests. (Jonsson, 2002)

As a river is being fragmented the ecosystems are becoming more vulnerable and the alteration of habitats makes it easier for invasive species to spread. The actual construction of a HPP involves a great deal of construction work and new material, which increases the risk of spreading invasive species. (Tang, 2009)

2.6.2 Impacts of Dams and fragmentation

HP constructions where water is dammed and a storage reservoir is created have additional environmental impacts in connection to the dam. The dam will flood the area upstream of the HPP and the river bed downstream will be dried. The dam will have a severe impact on people that might live in the area, the natural environment will be destructed and the construction and operation of a dam always involve certain safety risks. (Sørensen, 2000)

Different stages of a dam construction will put different type of stress on the environment. The effects can occur as direct consequences of the dam as well as indirect consequences. For pristine areas the environmental impact will usually be more serious or at least more noticeable, since infrastructure might have to be constructed in order to begin the construction work of the actual HP installation.

The construction of the HP and creation of a dam have the impact of causing obstacles in the river, destructive elements connected to the construction work, population displacement and modification of the landscape. These direct effects of the dam construction will in turn cause many indirect effects. This includes; barriers for migration of aquatic fauna, disruption of habitats and on wildlife in and around the river, increased sediment transport and turbidity in the water. The creation of a dam is significantly changes the landscape, but can in some cases lead to increased tourism and recreation as well as a new habitat. (European Environment Agency, 1999)

The fragmentation caused by a HP installation, as well as other structures in the water, has a severe impact on the habitats and the flora and fauna in the riverine environment. Many of the species living in the rivers are depending on migrations along the water course and to be able to colonise new habitats. The migration of fish is disrupted by the installations, but many other species are affected as well. Several aquatic insects spread in the riverine system by passively floating in the river, many seeds spread in this way as well. When the seeds are stuck at the dams, this has the effects of a fragmentation of the river vegetation. The plants that have seeds that float well will have an advantage over those plants with seeds that do not have as good floating properties. The result is a change of the composition of species along the river. (Jansson, 2006)

The dams change the composition of nutrient and sediment transportation through the river. Dams are basically artificial lakes, where the water is being retained and the water velocity is reduced. This changes the sediment and nutrient transport. The concentration of nitrogen and to some extent also phosphorus are normally lowered as a result of dams. Particles slow down and settle in the reservoirs – this has a negative impact on migratory fish, e.g. salmon and trout that requires gravelled river beds and constant flow of water with high oxygen concentrations. The reservoirs transform the former river environment to an environment more similar to a lake. (Svensk Energi, 2002)

The changed sediment concentrations have impacts downstream of the dam as well. The water that is being released from the dam contains lower concentrations of sediment, due to the sedimentation taking place in the still standing water of the reservoir. The lower concentration of sediments causes erosion in the river banks and the river beds downstream. The dynamics of the sediment transportation is, however, rather complex. In many cases the rivers have been straightened or somehow altered previously to the HP installation, which means that the sediment transport was already altered. The main consequences of an altered sediment transport are:

- Lack of gravel transport – causing river bed erosion, especially downstream of the last HPP, when there are series of consecutive installations.
- Higher sediment concentrations in reservoirs because of decreased transport capacity. (Summer et al, 1994)

2.6.3 Flow regime

HP installations (with storage reservoirs or pumped hydropower) cause the water levels to fluctuate in an unnatural way, causing impacts on the riparian zones of the storage reservoir as well as the river downstream of the installation. The strong fluctuations in the water level in both the reservoir and the river downstream are referred to as hydro peaking. There would naturally be some fluctuation in the water flow in an unregulated water course, but the fluctuations follows natural conditions such as precipitation and changes of seasons. The anthropological changes of the water levels are fast and extensive having negative impact of the riparian habitats. In a riparian zone where the levels are fluctuating unnaturally, the number of species diminishes and the only plant that can survive in the long run is the pelagic phytoplankton. Regarding the fauna of the storage reservoirs it is normally reduced to zooplankton and the fish that feed on these. (Jansson, 2006)

The long-time effects of the HP installations are difficult to fully predict. In the newer dams, not enough time has elapsed in order to identify the long-time impacts. In older installations, some of the older ones are up to 100 years old, observations regarding the environment were simply not done from the start. Still there are some studies comparing the species in and around storage reservoirs in newer and older dams. It has been observed that some re-colonisation takes place in a newly constructed reservoir and the number of species increases during the first 30 years after the construction. The diversity and number of species would still not reach the same number as before the construction. However, after about 35 years it appears that the diversity and number of species starts to decrease. The reason for this is most likely that the fine materials of the reservoir banks are being eroded. (ibid)

In the most extreme case of power generation in a river, the whole river bed will be dry downstream of the dam. This is of course devastating for any flora and fauna living in the water or in the riparian zones. The flora and fauna living in or around rapids and waterfalls are strongly affected. Today most HPP's have some regulation on a minimum flow, i.e. some of the water from the river will have to be left in the original riverbed. There are measures to improve the situation for migrating fish but a HP installation, even with proper measures for fish, will always mean extra stress for the fish and often delay the migration, which has a negative impact on the fish stock in total. (IVA, 2002)

2.7 Mitigation measures at hydropower installations

Depending on the type and size of the HP installation, different mitigation measures are available. There are several ways of mitigating the environmental impacts of a HPP. The most efficient, but also the most drastic, measure would be the removal of the HPP and restoration of the water course. This might be an option in some cases, e.g. at old mill sites, but the measure is otherwise expensive since the HP companies have to be compensated. Also, HP produces a large quantity of renewable electricity, which then has to be replaced. It is neither the purpose of the WFD nor desirable to necessarily remove HPP's – the positive social and economic benefits of HP are in many cases significant. This chapter will mainly focus on the mitigation measures available regarding fish and other water fauna.

In particular fauna passages at the run-of-the-river HPP's are suitable methods of leading fish and other fauna around or over the obstacle created by a HP installation. The principle of a fauna passage is that some of the water downstream has to be lifted to the same level as the water level upstream of the HPP and a new river course is constructed where the fish can bypass the HPP, see Figure 4. There are other similar methods in constructing a fauna passage around the HPP, e.g. part of the old riverbed can be left unexploited in order for fauna to pass the turbines. These are technical solutions where the characteristics of the river are simulated. These solutions benefit a large proportion of the fauna, but require space and are considered relatively expensive measures. (Degerman 2008)

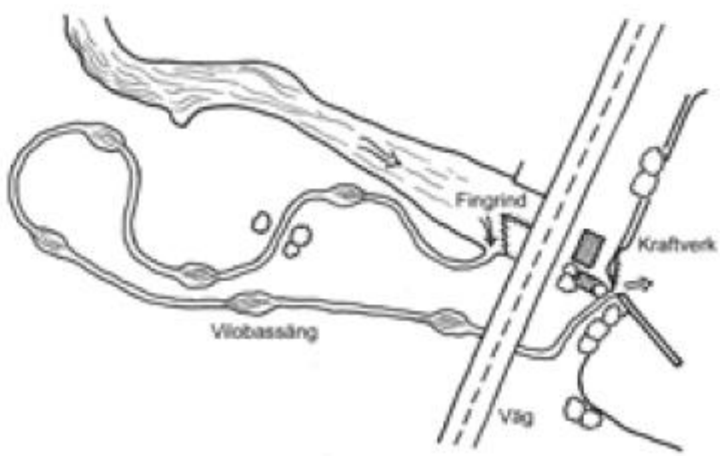

Figure 4. Fauna passage bypassing the Holstebro HPP, Denmark. (Source: Fiskeriverket och Naturvårdsverket, 2008)

Fish ladders are another common technical solution at run-of-the-river HPP's. There are plenty of types of fish ladders, but the principle is the same – water is lead through a construction where fish can swim or jump the distance across the HP installation, see Figure 5. Fish ladders are very space efficient, but the number of species that can migrate through the ladders are limited. The angle of the fish ladder and the speed of the water are usually high. Therefore only fauna with good swimming and jumping capacities can pass through, primarily salmon and trout. It is important that fish ladders are properly constructed and operated in order to work effectively. If the angle of the ladder is to steep or if the water flow is to strong, smaller individuals will find it difficult to pass. The ability to accelerate when swimming and jumping differ a lot between different species. A fish ladder that is operated incorrectly, by for examples not letting enough water pass through will be completely useless. Besides fish ladders, there are other solutions such as catching the fish downstream of the HPP and transporting it upstream with lorries or using fish elevators in order to transport the fish past the obstacle. (Schilt, 2006)

Figure 5. Fish ladder at Toggenburg, Switzerland. (Source: Hydroelectra AG, 2010)

Fish ladders are useful for the upstream migration of fish, however for the downstream migration of fish and smolt these solutions do not normally work. The fish follow the main flow of the river, which in the down-stream migration leads to the turbines. There are methods for directing larger individuals away from the turbines, but the smolt is, because of their small size, difficult to redirect. When the smolt goes thought the turbines, they are likely to die or get injured. (Schilt, 2006)

The Eel is one of the fish species that spends part of its lifecycle in the sea and part of it in freshwater systems. The situation of the Eel has in the latest decades deteriorated and in parts of Europe the inflow of glass eels has decreased to about 1 % of the levels of 1980 (Lövin, 2007). The lifecycle of the eel is complex and its life is not fully understood. There are probably many combined reasons for the retreat of the eel, one such is the obstacles in freshwater systems such as HP installations. There are specific measures in order to enhance the migration of eels. Since they cannot jump and are not very strong swimmers in rapid waters, they are unable to use normal fish ladders. Instead, eels are very good at slithering across obstacles and as long as the surface is wet, they can be above the water surface when they travel. Eel passages are normally square tunnels, see Figure 6, where the eels can slither across the HP installation. The main problem with the eel passages are that it can be difficult for the eels to find the inlet to the tunnels. (Degerman, 2008)

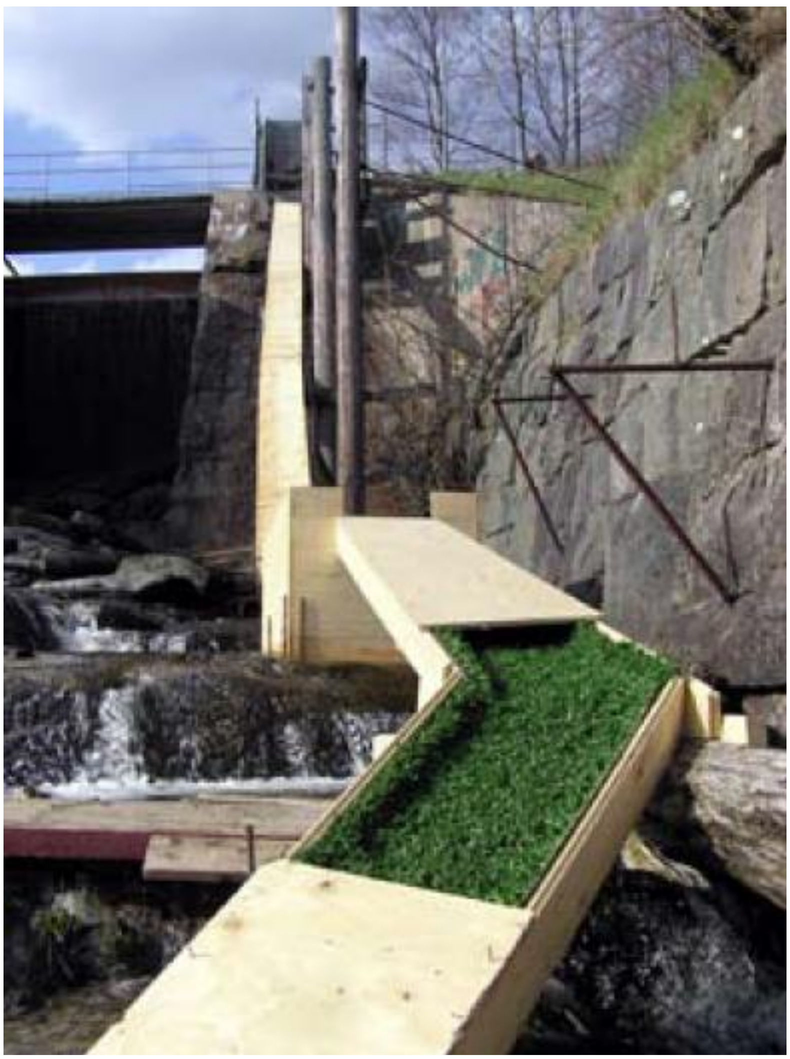

Figure 6. Example of an eel passage Säveån, Sweden. (Source: Fiskeriverket och Naturvårdsverket, 2008)

In order to mitigate the impacts of hydro peaking the flow rates can be kept within certain fluctuations that will allow a healthy river ecology. It can also be improved by installing weirs around estuaries, in order to increase the river levels. The problem of sedimentation can be mitigated by e.g. trapping parts of the sediment in small weirs for manual removal (IEA, 2006). But more large scale methods of removing sediment involve periodic flushing or dredging the reservoirs. Run-of-the-river installations also cause increased sedimentation, which can be reduced by flow diversion that excludes the sediment. Other, site specific, mitigation measures can be used as well. (International hydropower association et al. 2000)

3. Water Framework Directive

3.1 Overview

Directive 2000/60/EC more commonly known as the Water Framework Directive (WFD) was introduced for all the EU member states in the year 2000. The purpose of the directive is "to establish a framework for the protection of inland surface waters, transitional water, costal water and groundwater" (European Parliament, 2000). The purpose can be further developed into preventing the deterioration and to improve aquatic ecosystems, to promote the sustainable use of water, to reduce pollution and to help reduce the effects of floods and droughts. (Copestake, 2006)

The overall objective of the WFD is that all water bodies that are covered by the directive should obtain "good ecological status" by 2015. 2015 marks the end of the first management cycle. In special cases the objective of good ecological status might be postponed to 2021, the end of the second management cycle, or at the latest by 2027, the end of the third management cycle. (European Commission, 2010)

From the implementation in 2000 until 2015 when the first management cycle ends, there are several deadlines that the countries have to fulfil in order to fully implement the directive. The most recent one was due at the end of 2009, when the River Basin Management Plans including the program of measures had to be finalised. The idea is that once the WFD has successfully been implemented, the management cycles will run over six years time periods. Completing the first management cycle until 2015 is taking longer than six years in order to give the countries time to implement the new management of the water bodies. (ibid)

Each six year cycle contains certain measures of the water management. The measures are partly taking place parallel and the idea of the management cycles is that the work regarding the water bodies and water management can never be finished and abandoned, rather the water management has to be continuous and constantly aim at improving and maintaining the status of the water bodies. The management of water bodies are taking place at the river basin level and has to be integrated with other activities in society related to water. The cycle contains the following steps, which are executed in each administrative area based on the river basins:

1. Mapping and surveying of the water bodies.
2. The information gathered about the water bodies is used in order to assess the present status of the water resources.
3. The quality for each water body is designated and a deadline for when the status should be achieved is set up.
4. In order to reach the objectives a River Basin Management Plan, including an action plan, is established.
5. Monitoring of the water bodies.

6. Evaluation of the water bodies and the effect of the measures.

After the full cycle, the information from the evaluation is used in starting a new management cycle. In this way, experiences from the past can improve future management of the water bodies and this will continuously enhance the status of the water bodies. (Vattenmyndigheterna, 2010-03-23)

The WFD has in many ways modernised the way water is being managed. One important change is the view of the management borders. Previously the management has in many cases been based on administrative borders, but with the WFD the river basin is the spatial reference unit. The management should be pursued at each river basin, so that the measures are coordinated for the same ecological, hydrological and hydro geological unit (European Parliament, 2000). The perspective of the entire basin, i.e. the runoff area of a water body, will make it easier to work towards a common goal and decreases the risk of measures that contradict each other. The measures will be more holistic and with several authorities cooperating the activities should be better coordinated and the measures more cost-efficient.

The WFD clearly emphasises the role of public participation and states that "decisions should be taken as close as possible to the location where water is affected or used" (European Parliament, 2000, WFD, (13)). It is not only a matter of the democratic right of the citizens, but usually the success of a certain measure or new regulation lies in the support of the public. In other words, measures will be a lot easier to implement if the public understands the reasons of the measures and what the objectives of the measures are. More precisely this means that proper information has to be distributed and that the public should be allowed to participate and have opinions on planned measures before the final decision is made.

The WFD has been criticised, mainly from within the HP industry, for causing superfluous bureaucracy when it comes to the planning and construction of new HP installations and re-licensing of old installations. The regulation aimed towards less environmental impact by the installations and the environmental concerns have been widely recognised the last few decades. The more stringent regulation lead to higher administrative costs for the industry and environmental measures add to the investment costs. These extra costs are especially noticeable for smaller companies, where the revenue will decrease and can even lead to the installations no longer being economically feasible to run. Within the industry there is an uncertainty of what consequences the WFD will lead to. This itself could be an obstacle to investing in HP. Many stakeholders are of the opinion that there is a need for clarification regarding the WFD and to clarify to what effect it will have for the HP industry. (World Energy Council, 2007)

3.2 Heavily modified water bodies

The WFD uses the term water bodies for all types of surface waters, rivers, streams and lakes. However, some water bodies have been altered by human intervention, sometimes several centuries ago, to such an extent that they can no longer be considered natural water bodies.

These types of water bodies will be classified as heavily modified water bodies (HMWB). There are also water bodies that are completely manmade such as water reservoirs and channels, which will be classified as artificial water bodies. It is not possible for artificial and heavily modified water bodies to achieve the same level of ecological status as a natural water body, therefore they will be classified and measured on their own scale.

Another reason for a separate classification of the HMWB is that the activities connected to the water body, if they have important economical and social benefits, should be able to be continued (European Commission, 2003). Alterations caused by human activity have to be considered from an environmental, social and economical point of view. Some activities are of such an importance that they should be able to take place even though they have a negative impact on the environment. It is important to point out that even though a water body is considered as heavily modified, measures will still have to be taken in order to achieve an ecological potential.

The WFD defines which type of water bodies should be classified and defined as artificial or heavily modified. It is then up to the member states to identify these water bodies in their own river basins. According to the WFD an artificial water body is a “body of surface water created by human activity”. A HMWB is described as “a body of surface water which as a result of physical alterations by human activity is substantially changed in character” (European Parliament, 2000, p. 9). Examples of HMWB’s would be; port facilities, water storages e.g. with the purpose of drinking water supply, irrigation or power generation, water regulation and flood protection.

The European Commission has issued several guidance documents in order to clarify the implementation of the WFD and in order to assist the member states. There is a guiding document specifically regarding artificial and HMWB’s; Common Implementation Strategy for the Water Framework Directive (2000/60/EC), Guidance document no 4. This document assists in the identification and designation of heavily modified and artificial water bodies.

In order for a water body to be classified as heavily modified it has to be altered by human activity and substantially changed in character. According to the Guidance document, in order to assess if a water body is substantially changed, both morphology and hydrology needs to be taken into account. If both the morphology and the hydrology of a water body have been substantially altered, the water body has been substantially changed. If only either the hydrology or the morphology has been altered, the situation is less clear. (European Commission, 2003)

The Guidance document offers a stepwise method in order to identify the HMWB’s. The identification is made up by 11 steps and first of all identifies the preliminary HMWB’s. After the preliminary identification, the candidates are evaluated according to article 4 (3) of the WFD and the final HMWB’s are identified. (Naturvårdsverket, 2008)

Interesting in relation to HP is the approach concerning river beds downstream of dams. Under normal conditions only hydrological alterations are not exempt in order to classify the water as heavily modified. However, HP is assumed to lead to circumstances when the hydrological alterations are of such an extent that the water course can be considered heavily modified. One such example would be the river bed downstream of a dam, this would cause substantial hydrological changes. And even though the morphological alterations would be small in this area it is enough to consider the water body for a provisional identification as a HMWB (European Commission, 2003).

Regarding HP, the question of whether a water body is heavily modified or not is quite interesting. A water body classified as heavily modified will have less stringent environmental targets than natural water bodies. Artificial and HMWB's have to achieve good ecological potential by 2015. This differs from natural water bodies, which have to achieve good ecological status with more stringent requirements on the water bodies.

The classification of the water bodies has to be done with a method that can be comparable in all member states. The Guidance documents put forward approaches to how to implement and work with the WFD. There is a stepwise approach to the identification of HMWB, to ensure consistency in the method. This method can be applied by the member states in order to harmonise the implementation. The guiding documents are not legally binding and therefore only acts as a help and guideline for the member states.

The main reason to designate a water body as heavily modified has to do with the type of activity causing the deterioration in the environment. If the activity that causes the modification benefits society to a large extent, the water body can be designated as heavily modified. Still, the identification and designation has to be evaluated in each single case. HP is seen as one such activity that greatly benefits society but also has severe impacts on the environment and the water bodies where HP installations are present should therefore qualify at least to the preliminary identification of HMWB's. (Vattenmyndigheten Bottenviken, 2009)

Figure 7 displays the percentages of HMWB in the European river basin areas. The map is based on an environmental analysis that took place in 2004 and HMWB in the map are only being provisionally identified. The final identification will take place on a river basin level with identification tools provided by each member state.

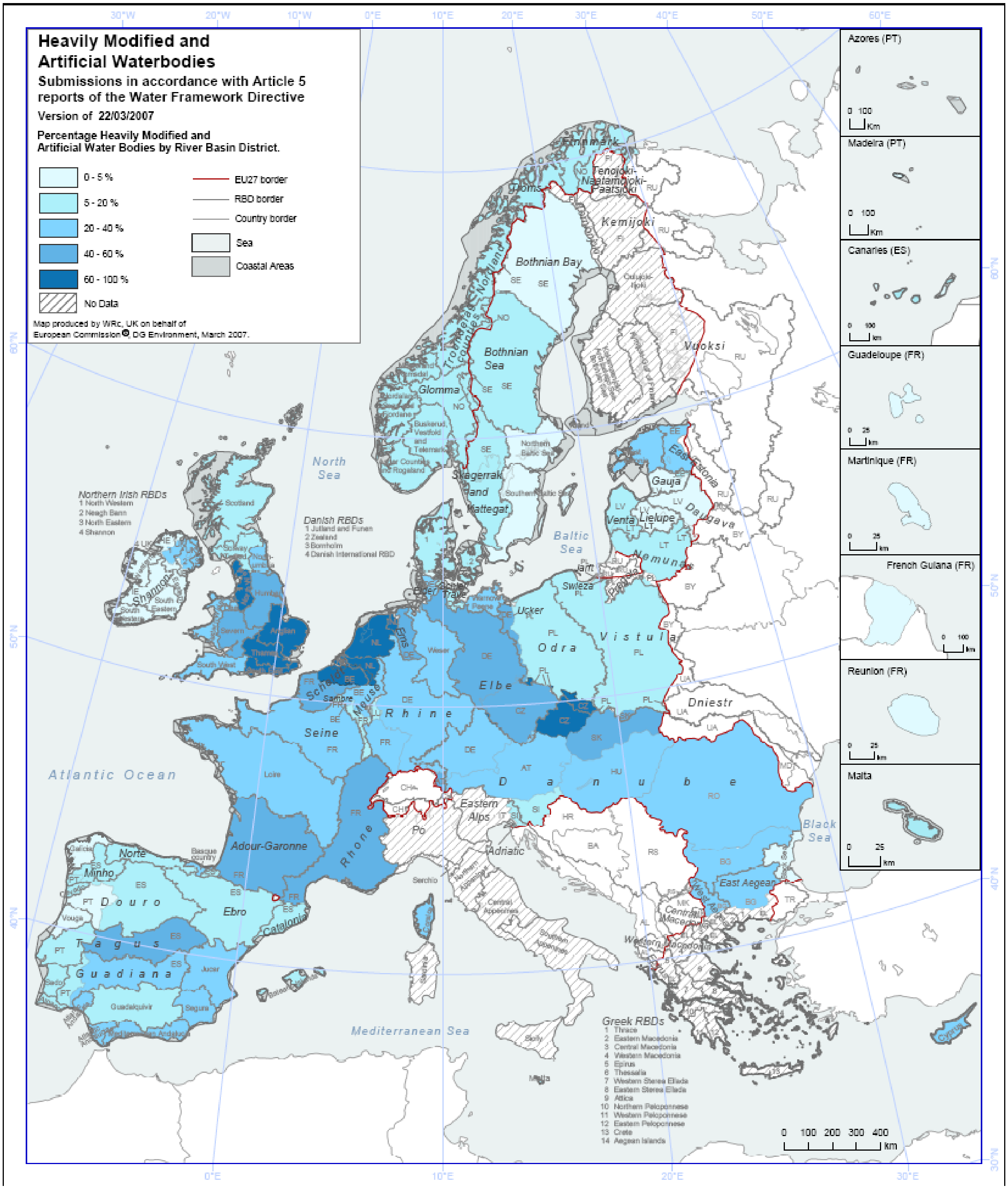

Figure 7: Heavily modified water bodies in the river basins of Europe. (Source: European Commission, DG Environment, 2007)

4. Stakeholders

4.1 Overview

Regarding hydropower and the WFD, there are several stakeholders involved. This chapter firsts aims at getting an overview of the types of stakeholders and secondly to take a closer look at some of these stakeholders in Austria, Scotland and Sweden. Displayed in Figure 8, the stakeholders have been divided into three groups; the hydropower industry, the regulators and the environmental NGO's. In this thesis the focus is limited to the EU and further focused on Austria, Sweden and Scotland.

The stakeholders operate at different levels, which are displayed in Figure 8. Regarding the hydropower industry, the small-scale hydro is normally run by rather small companies at a local level or even individuals while the large-scale HP is normally run by larger companies at regional, national or even international level.

The regulators are made up by authorities at different levels. Since the WFD is an EU directive, the EU in turn will be the highest regulatory instance. On a national level, normally the countries EPA's will be in charge of the implementation and the overall regulatory work. The river basin management is normally divided on a national basis into authorities that have special responsibility for the different river basins. The river basin authorities are responsible for the RBMP and all identification of water bodies, as well as proposing measures.

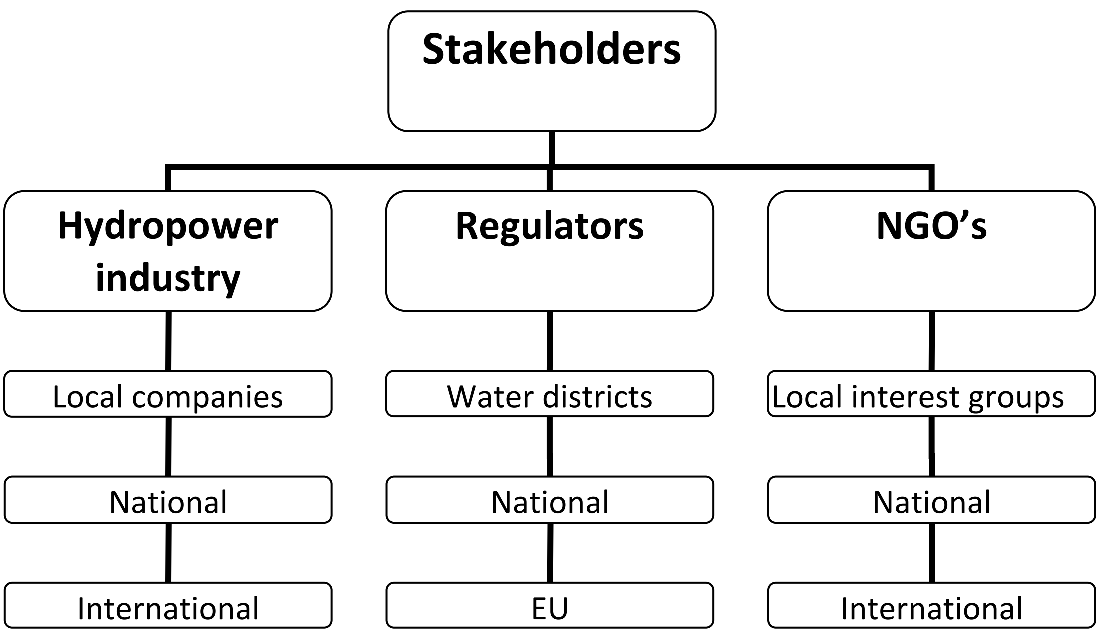

Figure 8: ***Stakeholders on the hydropower scene in Europe.***

4.2 Non Governmental Organisations

When it comes to the non-governmental organisations (NGO's) they operate at different levels, from global to local. Greenpeace and the WWF would be examples of two of the larger international environmental organisations. On a national level there are NGO's concerned with nature conservation and environmental protection. On a more local scale the NGO's are smaller and normally more diverse. They can be formed with the purpose of protecting a certain area if there are plans of exploitation or they can have a specific interest, such as fishing, bird watching etc.

Environmental organisations are not necessarily against HP as such. They realise the need for renewable energy and that HP plays an important role here. One of the larger environmental organisations Greenpeace, promotes the construction of small-scale, run-of-the-river HP plants instead of large-scale HP with larger environmental impact. They conclude that large-scale HP with water reservoirs often has major negative effects on the local environment (Greenpeace, 2005). However, there are no scientific proofs to back up this argument.

Hobby organisations such as fishing clubs, kayak and outdoors organisations often oppose to the exploitation of rivers.

4.3 Hydropower industry

The European Small Hydro Association (ESHA) is an international association representing the sector of small-scale HP. It is a platform for the stakeholders in the SHP industry and provides information and exchange of information. ESHA promotes the environmental benefits of SHP – and states that both economical and environmental benefits from SHP in Europe can be enormous. (ESHA, 2010)

ESHA finds it difficult at present to estimate what effects the WFD would have on the SHP sector, since the directive has only been implemented relatively recently. How the WFD is implemented and interpreted in each single member state is seen as the key aspect for the SHP industry. However, ESHA predicts that the WFD will have the following impacts; reduced electricity production due to regulations regarding larger environmental flow and sediment management, increased investment costs due to measures to improve fish migration, more stringent regulation regarding water levels in storage reservoirs and finally the closing down of some plants. (ESHA, 2004 (a))

In an article ESHA points out that the WFD to some extent contradicts the EU directive on renewable energy sources (RES), which aims to increase the renewable energy production in Europe by 20 % until 2020. A better harmonisation between the two directives is therefore requested. Again, ESHA points out that it is the implementation in each single country that will decide the exact impacts for the industry. Depending on the implementation a production loss in the SHP sector of 15-20% in the EU is estimated. (Lins et al. 2005)

Kleinwasserkraft Österreich is an organisation for the SHP industry in Austria with approximately 1000 members.
A representative from Kleinwasserkraft Österreich, Martina Pretchtl, has the following opinion regarding the WFD:
Although Kleinwasserkraft supports the goals of the WFD, there will be some impacts on the SHP industry in Austria, mainly because of the economic impacts of mitigation measures such as fish ladders but also because of loss in revenue due to more stringent regulation on residual flow. Future development of HP will have higher investment costs and it is possible that the WFD will influence the number of feasible sites for SHP. (Pretchtl, 2010)

Österreichische Elektrizitätswirtschafts-AG more commonly known as Verbund is the single largest electricity company in Austria. Verbund produces and transports about 40% of the Austrian electricity and out of this production about 90 % comes from hydropower. Verbund owns and operates 123 hydropower plants within Austria and Bavaria, which add up to an installed capacity of HP of 7500 MW. (Verbund, 2010)
A representative from Verbund, Otto Pirker, has the following opinion regarding the WFD:
The Verbund takes a lot of interest in the implementation and the future development of the WFD. However, there seems to be a contradiction between the WFD and the RES directive.
The Verbund is planning on investing 30 million euros until 2015 in order to improve the continuity in the rivers at the HPP's. Mainly fish passages are being constructed. However, if there is a lack of space, fish ladders are an alternative option.
The Verbund has a stepwise approach to mitigating the effects of HP; the fist measure is construction of fish passages and increased residual flow in order to improve the continuity, the aim is to achieve this until 2015. The second measure would be to continue working with the residual flow in order to reach good ecological potential and finally hydro peaking will be addressed, the goal is to achieve this by 2021 or alternatively 2027. The estimated loss of productivity in order to provide enough residual flow to ensure continuity is 400 GWh/year, around 1 % of total HP generation per year. Providing enough residual flow to achieve the good ecological potential/status could result in a production loss of about 5%.
Mitigating the effects of hydro peaking is difficult and there is a lack of knowledge of appropriate measures.
The WFD is still rather young and therefore it makes it difficult to make any predictions for the future. However, the first RBMP has been very good and helpful in order to approach the environmental problems caused by HP. (Pirker, 2010)

Vattenfall is one of the major Swedish energy producers. The company owns and operates 112 HPP's mainly in Sweden, but also in Finland. Many of the HPP's were constructed in the 1950 – 1970's and are therefore in need of updates and renovations. Vattenfall is at the moment working on renewing many of the older installations as well as improving the mitigation measures and improving dam safety. (Vattenfall, 2010)
A representative from Vattenfall, Arvid Sundelin, has the following opinion regarding the WFD:
Since the WFD most likely will have an impact on the HP installations, Vattenfall follows the implementation and the development very closely. The WFD is still rather new and the full consequence for the HP industries still seems a bit unclear. Vattenfall has worked out a strategy

regarding the WFD in order to be able to adapt to the new requirements. Within Vattenfall there is a concern that the WFD will negatively influence the revenue from HP and Vattenfall suspects that there will be more stringent regulation of the minimum environmental flow. There is also an uncertainty about what objectives and what aims that will be legally binding through the Environmental Code. The legally binding objectives at the present are those of good environmental status/potential. The concern is that more precise parameters such as flows and water levels will be legally binding through the environmental quality standards. (Sundelin, 2010)

Scottish and Southern Energy group (SSE) is the largest electricity and gas company in the UK. Scottish Hydro is part of the group. SSE owns around 11 300 MW of electricity generation capacity, of which 2 370 MW is renewable capacity, throughout the UK and Ireland (SSE, 2010). SSE representatives were not willing to comment on the WFD or answer questions when contacted.

4.4 Regulators

The Scottish Environmental Protection Agency's (SEPA) mission regarding HP development is to strike the right balance between renewable energy development and achieving Scotland's objectives for the water environment.

The following paragraphs are based on answers from Peter Pollard at SEPA:

When it comes to upgrading of existing HPP's this can sometimes be undertaken in a way that do not deteriorate the water status. Regarding the construction of new HPP's, many of the new constructions will be small-scale HP, many even very small. This means that the environmental impact of each single of the small schemes is very small, but the SEPA has to take into consideration and manage the cumulative impacts of the large number of small schemes. The small schemes contribute with very little electricity generation, which also has to be taken into consideration in the decision making.

However, many of the new HP installation create a significant risk of deteriorating the water status. But if the installations are located at a suitable location with the appropriate mitigation measures, it will be possible with a development that does not interfere with the objectives of the WFD.

The most important issues for the implementation of the WFD are to improve the understanding of ecological impacts and finding the right balance between the renewable energy development and the goals of the WFD. (Pollard, 2010)

The Swedish Environmental Protection Agency is the link between the River Basin District Authorities and the EU. The Swedish EPA has a guiding and prescribing role and represents the country at a European level. EPA also has to make sure that the implementation of the WFD is coordinated across the country.

The following paragraphs are based on answers from Peter Sörngård at the Swedish EPA:

The Environmental Code, in which the WFD is implemented into the national regulation, is very clear when it comes to what is allowed in the utilisation of the water. However, there is a certain amount of uncertainty when it comes to implementing the laws and regulations. It is difficult to

discuss what impact the WFD would have on the present and future Swedish HP industry. This has to be discussed for each individual case. The HP industry has to take all possible measures to ensure that the impact of the HP is as small as possible. The measures have to be within a reasonable cost, but agreeing on the reasonable cost could most likely be discussed. This is connected to the "polluter pays principle" which states that it is up to the polluter to take measures to limit the environmental damages.
Regarding the classification of HMWB's; a water body with a HP installation is not per definition a HMWB. Again if a water course is defined as natural or heavily modified has to be decided in every separate case. Although it is important to point out that the HP companies cannot avoid taking measures at a HP plant depending on the classification.
Finally; the main present problems related to water status in Sweden would be primarily eutrophication and acidification. In the north of Sweden the dominant problem would be morphological alterations of the watercourses. (Sörngård, 2010)

The Swedish River Basin District Authorities are in charge of implementing the WFD and there are five districts in Sweden, based on the borders of the river basins.
The following paragraph is based on answers from Lisa Lundstedt at the River Basin Authority of Bottenviken:
The development of HP has led to deteriorated river morphology being the most prominent environmental issue in the north of Sweden. HP will most likely play an important role in the Swedish electricity supply in the future as well, especially since fossil fuels will be increasingly abandoned and nuclear power might be reduced as well. The future of nuclear power is unclear in Sweden. It is heavily debated and yet there are no clear political decisions taken. When it comes to achieving the objectives of good ecological status or potential, the existing HPP's first of all has to become more efficient as opposed to constructing new installations. Regarding mitigation measures at the HP installations, it is crucial to study the entire course of the river and implement measures, where they can have the best effect on the river. The measures include increased environmental flow, fauna passages and measures to improve sensitive habitats.
When it comes to the role of small scale HP and the large scale HP; more effective large scale HPP's could mean that small scale HPP's can be completely abandoned or removed. Finally, the most important role of the WFD is that the directive coordinates different authorities, and these coordinated efforts are crucial in order to achieve the overall objective of good ecological status. (Lundstedt, 2010)

In Austria the Federal Ministry for Agriculture, Forestry, Environment and Water Management are responsible for the implementation of the WFD.
The following paragraph is based on answers from Veronika Koller-Kreimel at the Ministry:
According to the WFD goal of good ecological status, which is defined in the national Ordinance on Ecological Quality, upgrading or construction of new HPP's can be done as long as the quality objectives of the Ordinance are met. As long as a minimum flow is guaranteed the continuity can be maintained through fish migration measures and therefore deterioration of water status can be avoided. However, even if there is a deterioration in status HP development could still be acceptable based on the prerequisites of Art. 4 (7) WFD.

Both SHP and LHP are important and will be developed in Austria in the future.
When it comes to achieving the national targets of renewable energy HP plays an important role. In an Energy Strategy document from 2010 it is estimated that a further 3.5 TWh will be developed.
The main existing problems of the waters in Austria are firstly changes in hydro morphology in the rivers due to flood defence and by disruption of continuity, straightening of rivers, bank and soil fixation. Secondly hydropower causes negative impacts on the environment where no ecological minimum flow causes disruption of river continuity and the character of flowing rivers are changed to a stagnant/lake character due to impoundments, flow fluctuations due to peak load production etc. (Koller-Kreimel, 2010)

5. Country profiles

5.1 Overview

This section will look closer at three European countries; on the national implementation of the WFD, the present situation for HP, the future potential of HP and finally the river basin management plans especially in connection to HP. The countries that will be investigated are Sweden, Scotland (will be studied as a separate part of the UK) and Austria. These countries all have HP, which they depend on to a smaller or greater extent. The reason for choosing the specific countries are for practical reason, geographical spread and that they have different views on HP. Regarding the practical aspect, good data availability for the chosen countries was the most important criteria. The three counties were also picked on the grounds of existing HP and the development of HP.

Sweden has a long tradition of generating electricity from water, many of the suitable locations have been developed and most of the installations are rather old, most of them 30 years or more. A large share of the country's electricity is generated from HP installations, but the development has to a large extent stagnated. The future of HP is difficult to predict, with a strong opposition against HP development on environmental grounds, but the need and pressure to increase renewable energy is increasing.

Out of the three countries in the study Austria is the country with the highest percentage of electricity from HP. HP has a long history and many of the suitable locations have been developed. But the Alpine region in general has very favourable conditions for HP, with very high elevation differences, which creates many suitable locations. In choosing the countries for the study it seemed important to include one of the countries in the Alpine region. Austria as well as Sweden has a long experience of HP. The environmental concerns regarding HP have increased during the last decades. There seems to be a will, including a new "Masterplan for Hydro" (Verband der Elektrizitätsunternehmen Österreichs, 2008) to develop HP and new schemes are planned and have been commissioned.

Scotland has a small share of electricity produced from HP and there are few large scale installations, especially compared to Austria and Sweden. With the EU objective of 20% renewable energy in 2020 and the increasing interest to develop renewable energy sources, there is a driving force to develop HP and especially small-scale HP. Small-scale HP is seen as a good way of producing renewable energy and there are many suitable locations for this type of installations. A feed-in tariff was introduced in the UK in 2010, which makes small scale more profitable and more locations feasible for development. There are environmental concerns regarding HP in Scotland, but so far this does not seem to limit the development to any great extent.

The focus will be mainly on the role of HP and the future of HP in each country. Table 1 presents the renewable energy targets that have been adopted for all the EU member states. The overall target for the EU is to achieve 20 % renewable energy production by 2020. The final version of the directive was adopted in 2008 and is commonly known as the RES directive (2001/77/EC). The targets are a result of the national strategy plans that were required by the directive in order for the member states to fulfil their targets. (Euractive, 2010)

Table 1. Renewable targets for Austria, Sweden and Scotland. (Sources: Euractive, 2010. Naturvårdsverket, 2010)

Country	**EU renewable energy policy**
Austria	34 % renewable energy in 2020
Sweden	49 % renewable energy in 2020. Addition of 10 TWh, 2002 – 2010 electricity
Scotland	40% by 2020 electricity UK: 15 % renewable energy in 2020.

The situation for HP differs in the three chosen countries. Table 2 presents an overview of the present installed HP capacity, the share of SHP, the available future potential and if more HP is planned for the future. The available future potential is based on what is economically and technically feasible. However, the methods of estimating the available potential might differ slightly between the countries.

Table 2. Overview of Austria, Scotland and Sweden's HP situation as well as future potential. (Sources: Europe's Energy Portal, 2008; IVA, 2002; Scottish government, 2010)

Country	Present HP	SHP	Total available Potential	Planned future development of HP
Austria	12 381 MW; 40 677 GWh/year	1201 MW	13 TWh	yes
Scotland	1 400 MW; 5895 GWh/year	No figure	1209 MW	yes
Sweden	16 200 MW; 64 000 GWh/year	962 MW; 1500 GWh/year	23.8 TWh	no

5.2 Sweden

5.2.1 National implementation of the WFD

The WFD has been implemented in the national regulation "Förordningen om förvaltning av kvaliteten på vattenmiljön (SFS 2004:660)" and in the Environmental Code. The Environmental Quality Standards, which includes the WFD objective of good ecological status and no deterioration of water status, are regulated in the Environmental Code.

In order to implement the WFD a new authority has been created; the river basin district authority, consisting of five districts. These are illustrated in Figure 9. The management borders of the new authorities are based on the river basins. This means that several of the county boards have to cooperate within a river basin authority and that some counties will belong to more than one river basin district authority. The river basin district authorities are responsible for the daily work of the WFD and produces river basins management plans as well as suggestions of measures in the district.

When it comes to the HMWB, Sweden closely follows the guidelines of the European Commission. The method of classifying the HMWB's begins with a preliminary identification of water bodies that can be heavily modified. The water bodies that have been preliminary identified are evaluated on the grounds of what mitigation measures need to be taken in order to achieve good status of the water body. The costs as well as the social and economical benefits of the activity are evaluated and taken into consideration. The final decision as whether the water body is heavily modified or not lies in evaluating the alternatives to the activity causing the modification of the watercourse. If there are no reasonable ways to reach a good status of the water body and if the criteria for identifying a HMWB can be met, the water body is finally identified as heavily modified. (Vattenmyndigheten Bottenviken, 2009)

Figure 9. Map of Sweden divided into the five river basin district authorities. (Source: Vattenmyndigheterna, 2009)

5.2.2 Hydropower today

Total capacity of HP in Sweden is about 16 200 MW, where SHP contributes with 962 MW, and during a normal year about 64 TWh are produced, making up about half of Sweden's electricity production. The 1200 small-scale HPP's contribute with about 1.5 TWh per year, the 700 large-scale HPP's contribute with approximately 62.5 TWh. The potential for installing new capacity is limited by environmental, political and technical factors. The production is concentrated in the north of Sweden, where the major rivers are located and where elevation and runoff are favourable. The largest installation is *Harsprånget* in Lule River, with an installed capacity of 830 MW. (IVA, 2002)

Today the major problem with river morphology in north Sweden is related to HP. Using running water in order to create mechanical power is a very old technique and in the 1880's the first turbines and generators were constructed on existing water mills in Sweden. The expansion of HPP's played an important role in for the Swedish industries and development. (ibid, p.5)

One great advantage of the larger HPP's that can store water is that the stored water holds energy and can be used as a reserve potential. The water in all Swedish HP dams holds a capacity of in total 34 TWh, i.e. approximately half of the electricity output on an average year. This is valuable as a backup at peak demands and a way to store electricity.

Regarding the minimum flow, there is a rule of thumb in Sweden that at least 5 % of the production value (the water) should be set aside for environmental purposes. In rivers with higher environmental values, more water might be required to be set aside. This extra production loss is then compensated by the government. (*Malm-Renöfelt, 2010*)

The permits conditions for HP plants have in many cases been updated. The validity for a permit depends on when it was given, but it is common with 10 years. The reason for updating the conditions of the permits has normally been to improve the conditions for migrating fish through e.g. new fish ways and to improve the water environment by regulating the residual flow. However, the conditions imposed to improve the water environment are economically constrained. The owner of the HP is being economically compensated for the loss of water flow and this sets the limits for the mitigation measures. (Naturvårdsverket, 2007)

5.2.3 Future potential

There are favourable conditions for HP in the north of Sweden, with mountains, highlands, high precipitation and low evaporation. The disadvantage of the area is that a lot of the precipitation is held up as snow or ice for quite a long period of the year. The total untapped technical potential has been calculated to 23.8 TWh. This also includes the four national rivers that by law are protected from development. Without these the technical potential would be 11.1 TWh. Taking environmental considerations into account, it should be possible to develop about 5 TWh. (IVA, 2002)

The possible potential that can be developed in Sweden does not really depend so much on economical or technical limitations. Rather the development depends on what environmental effects can be accepted in relation to HP installations. No politicians today would really speak very passionately in favour of an HP development. There is a decision from the parliament in 1997 that limits the development to 2 TWh. The Swedish Energy Agency estimates an expansion of only 0.5 TWh whilst the HP industry umbrella organisation, Swedenergy, believes that an expansion up to 5 TWh is realistic. It is difficult to predict how the future development of HP in Sweden will turn out, but it seems like the energy companies will have a difficult task in convincing the public about the positive sides of HP. (Müller, 2005)

Most of the suitable areas for HP development are today regulated and protected thought the Environmental Code. Four of the main rivers, the national rivers, are completely protected from any anthropogenic intervention. The possibility to develop other locations is hard to predict since each single case has to be considered by a court. (Elforsk, 2007)

An important function of the HP is the role it plays together with other renewable energy sources like photovoltaic (PV) and wind power. These two, but mainly wind power, are expected to increase significantly in Sweden. In order to balance PV and wind power, on cloudy and calm days, a back up is necessary in order not to drop the frequency on the grid. This could of course be covered by many different energy sources. HP would, however, be the only renewable option that is available today and that can be employed on a large scale. In order to expand the capacity of wind and sun power, it is necessary to have a complimenting energy source. (Royal Academy of Science, 2009)

5.2.4 Impacts and conflicts

The impact on migrating fish is commonly discussed regarding HP in Sweden. One of the reasons for this is probably partly that the fishing organisations are influential and powerful lobbying groups. Salmon, trout and eel are species that are in particular affected by HPP's because of their migration to their spawning grounds (regarding salmon and trout).

The importance of conserving pristine areas is another strong argument. Most HPP's in Sweden were constructed at a time when there was very little or no consideration of the environmental impact of the installations. Today this approach has radically changed. This in turn gives completely new conditions when it comes to changing existing HPP's or planning new ones.

The Not In My Back Yard (NIMBY) argument is quite strong regarding HP but also regarding other renewable energy sources, since people generally do not want to cut their electricity consumption or standard of living to any greater extent, but still want pristine water environments.

In Sweden the main mountain range and therefore the majority of the HP installations are located in the northern part of the country. The north is sparsely populated compared to the more densely populated south of Sweden. In other words, the HPP's in the north supplies the southern parts with a large share of the electricity. Many of the local residents and politicians already feel that they are contributing with more than their fair share and do not see why nature nearby should be exploited to provide other parts of the country with more electricity.

5.2.5 River basin management plan in north Sweden

The RBMP's are available for all of the five administrative areas of the river basin district authorities in Sweden. Bottenviken is the most northern administrative area of the water authorities in Sweden, see area no. 1 in Figure 9.

The regional differences in the water environments in Sweden are prominent, the water bodies are of very different character and many of the environmental problems differ at different locations in the country. In the northern parts of Sweden the most crucial environmental problem is that of morphological alternations of water bodies.

The major rivers in Sweden are located in the north and many of these have been altered as a consequence of most importantly log-driving and hydropower. Log-driving dates back to the seventeenth century in Sweden and has played an important role in the development of the Swedish timber industry although it became increasingly outdated and was completely abandoned in 1980 (Länsstyrelsen Västebottens län, 2007). The impact of the logging is left long after the activity itself has ended. It was common to improve the transportation of the timber by clearing the riverbed and in some parts straightening the course of the river. Dams were constructed in some areas to gather the logs and this had major impact on the water regime as well as the aquatic fauna. (Rosander and Sundberg, 2010)

What makes the RBMP of Bottenviken interesting is that a large number of HPP's are located in this area and many of the surface waters have been modified mainly for HP and log-driving purposes. The purpose of the RBMP is to ensure that the Environmental Quality Standards for the surface waters are reached. This corresponds to the national implementation of the WFD and the overall objective is to ensure good status in all waters by 2015. (Vattenmyndigheten Bottenviken, 2010)

The RBMP concludes that morphological changes of man made character have occurred for a long time in the entire country, but in the north, where the major rivers are located the problem is extensive. The main reason for the physical changes and also the activity with largest impact is the development of HP. At the time of construction, most of the plants were built with no consideration of the environment. The magnitude of the problem becomes obvious when the report concludes that the physical modification of the waters is the main obstacle in reaching good ecological status (ibid, p. 39)

In order to make sure that the water bodies presently below the good ecological status or potential will reach their goals by 2015, major restoration work is required. The water authorities give recommendations on taking measures and fulfilling the objectives. Today there are already several ambitious restoration projects taking place with the objective to restore habitats in the rivers. Governmental funding has also included measures directly towards hydropower plants; fauna passages past dams and weirs and buying part of the water from the electricity generation to create a better environmental flow. (ibid, p. 43)

When it comes to lakes and riverine systems 19.5 % of the surface waters do not achieve at least good status because of morphological alterations. On top of these, there are surface waters that today reach good ecological status, but due to morphological changes risk deterioration. All these surface waters require measures in order to reach or to keep the objective of good ecological status (ibid, p. 44)

5.3 UK (Scotland)

5.3.1 National implementation of the WFD

Although Scotland belongs to the UK, there is an independent EPA; SEPA. SEPA are responsible for the implementation of the WFD in Scotland. All Scottish river basins lie completely within the Scottish administrative border except one. Part of Scotland shares a river basin with England, Solway Tweed, where a separate management plan is set up. Figure 10 presents the borders of the Scottish river basin as well as the major water bodies. (Scottish Government, 2009 (a))

Regarding the identification of HMWB's, Scotland closely follows the guidelines from the European Commission; Common Implementation Strategy for the Water Framework Directive (2000/60/EC), Guidance document no 4. The methods include a stepwise identification of the HMWB's.

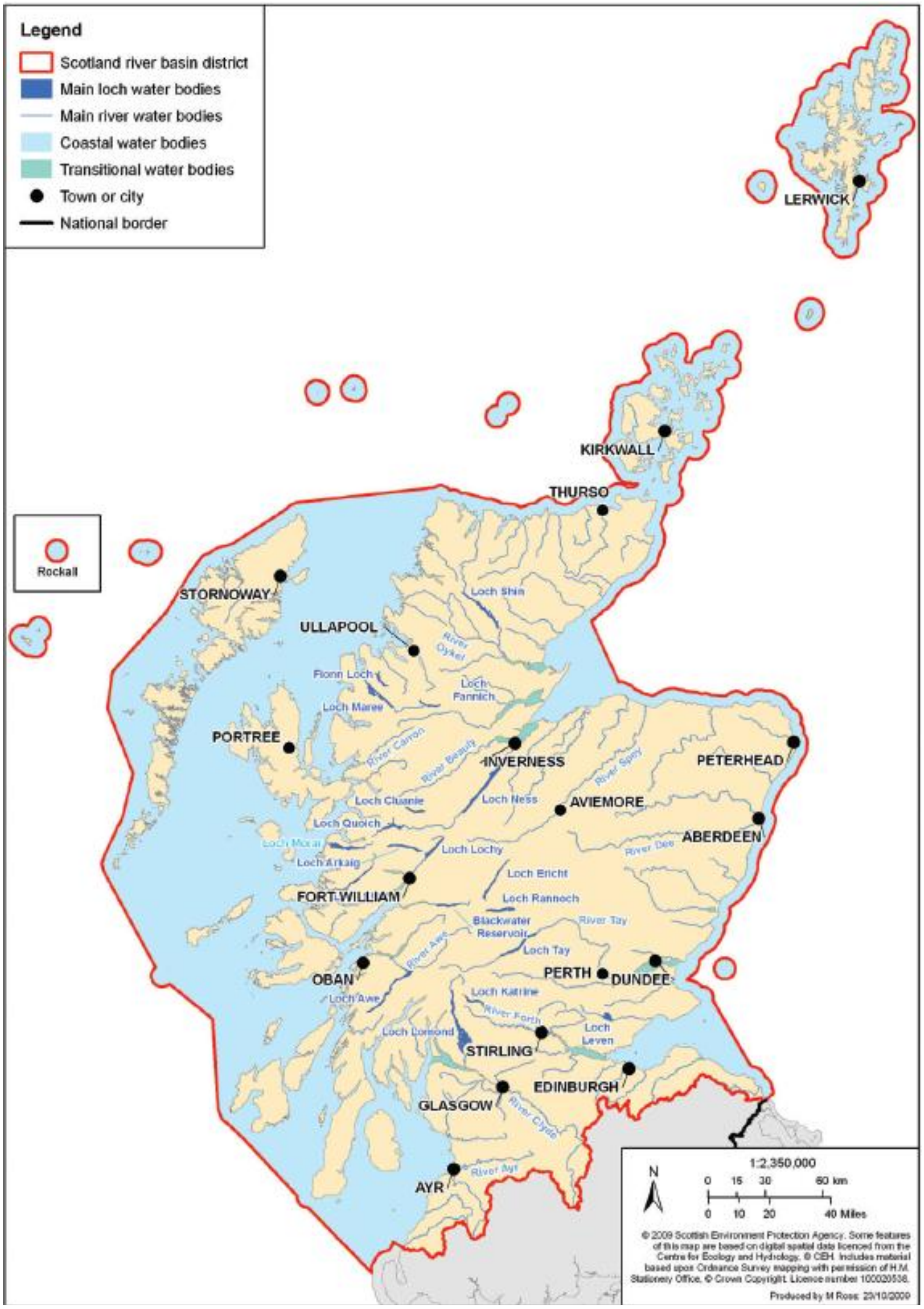

Figure 10. Map of the area covered by the Scottish river basin district (Natural Scotland, RBMP Summary)

5.3.2 Hydropower today

The share of HP in Scotland is substantially lower than in countries like Austria and Sweden. Also, the potential for installing new capacity is much lower, since the feasible locations are fewer and smaller than Sweden and Austria. The generation from run-of-the-river as well as pumped HP in 2007 was in total 5895 GWh, which corresponds to over 1.4 GW of installed capacity. The pumped Hydro represents approximately 2.5 % of the country's total electricity production and run-of-the-river is representing nearly 10 %. The main sources for electricity are based on non-renewable energy sources such as nuclear, coal, gas and oil. (Scottish government, 2010)

At the moment there are only 20 HPP's in Scotland that exceed 5MW of installed capacity. Out of these installations only one has been built during the last 35 years, Glendoe Hydroelectric scheme. Number wise the growth is primarily in small-scale HP's, with around 50 schemes authorised for production since 2006. In order for the Scottish waters not to deteriorate in status, the SEPA has an important role to play in balancing the interests and striking the balance between developing HP and conserving the water environments. (Scottish Government, 2009 (a))

5.3.3 Future potential

In the study by Forrest et al. from 2009 the potential of Scottish HP has been revised from what was previously estimated. The majority of the untapped potential is available in small scale HP, in this case defined as below 1 MW. At 8 % discount rate the total available potential would be 1209 MW installed capacity, this would correspond to around 7000 new installations. This is a larger available potential than earlier expected, one of the main reasons being the implementation of a feed-in-tariff for the production of electricity from HP. The feed-in-tariffs, which is a political instrument implemented in order to boost renewable energy production, favours the small-scale implementations up until 1MW. Larger installations benefit more from trading Renewable Obligation Certificates and are therefore not affected by the feed-in-tariffs. This is part of the explanation why there is a relatively large potential for the small-scale installations. (Forrest et al. 2009)

The implementation of feed-in-tariffs immediately increases the economically accessible untapped potential. In order to develop the untapped potential 4.7 million man-days of work would be required – this is therefore also a huge potential of work opportunities and development of rural areas. It is clear that most of the work opportunities would be in the smallest developments below 100 kW. (ibid)

According to the Renewable Action Plan, published by the Scottish government, there is a vision of building a strong, renewable heat industry in Scotland in order to obtain the renewable energy targets of 2020 and in order to tackle climate change. HP also has a role to play here. The vision for HP is a "full exploitation of hydroelectric potential in Scotland in harmony with environmental obligations." Based on studies regarding the future potential of HP in Scotland, the Plan supports both the development of pumped storage HP and small and micro-scale HP. (Scottish government, 2010)

5.3.4 Impacts and conflicts

In Scotland, like in most other places, there are questions raised as to where to find the right balance between exploiting and keeping the rivers in its natural state. The regulatory authorities have to strike the right balance between different interests.

According to Peter Pollard at SEPA, single HPP's can generate significant opposition. Especially if the installations are located in areas where kayaking and other water sports are popular, if there is valuable fishing in the waters or if there is beautiful scenery. (Pollard, 2010)

5.3.5 River basin management plan in Scotland

The total amount of water bodies that are being identified in the Scottish RBMP are 3095. This includes natural, heavily modified and artificial surface waters as well as groundwater. Out of these, 413 are classified as heavily modified or artificial and in this category only 50% of the waters achieve good or high potential. Out of the water bodies 65% in total are achieving good or high status. The goal for the RBMP is that 98% of the waters should achieve good or better status by 2027. The WFD states that the objectives in principle should be achieved by 2015, but there are exceptions to this objective. Scotland's goal for 2015 is that 71% of the water bodies should have obtained minimum good status. As the WFD states, this means that efforts have to be made both to prevent deterioration amongst the water bodies with good or high status as well as bringing all the other water bodies to a state of minimum good status. (Scottish Government, 2009 (b))

In Scotland, as well as in many other countries, many water protection measures have mainly concerned pollutants in the water. The WFD broadens the perspective and brings in other values including hydro morphological alterations. There are 125 water bodies (in 2008) that are adversely affected by hydropower. The aim is to reduce this number to 8 in 2027. (ibid)

5.4 Austria

The Austrian river basins differ quite substantially from the situation in Sweden and Scotland. Austria belongs to three river basins; Danube, Elbe and Rhine, which are all large international rivers, where the river basins cross many national boarders across central Europe. Out of the three river basins Danube is by far the basin that drains the largest part of Austria's area. Since Austria's river catchments are part of international basins, international river management plans are established together with the other countries sharing the same river basin. The management of the international river basins and the implementation of the WFD will therefore have to go hand in hand.

Austria is an alpine country and the combination of high mountains and high precipitation provides favourable conditions for HP. There is no coastline in Austria and many rivers and creeks have their source in the Austrian Alps.

5.4.1 National implementation of the WFD

The authority responsible for the implementation of the WFD in Austria is the Federal Ministry for Agriculture, Forestry, Environment and Water Management. The eight river basin districts are illustrated in Figure 11 below. Six of the river basin districts are within the Danube river basin, one district is within the Rhine basin and one district is within the Elbe basin. Since the eight different districts are seen as quite similar concerning pressures and impacts, they all share the same river basin management plan ("Nationaler Gewässerbewirtschaftungsplan"). There is thus one national RBMP which includes all the water bodies of Austria. (Koller-Kreimel, 2010)

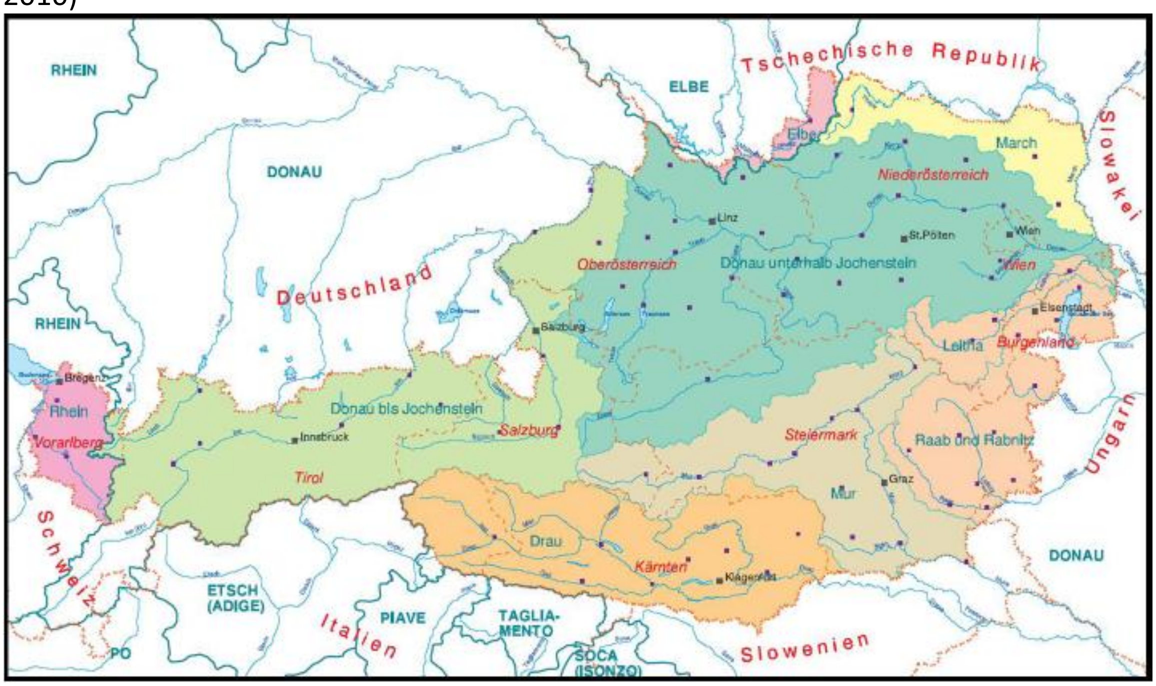

Figure 11 Map of Austria and its eight river basin districts. (Nationaler Gewässerbewirtschaftungsplan, 2009)

5.4.2 Hydropower today

In a European perspective, Austria already has a very high percentage of renewable energy. Around 65 % of the electricity supply is renewable and a majority of this comes from large-scale HP. Pumped storage contributes with about 5 % and other renewable energy sources only make small contributions in the electricity supply (Eurostat, 2008).

HP plays a crucial role in supplying electricity in Austria. The conditions regarding precipitation and altitude are favourable for HP production and enables HP to play a prominent role in national electricity production. There are 2544 HP installations in Austria, which corresponds to an installed capacity of 12 381 MW, in the year 2008 a total of 40 677 GWh was produced (E-control, 2008). The large-scale HPP's are dominant when it comes to electricity output, the large-scale HPP's are defined as having a capacity above 10 MW (Nationaler Gewässerbewirtschaftungsplan, 2009, p. 34). Approximately 90 % of the electricity is generated at large-scale installations, while the small-scale HP contributes with about 10 % corresponding to an installed capacity of 1201 MW in 2008 (Europe's Energy Portal, 2008).

The rivers in Austria are of great value, in several ways. When it comes to the economical value, there are many industries that depend on the water. Agriculture, industrial production, HP, drinking water and waste water are the major large-scale industry that directly uses and are dependant on water. On top of these, the tourism industry plays an important role. Measures taken regarding water courses will in many cases have an impact on this type of industries and in order to take good measures and to get a good balance between utilising and protecting the water environment, it is important to analyse the water bodies from an economical point of view. This enables a cost-efficient management and well prioritised measures.

5.4.3 Future potential

As always the future potential depends on a number of factors. The maximum total potential left in Austria is estimated to 38 000 GWh/year. This is without taking economical, technical, environmental or social aspects into account. The available potential is heavily reduced if technical and economical aspects are taken into account and if heavily sensitive areas, such as national parks, are not included. When including these factors the available potential would be around 13 000 GWh/year. As a part of the EU directive on renewable energy sources (the RES-directive), Austria has the objective of increasing its renewable energy production from the present of 23% till 34% in 2020. In order to reach the objective of renewable energy and in order to reduce the emissions of green house gases leading to climate change, the Austrian RBMP concludes that a future expansion of sustainable HP is necessary in order to reach these goals. (Lebensministerium Austria, 2009)

The Austrian Water Protection Law (Wasser rechts gesetz) regulates, amongst other things, the public interest of water. HP is one such public interest but there are other interests that might be contrary to the HP development. The main conflict is caused by the public interest of having water courses with high ecological values and good environmental conditions important for recreation and tourism. In a way this sums up the problem, but compromises have to be made and the solution has to be as suitable as possible for all stakeholders. The compromise also has to lie within the objectives of the WFD and the WFD in principle allows no deterioration of ecological status. The Austrian RBMP concludes that large-scale HPP's with reservoirs that changes the character of a river from a free flowing river to a water body with more stagnant conditions will in general not be able to meet the goal of not deteriorating the water status. Run-of-the-river HPP's, when constructed in a way that environmental flow and continuity is guaranteed, are expected not to necessarily deteriorate the status of the water course. Regarding water courses with very good status, i.e. pristine water courses, the construction of even small-scale HP will lead to a deterioration of status. (ibid)

5.4.4 Impact and conflicts

There are many environmental impacts from HP installations, see Chapter 2.6, both direct and indirect ones. One severe and very direct impact is a reduced flow often leading to dry river beds. This is caused by damming of rivers and by diversion of the water to a HP installation. HP production is responsible for 576 seasonally dry riverbeds in Austria and these dry courses of the river have a significant impact on the water environment although the magnitude of the impact varies with the length of the dry river bed. (ibid)

One of the other major impacts of HP is the fragmentation of the water courses, which disconnects habitats and has negative impacts on migrating fish and other water fauna. It is not only HP is responsible for the fragmentation, protective measures for floods and torrents are a factor too. It is estimated that there are around 28 000 water structures fragmenting the water courses in Austria (ibid, p. 151). The obstacles for migrating fish have already had serious consequences for the fish population in the rivers; the long-distance migratory species of fish do no longer exist in Austria and middle-distance migratory fish is severely threatened. However, the long-distance migratory fish is blocked in the Danube already at the Iron Gate HPP in Romania (Koller-Kreimel, 2010).

Finding the right measures in order to improve the overall status of a water course is essential in order to achieve the most cost-efficient measures first. The solutions have to be sustainable and it is crucial that the backbone of the river is functioning before smaller measures upstream are taken. Focusing on smaller measures at the wrong location, will be costly and not give any benefits for the water course in total. This is why the integrated approach is necessary and why win-win situations, where HP is combined with e.g. irrigation or flood defence applications, has to be identified. (Habersack, 2002)

It is crucial to find the most cost-efficient measures to improve the river ecology. The costs for improving the ecological status are quite extensive. At the approximately 2000 small-scale HP installations (defined as below 10 MW of capacity) about 90% of the installations lack mitigation measures and are definite obstacles for migrating fish. The estimated cost in order to construct fauna passages for these would be 90 million euro. (Stigler et al. 2005)

The cost of improving the situation for large-scale HP, many of them with reservoirs of water, differs a lot and the cost is closely connected to the elevation of the dams. There are many measures that might be required in order to ensure a good environmental status or potential and it is quite difficult to generalise about the larger HPP's. To get a rough estimate of the costs related to measures aimed at improving the water environment, cost-calculations have been made for mitigation measures applied at the large-scale HPP's where such structures are missing. The estimated cost for restoring connectivity is up to 144 million euros, regarding reservoirs up to 1200 meters above sea level. The measures include fish ladders as well as measures to increase the connectivity to tributaries and water bodies close by. (ibid)

5.4.5 River basin management plan in Austria

Due to the similarity of the river basin districts there is one national RBMP of Austria, which covers all the eight river basin districts and all the aspects of the WFD. There are no separate RBMP's for the river basin districts.

The Austrian RBMP clearly points out that the purpose of the planning and management concerning water bodies is to find a good balance between water protection and the utilisation of water. The most cost-efficient measures both in protecting the water courses and in utilising the water is central in both securing healthy water bodies as well as getting good use out of the water, which in turn benefits society and public interests. The WFD has been implemented in Austria, but before the implementation there were already several water laws regulating the use and protection of water bodies. The WFD adds more dimensions and a holistic approach to the management of water, where the condition of water bodies is mapped and where the value of the water is central.

Since there is such a large number of water bodies in Austria that needs to be restored, the first RBMP is prioritising on improving the status of the water bodies of catchment areas larger than 100 km^2 with population of medium migratory fish. Measures to improve the status in these water bodies, which are mainly rivers, include restoring river continuity, ensuring environmental flow and an overall improvement of the morphology. The water quality in Austria is mostly of good status. The main existing problems are the changes in hydro-morphology. The morphological problems are caused by flood defence and the use of hydropower. (Koller-Kreimel, 2010)

6. Case studies

6.1 Overview

A single case study has been chosen in Austria, Scotland and Sweden respectively. The objective is to highlight the situation for hydropower by describing an actual case. The method of choosing the HP installation was by recommendations from stakeholders or simply that the cases seemed interesting. The cases that will be presented are; river Vojmån in Sweden, Glendoe hydro electric scheme in Scotland and Gössendorf and Karlsdorf HPP's at river Mur in Austria. The installed capacity at the plants in the case studies would be 33 MW in Sweden, 100 MW in Scotland and 37 MW (sum of two plants) in Austria.

6.2 Case1: Vojmån, Sweden

Figure 12. River Vojmån, Sweden.

Vattenfall, one of the major Swedish electricity and energy companies, had plans to exploit the river of Vojmån in the municipality of Vilhelmina in the north of Sweden for power purposes. The pre-study started in 2006 and the plan was to redirect some of the flow in river Vojmån to an existing HPP in a river nearby by a 23 km tunnel. The redirecting of the river was estimated to contribute with 150 – 170 GWh/year of electricity and the additional installed capacity would be 33 MW. The environmental impact would include a lower water flow of the river Vojmån, which in turn would impact rivers and lakes further downstream. The construction of the tunnel would also have negative impacts on the environment. (Vilhelmina kommun, 2007)

Already at the stage of a pre-study of the project, which continued in 2007, there was a very strong opposition among the local residents and some local politicians. The town was polarised between stakeholders and residents for and against the plans.

Arguments against the HP installation included:

- Lower standard of living for the residents around the river.
- Environmental concerns because of the rare and vulnerable fauna and flora in the area.
- A redirection of the river would cause decreased revenue from fishing and tourism.
- There are already several other HP installations in the municipality, 85% of the electricity produced is exported to the rest of the country. There is a view that the municipality of Vilhelmina already has contributed enough.

Arguments in favour of the HP installation included:

- Work opportunities; around 100 fulltime work opportunities over 8 years. This is quite a lot for a small rural municipality, already struggling with unemployment. (Boström, 2005)

The HP Company and the municipality came to an agreement; following the pre-study of the site where all environmental aspects as well as all other aspects would be studied, a municipal referendum would decide the future of the project. If the municipality voted against the proposal, the plan would be abandoned. If they voted in favour of the proposal, the planning would continue. Public participation and communication with the local residents was given high priority. (Andersson and Wisæus, 2008)

The municipal referendum took place in 2008 and the outcome was against the proceeding of the plans of redirecting the water of river Vojmån. The debate concerned issues like environmental conservation, fishing, renewable energy generation, job opportunities, quality of living etc. The agreement between the HP Company and the municipality to let the general public decide through a referendum is unique. The case highlights how sensitive the debate regarding new HP installations is in Sweden as well as the importance of involving local residents and stakeholder.

6.2.1 Comment on data availability

The cooperation between the HP Company, Vattenfall, and the municipality in Vilhelmina was easy to follow on a website especially set up for this case. The website contained plenty of information about the planning procedure and the views from different stakeholders.

The dialogue with residents was open, with several channels of communication. One could deal either directly with representatives from Vattenfall or the municipality or by leaving comments and opinions on the website set up for the project. Several information meetings were arranged as well.

6.3 Case 2: Glendoe Hydroelectric Scheme, Scotland

The Glendoe Hydroelectric scheme was opened in June 2009. It is owned and operated by SSE Generation Limited. With an installed capacity of 100 MW, it is the first larger HP scheme commissioned in Scotland in over 50 years. It is located close to Fort Augustus, by the Monadhliath Mountains, figure 13. The scheme consists of a storage reservoir that is being fed by a 75 km^2 catchment area, see Figure 14. The reservoir is supplied with water either directly or by underground pipes of aqueducts. From the reservoir the water is led through a tunnel to the power station, close to the outlet at Loch Ness. (Ash Design Assessment, 2010)

The Environmental statement for the proposed plan analysed alternative locations and designs as well as impacts on environment. The remote location of the installation leads to low level of impact on humans and human activities. Low level of impact was also concluded on land use terrestrial ecology and cultural heritage. The hydrology would be altered by the dam and pipelines, however, the dam could reduce the flood events that regularly occur in the downstream areas. The aquatic ecology was evaluated in the areas downstream of the HP installation, several migratory species of fish was confirmed. Still, the HP installation was expected not to have any major impacts on the fish population, one of the reasons being that many of the spawning grounds are located at different locations downstream of the installation. (Glendoe Environmental Statement, 2003)

In 2003, the project received consent and a deemed planning permission from the Scottish government. A number of organisations and departments were involved in the decision and gave their opinions on the proposed scheme:

- Scottish natural heritage (SNH); first stated that there was insufficient information for them to base their opinion on natural heritage interests. Following additional information the SNH concluded that the proposed scheme was acceptable.
- Scottish Environmental Protection Agency (SEPA); First objected the scheme because it would interfere with the objectives of the WFD, since the scheme would deteriorate water status and potentially compromise future water body restoration plans. After a number of conditions were put in place regarding water crossings, sediment management, management of foul drainage, on site pollution and waste management during the construction phase. After theses deficiencies had been addressed SEPA withdrew its objection. (Scottish executive, 2005)

Figure 13. Glendoe Hydro electric scheme, Scotland. (Source: Scottish and Southern Energy, 2010).

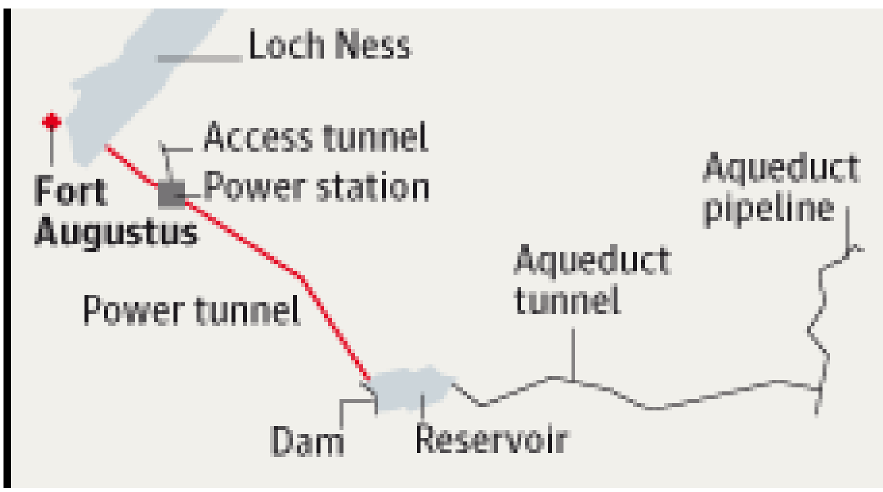

Figure 14. Schematic view on the Glendoe hydro electric scheme. (Source: Guardian, 2008)

6.3.1 Comment on data availability

Data regarding the project was not easily accessibly through the internet. Mostly brief information about the project was published. The Environmental Statement for the scheme was neither available on the internet but was received after contacting the HP Company.

6.4 Case 3: Gössendorf-Karlsdorf, Austria

The two run-of-the-river HPP's; Gössendorf and Karlsdorf were simultaneously commissioned at the river Mur. The construction started in year 2009 and the plants are expected to be fully functional by 2011. The plants are both large scale and will have installed capacities of 18.75 and 18.51 MW respectively. (Verbund AG, 2010)

The two plants are expected to deteriorate the status of the water body, but still got a consent (referring to Art. 4 (7) of the WFD). The reason for the consent was the overriding public interest – the two plants will play an important role both when it comes to the local electricity supply as well as being a valuable contributor to the national renewable energy target and there were no better environmental options. (Koller-Kreimel, 2010)

Österreichische Elektrizitätswirtschafts-AG (more commonly known as the Verbund) is commissioning the plants and in their own description of the new constructions, they put a clear emphasis on environmental factors. According to the Verbund the plants have been carefully planned in order to minimalise the impacts on the surrounding environment and the environmental aspects have been considered since the beginning of the planning process. The construction of the HPP's will also improve the flood protection of the area. (Verbund, 2010)

In an evaluation of the HPP's impacts of the surrounding environment as well as the measures to mitigate these were investigated. A selection of some of the mitigation measure specifically constructed to enhance the flora and fauna for each HPP were:

- Two constructions in order to enhance fish migration. (Not specified which type).
- Facilitation of new riparian forest areas
- Reconstruction of the riparian zones that are impacted by the HP construction.
- Facilities for amphibians and reptiles.
- Insect friendly use of lighting during the construction phase.
- Leaving dead wood along the river banks.
- Creation of islands and shallow water areas in the dammed part of the construction in order to create different types of habitats.
- Protection of the amphibians and reptiles during the construction phase.
- Monitoring and measures to improve the surrounding forests and wetlands.
- Connectivity in the riverine system as well as between the main river course and smaller tributaries.
- Redirection of water to parallel wetland and riparian forests at high water levels. (Energie Steiermark, 2006)

The measures seem ambitious, however no quantitative descriptions of the measures were given in the evaluation report. Therefore, it is difficult to estimate to what extent the negative impacts will be mitigated. Figure 15 displays an overview of the developed river course, with the two HP installations as well as measures taken in and around the river. (ibid)

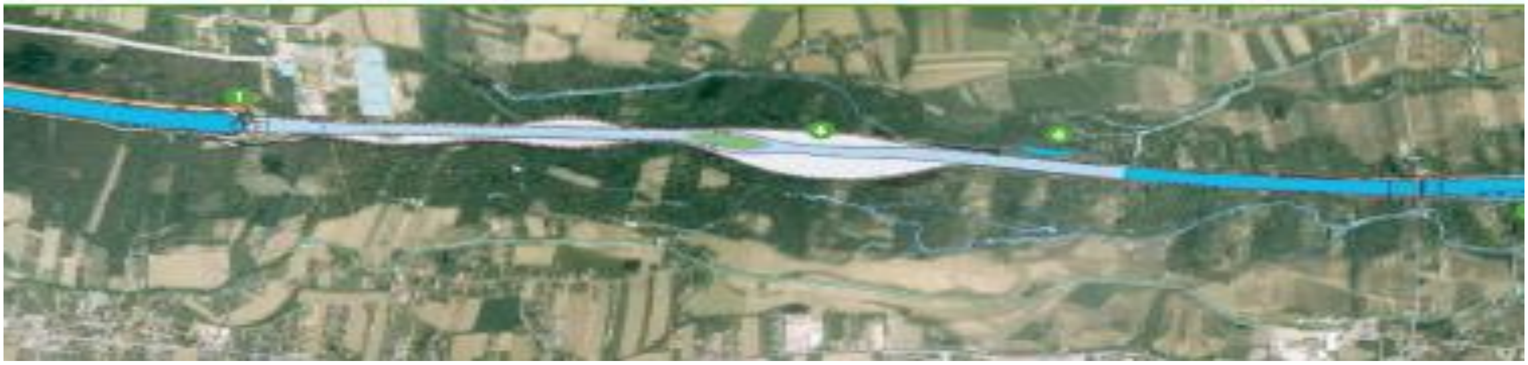

Figure 15. View of the river Mur, with the proposed HP schemes and measures. (Energie Steiermark, 2009)

There are several species of fish in the river Mur and the connecting tributaries. 21 species of fish from 7 different fish families have been identified in the riverine system. Negative consequences for the fish are expected during the construction phase, mainly because of temporarily blocked stretches of the river, different flow management and by pollution as a result of the construction work. Once the construction phase is over and the HPP's are operating normally many of the negative impacts are expected to disappear. (Energie Steiermark, 2006)

The river Mur is far from a pristine river, it is already exploited by HP to a great extent. As displayed in figure 16, several run-of-the-river plants are already in place, many of which lack fish migration measures.

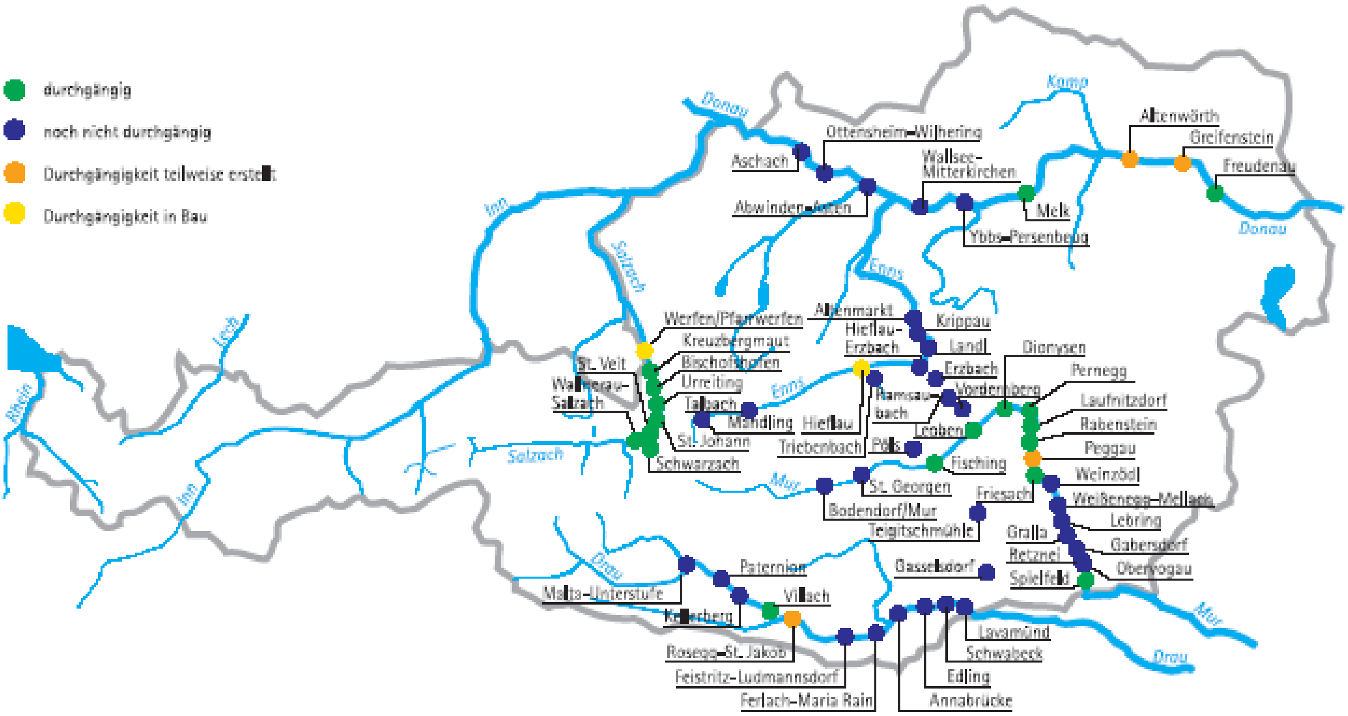

Figure 16. Schematic view of the run-of-the-river HPP's in Austria. The colour coding represents; green – migration measures for fish in place, blue – no measures for fish, orange – migration measures party in place, yellow – migration measure are being constructed. (source: Verbund, 2008)

6.4.1 Comment on data availability

Data availability regarding the Gössendorf and Karlsdorf HPP's were in general adequate and sufficient. The data was easy to find on the companies as well as authorities websites, although mainly in German. Documents for downloading were detailed and gave plenty of information about the project.

7. Discussion

This chapter aims at answering and discussing the objectives set up at the start of this thesis. Based on the material presented in the previous chapters a discussion of the objectives follows:

- **What are the main potential conflicts between HP and the WFD?**

The main conflict goes beyond HP and the WFD – it is ultimately a question about whether to use water to produce renewable energy or to conserve precious and vulnerable water environments. However, production of renewable energy, while also minimising the serious environmental impacts by HP, can to a certain extent be possible through adapting mitigation measures and by making sure that only suitable locations are developed. Investment in mitigation measures and careful planning would decrease the negative impacts of HP.

Possible conflicts arise with the hydropower industry when the WFD is implemented. They fear production losses and smaller revenues due to more stringent regulation. Providing mitigation measures, e.g. fish ways, and preventing hydro peaking are examples of activities that will increase the costs for the HP companies. Also, there will be increased bureaucracy due to the requirements of legally justifying the sustainability and the compliance with the WFD when planning new HP installations. Many of the companies that operate HP installations or organisations that represent the industry (e.g. Kleinwasserkraft Österreich, Vattenfall and ESHA, see Chapter 4 on Stakeholders) point out that they are following the development of the WFD closely and that they are committed to protecting the environment and mitigate environmental impacts at their HPP's.

A potential conflict also lies in the goals of increasing the production of renewable energy sources. The overall aim in the EU is set through the RES-directive, i.e. to achieve 20 % renewable energy by 2020. ESHA points out that the RES-directive and the WFD are contradicting each other. But if the WFD really would have such an impact that it threatens the goals of the RES-directive has not been proofed yet. However, it seems unlikely that this alone would threaten the goals of renewable energy since HP is just one of several renewable energy sources in the energy mix. Many of the other renewable energy sources are expanding and HP has to be seen in the context of these and its role in finding a suitable energy mix. From the countries analysed in this study, however, both Austria and Scotland have commissioned and planned new HP installations since the implementation of the WFD. Indicating that the HP industry is still expanding.

The case study from Austria, Gössendorf-Karlsdorf, was planned and permitted after the implementation of the WFD. This is one example where the Austrian EPA made the decision of giving consent on the grounds of the benefit the HPP's would have on society with their input of renewable electricity. In the planning of the plants, several environmental mitigation measures were included although it is unclear to what extent since no quantified information was available (Energie Steiermark, 2006). When the consent was given it was also pointed out that these plants were the best available environmental option when it came to increasing the renewable energy sources in Austria. This would essentially mean, provided that the WFD was correctly implemented, that there is not such a major conflict between developing HP and applying the WFD. However, the conflict between environmental conservation and exploring a natural resource still exists. Applying the WFD provides tools to handle this conflict.

It is important to emphasise that the conflicts that arises when exploiting natural resources are not unique to hydropower. It is a conflict that arises in all cases of using natural resources and the crucial question is; what do we want to use our natural resources for? In a comparison with another renewable electricity source; wind power, similar conflicts arises. With wind power the discussion is somewhat similar to that of HP. Wind power is being criticised for taking up land, creating noise and ruining the landscape.

The core of the conflict regarding HP has been present since the large-scale development of HP started taking place and the environmental concerns started to intensify a few decades ago. There have, in other words, been conflicts long before the WFD was implemented. But the WFD offers tools to deal with the water management in a holistic and integrated approach.

One specific conflict concerns the residual or environmental flow of hydropower with storage reservoirs or at pumped hydropower plants. These HP installations create great fluctuations of water levels and at times causes dry river beds downstream of the dam. As previously explained in the thesis (Chapter 2.6), hydro peaking has major negative impacts on the river environment and the species associated with such environments. Also, fluctuations in water levels and fragmentation of the watercourse are likely to cause serious degradation of the ecological status and thus interfere with the objectives of the WFD. The purpose of damming the water is to be able to release it and generate electricity at a certain point in time. Therefore there is a clear conflict between the timing of the electricity generation and providing enough residual flow to maintain the ecological functions of the river.

In order to maximise the revenue of the energy production at a HPP, the water from the dam is released through the turbines at times of high demand. In an unregulated electricity market, the price is decided by supply and demand, thus high demand will drive up the price. Therefore it is economically sound to collect water in the reservoirs during low demand and release the water to create electricity when the demand, and in turn the price, is high. This type of flow regime, with substantial and fast fluctuations, is far from the natural fluctuations that an unregulated river would experience. Thus the economical and environmental aspects contradict each other. The WFD provide regulation to protect the environment against economical interests and to mitigate the environmental impacts, such as hydro peaking, of HP installations.

Another potential conflict that arises at the HP sites would be the costs of the measures required to mitigate the environmental impacts in order not to deteriorate the status of the water course. An example would be the different fauna passages that can be employed at HPP’s in order to improve the up- and down-stream migration of flora and fauna. The case of Austria, where 90 million Euros would be required to provide measures at all the SHP installations in the country that lack such measures, illustrates the costs of environmental protection and restoration measures (Stigler et al. 2005). The investment of the mitigation measures have to be paid, either by the operating companies or by public funding. If the companies pay for the measures, the cost would normally be reflected on the bill of the electricity users. If the mitigation measures are provided by public funding, the citizens will pay in form of taxes etc.

- **How do the potential conflicts differ between the Austria, Scotland and Sweden?**

Among the three regions discussed in the thesis, Austria, Scotland and Sweden, Austria and Sweden both have a highly developed HP industry and a large share of the electricity comes from HP. In Scotland on the other hand, there are fewer suitable locations for HP. HP plays a less important role and contributes with about 10 % of the electricity production (Scottish government, 2010-04-13).

The case study from Sweden, river Vojmån, is in a way unique – but also in many ways typical for the view on HP in Sweden. The fact that the residents of the municipality had the final decision regarding a HP development trough a referendum is very rare. Although the public participation did not benefit Vattenfall this time, it still shows how important it is for the companies wishing to develop HP to have a dialogue with the local residents and stakeholders. In the long run the large public participation is likely to benefit Vattenfall. The WFD emphasises the role of public participation and local decision-making, which means that any company wishing to construct HP has to involve local residents and persuade them of the benefits of HP. The proposed scheme at river Vojmån made it clear that HP installations face large public disapproval in that part of Sweden and that the subject evokes rather strong feelings.

The problem with the *not in my back yard* mentality is also obvious. Most people would like to enjoy the electrical facilities of modern life – but very few would like to have a HPP in their neighbourhood. The regional aspects also play a role in the Swedish case study – the majority of the HPP's are located in the sparsely populated north, which in turn supplies the more densely populated south with electricity. The communities in the north do, to a certain extent, feel that they have contributed enough with the HPP's that are already in place.

The sometimes heated debate regarding hydropower in Sweden has contributed to the fact that no political party pushes the idea of adding new HP capacity. There is a parliamentary decision to increase the production with an extra 2 TWh/year (to the existing 64 TWh/year), but there seems to be little enthusiasm backing the decision.

In Scotland the HP has not had such a prominent role as in the case of Sweden and Austria. The feasible locations for large-scale HP are much fewer as well. The potential to develop SHP has lately been seen as an environmentally friendly way to produce renewable electricity and a way for Scotland and the UK to fulfil their national obligations regarding renewable energy. Since the HP has not been developed to such an extent in Scotland compared to Sweden and Austria, the opposition against HP is not as strong although single schemes do generate significant opposition. The planning and commissioning of new SHP shows that Scotland is largely positive when it comes to new developments.

Austria is the country with the highest proportion of electricity produced from HP in this study. The recently launched Masterplan regarding hydropower indicates the political will to continue the development of HP. The ongoing planning and construction of new plants also proves that the country is rather positive to HP development. However, this could be changed when the WFD is further implemented and it has to be evaluated if water bodies with intense HP managed to achieve good ecological status by 2015.

The WFD requires the HP companies to carefully develop the water courses and to facilitate appropriate mitigation measures. This is obvious from the case study of Gössendorf and Karlsdorf at the river Mur. There is plenty of material available from the HP Company regarding the design and mitigation measures at the installations (Energie Steiermark, 2006). They emphasise that the new installations will be environmentally friendly and they provide information regarding impacts and mitigation measures. What is striking though is that most of the mitigation measures are not quantitatively presented. It is difficult to know to what extent the company actually mitigate the negative impacts of the installations.

Since the public participation is important and that local residents and stakeholders can have opinions on decisions taken nearby, it is crucial to persuade residents and local stakeholder of the benefits of HP. It is a legal obligation under the WFD to include the results of the public participation in the decision making. As mentioned above, the Swedish case study clearly proves this point. A positive response from the local residents can be crucial in the planning of future HP installations. This is why it is important for companies to have good relations with the public and to prove that they can develop HP schemes with low environmental impacts.

Regarding the Austrian case study with the large scale run-of-the-river HP, it is interesting to note that the application at first was rejected. The reason for this rejection was that the installations would not be in line with the WFD’s demand of no deterioration of water status. Since this rejection was later withdrawn on the grounds that the HP installations would greatly benefit the electricity supply in the area makes it evident that the social and economical aspects are considered important – in this case more important than ensuring no deterioration of status. The installations are, however, planned with several mitigation measures in order to protect the river and the water environment.

In the study of the three regions, Sweden stands out as the country which is most negative to development of HP. The reasons for this include the fact that many of the feasible sites have already been developed and that many rivers have been altered as a result of HP development. Local residents, as well as environmental organisations, oppose planned schemes and seem to have a rather strong influence on decisions. There is no new HPP’s being commissioned at present and no plan of large-scale HP development. The possible increased capacity would come from the upgrading of existing schemes.

In Austria, with a highly developed HP sector, the situation for HP seems rather positive with new schemes being proposed and planned. Similarly, in Scotland, in particular the SHP sector is expanding and several installations are planned.

- **How would it be possible to maintain and develop HP without interfering with the WFD goal of good ecological status/potential? Or is it possible at all?**

Since every HP development has to be considered from its own unique aspect and situation, it is difficult to give a general answer to the future of HP development. An example of this would be the EPA in Sweden, that clearly emphasise that they take every installation into consideration before considering e.g. if the water body is heavily modified or not. This, however, only applies to existing plants.

Still, from the three countries studied in this thesis, there are some patterns to how the WFD is being implemented and how that influences the development of existing and planned HPP's. And since HPP's have been commenced within the EU after the implementation of the WFD – this has to be interpreted as that new constructions of HPP's are possible under certain circumstances and conditions. The large scale run-of-the-river HPP's Gössendorf-Karlsdorf in Austria were commenced in 2009, after all the aspects of the directive had been considered. Careful planning, where aspects of flora, fauna and environmental impacts were taken into consideration from the start was probably one reason for the approval. Mitigation measures were considered throughout the planning, construction and operating phase of the plants.

From the experience in Sweden, where no large scale installation has been commissioned recently and where most likely none will be constructed in the near future either – the importance of involving the public and persuading them as to why HP is beneficial becomes crucial.

Run-of-the-river plants are usually considered as more environmentally friendly than pumped hydro or hydro with a storage reservoir. This is largely true, the fact that a run-of-the-river plant does not have any dam means that the environmental impacts connected to dams are avoided. But what type of HP to construct is also a question of the topography and location of the plant. Pumped hydro or hydropower with at storage reservoir, simply requires certain elevation differences, while run-of-the-river plants normally are situated in low land areas. The solution is not as simple as only developing run-of-the-river plants. This type of installation lacks the ability to store electricity. The ability to store electricity is crucial in order to meet short and long term shifts in demand and to compensate for the lower continuity and reliability of wind and photovoltaic in an integrated strategy for renewable electricity sources. The negative impacts of e.g. river fragmentation and hydro peaking are mainly avoided in a run-of-the-river installation. The main negative impact of run-of-the-river plants is the one on migratory fish, however this is possible to mitigate with correct measures. With less impact on the water environment, it seems likely that run-of-the-river plants in suitable locations and with suitable mitigation measures can be developed and still be in line with the objectives of the WFD.

The ways in which it is possible to develop HP without interfering with the objectives of the WFD, lies in the hands of the regulatory authority. HP can be constructed if no deterioration of status occurs. It is unlikely that HP installations will cause no deterioration, but social and economical aspects are taken into consideration in the decision making. The installations that receive a permit are required to take substantial environmental measures.

- **How does the conflict differ between SHP and large scale HP?**

There is no official definition distinguishing clearly between small-scale and large-scale HP. The most widely used definition is that small scale HP has a capacity of 10 MW or below. SHP is nearly always run-of-the-river installations, while large-scale HP can be either run-of-the-river, hydropower with storage reservoir or pumped hydropower.

Many environmental organisations suggest SHP as a good renewable energy source. The arguments in favour of SHP are that SHP has a much smaller impact on the environment compared to large scale installations as well as the benefits of producing renewable energy. E.g. Greenpeace are against large scale HP, arguing that the environmental impacts are vast, with great habitat losses, loss of species and other negative impacts as a result (Greenpeace, 2005).

Generally it is true that SHP has smaller environmental impacts than large scale ones, since the environmental impacts usually are greater the larger the installation. But to state that small-scale, run-of-the-river plants create environmentally friendly electricity, is quite an oversimplification. The environmental impacts of a HPP must be measured against the electricity output to be able to somehow measure or judge if the HP is environmentally friendly or not. If a large number of small-scale HPP's are required in order to achieve the same electricity output as one large-scale HPP, it might be that the sum of the environmental damage from the small-scale HPP's are greater than from the one large-scale installation in relation to the same electricity output. If this is the case the small-scale installations are not necessarily very environmentally friendly. However, it is difficult to measure and compare environmental impacts between different HPP's and no common indicator or method of comparison is developed yet.

If the electricity output is measured against the environmental deterioration it is possible to evaluate how well the natural resources are being utilised. In the case of HP development - rivers, streams and any running water are limited resources that have to be managed and utilised in the best possible way. The goal is to optimise the energy output while minimising the environmental impact.

The differences in environmental impacts of different types of HP installations are important to take into consideration – e.g. the creation of a dam will involve flooded areas as well as an unnatural flow regime and hydro peaking. These impacts do not exist or are at least considerably smaller at SHP run-of-the-river installations. However, the problem of fish migration and fragmentation of water courses applies to all different types HP installations. But, other factors than the local environmental impacts have to be considered when comparing the benefits of HP versus the negative environmental impacts of different HP installations. One such factor is the different applications of the run-of-the-river and the storage reservoir and pumped hydro. The small scale installations (normally run-of-the-river installations) lack the ability to store water and thus to store energy. This is a huge benefit of the HP with a storage reservoir or the pumped hydro. Since Europe is aiming at greatly increase the renewable energy and electricity production, the regulating role of HP becomes increasingly important. In this perspective large-scale HP has a great advantage over SHP.

- **What role could small-scale hydropower play in reaching the European goals of renewable energy?**

The goal of renewable energy for Europe is to achieve 20% renewable energy sources by 2020. It is difficult to estimate the future demand and supply of energy. But the future role of SHP in the European electricity supply depends to a great extent on the development of other renewable energy sources as well as if demand can be cut through e.g. more efficient use of electricity. Increasing use of other renewable energy sources decreases the quantitative contribution SHP can make. Political decisions are pushing the development of renewable energy sources in many countries including SHP, and the total renewable energy production is increasing.

The installed SHP capacity of EU is 12 932 MW (Europe's Energy Portal, 2008). And since SHP produces 7 % of the total HP electricity in Europe, it is still way behind the importance of LHP. Compared to the total gross electricity generation of the EU-15[5], 2 832 400 GWh (Eurostat, 2004) the SHP contribution of 40 000 GWh in the EU-15 (ESHA, 2004) is about 1.5 %. Even if the potential SHP capacity was developed, which with economical and environmental constraints would add 7 800 MW, the SHP would still only make up 10 % of the total HP electricity production. In the energy mix of a region SHP is only one of several renewable energy sources, of which many are predicted to increase.

SHP lacks the important ability to store energy, which is possible in HP with storage reservoirs and pumped hydro. This is a characteristic that makes is extremely important with LHP with storage ability in the electricity system since no other renewable energy source can store energy in such large scales an can compensate for the shortcomings in continuity of solar and wind. The fact that SHP can not store energy does not give SHP any extra advantage in this sense compared to LHP.

On the other hand SHP installations cause much less environmental impact per installation. As discussed earlier, this does not necessarily mean that SHP produces environmentally friendly electricity – each installation has a lower environmental impact, but also produces much less electricity than a LHP installation.

SHP does have other advantages than only producing electricity. In Scotland it is emphasised that SHP creates job opportunities, especially in rural areas. Scotland also lacks the right conditions for LHP development to such a great extent as e.g. the countries in the alpine region. Therefore, SHP development can probably be relatively more attractive in Scotland.

[5] EU-15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.

With the correct mitigation measures and provided the environmental impacts of each scheme are kept relatively small SHP could play its role in producing electricity locally and where other renewable energy sources are not suitable. What role the SHP will play in reaching the European goals of renewable energy is, however, difficult to predict, since both the future electricity consumption as well as the development of other renewable energy sources has to be taken into account. But since SHP contributes only 7 % of the total European HP production, it is unlikely that SHP will play a major role in the achievement of the renewable energy source goals.

8. Conclusions

The main conclusions that can be drawn from this thesis are:

- The main conflicts regarding hydropower that arise with the implementation of the WFD are economical, with the industry, and possibly regarding obtaining the goals of renewable energy.
    - The main concern of the HP industry is expected production losses as a result of more stringent regulation.
    - The conflict of residual flow and mitigation measures illustrates the dilemma between maximising the generation of electricity and maintaining the ecological functions of the river environment.
    - More stringent regulation of HPP's results in less renewable electricity. If this will actually have an impact on achieving the goals of renewable energy is uncertain.
- The future of the HP development is rather different in Austria, Scotland and Sweden.
    - Austria is largely positive towards HP. There is a political will and HPP's are at the moment being permitted and constructed. However, this could have doubtful effects of the implementation of the WFD. The WFD is still a young directive and to study the effects of the implementation over time is necessary in order to evaluate the success of the directive.
    - Scotland is largely positive to constructing SHP as well as LHP, although the main potential is within SHP.
    - In Sweden, strong public opposition is one of the reasons why HP is not being developed further. There are no larger new plants commissioned. HP gets rather low priority and other renewable energy sources are much more prominent.

- When sufficient mitigation measures are in place, it is possible to carefully develop HP in Europe without conflicting with the objectives of the WFD.
    - This requires careful planning of suitable location as well as identification of environmental impacts and how to mitigate these.
    - Aspects other than environmental and economical ones appear to be important in the success of a new installation. It can be dependent on the general view of local residents and organisations. This is also in line with the WFD's ideas of public participation and taking the decisions close to the actual location.
    - HPP's are presently being planned and commissioned within the EU. Providing that the WFD has been correctly implemented, the conclusion would be that a further development of HP can be in line with the goals of the WFD.

- SHP and LHP has to be compared differently
    - Firstly, small-scale run-of-the-river HPP's have different applications compared to HP with storage reservoir or pumped hydro. The later two have the important ability to store energy which run-of-the-river SHP lacks.
    - Secondly, the magnitude of the environmental impact has to be measured against the benefit of the HPP's, i.e. the electricity output. Rather than just estimating the environmental impact at a single scheme without putting this in relation to the electricity output.
    - There is no easy method of comparing environmental impacts, which makes it difficult to compare different installations and the environmental impact per MW (or similar unit)
- It is likely that SHP will not play a prominent role in reaching the European goal of renewable energy sources.
    - Achieving the goals depends on the whole suite of renewable energy sources as well as changes in electricity demand.
    - SHP can contribute with rural job opportunities and might play a more important role in countries with no possibility of LHP development.

9. Suggestions for further studies

Since the WFD has been implemented relatively recently, the first management cycle finishes in 2015, further studies are required to follow up the results of the WFD. The further studies could include to what extent the WFD has protected and improved the ecological status and potential in the water bodies in Europe. Also, studies concerning the effects on the HP industry are suggested.
This thesis covers three regions in the EU. The rest of the member states need to be investigated to give a clearer picture regarding the WFD implementation and the situation for HP.

SHP is interesting in the way that there is a rather large untapped potential left in Europe and that each single installation might be promoted having a low environmental impacts if the correct mitigation measures are taken. The actual role of SHP in order to reach the EU's targets of renewable energy would be an interesting aspect to investigate, verifying the findings here with examples from other European regions.

At the moment there is no suitable method in measuring the environmental impacts of a HP installation. A standardised method of estimating and measuring environmental impacts would be extremely valuable in order to compare different installations as well as measuring the electricity output against environmental impacts.

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11. Appendix

E-mail correspondence with Lisa Lundstedt, Vattenmyndigheten i Bottenvikens vattendistrikt, Sweden:

Hur är det möjligt att behålla, uppgradera och/eller bygga ut vattenkraften utan att kompromissa om målen om god ekologisk status eller potential?
Genom en effektivisering av befintliga kraftverk. Sedan bör man ha en helhetsbild av hela det vattendrag som är utbyggt och sätta in åtgärder där de gör bäst nytta genom exempelvis anläggning av vandringsvägar, ökad minimitappning samt andra biotopförbättrande åtgärder. Dessutom behöver vi skärpta krav på egenkontroll för kraftverk o dammar som idag står utan den recipientkontroll som miljöfarliga verksamheter måste bedriva.

Vilken utveckling tror ni skulle vara mest gynnsam för Sverige; främst småskalig vattenkraft eller främst storskalig vattenkraft?
En effektivisering av befintliga större vattenkraftverk skulle kunna leda till att mindre vattenkraftverk kan tas bort.

Vilken roll kommer vattenkraften spela i Sveriges framtida energiförsörjning?
Vattenkraften kommer förmodligen få en fortsatt stor roll då vi ska gå över från fossila bränslen och ev. minskning av kärnkraft.

Vad är vattendirektivets viktigaste uppgift?
Den viktigaste uppgiften är att arbeta för och samverka så att olika instanser i landet arbetar så att vi når god status i våra yt- och grundvatten.

Vad är det mest akuta problemet som behöver åtgärdas i svenska sjöar och vattendrag?
För norra delen av Sverige är det största miljöproblemet Fysiska förändringar som en följd av vattenkraftsutvinning, flottledsrensning samt vandringshinder i form av ex fellagda vägtrummor. För södra Sverige är det mycket fokus på övergödning men även här är det mycket fysiska förändringar som försämrat situationen för vattenlevande växter och djur. Men det mest akuta miljöproblemet i hela landet kan nog vara miljögifter.

Telephone interview with Arvid Sundelin, Vattenfall, 19/3 2010:

How do you think that the implementation of the WFD could affect the expansion of HP capacity or the revenue from HP where your company is operating?
There is definitely a risk and a worry that the WFD will negatively influence the revenue from HP. Possibility of stricter regulation when it comes to minimum environmental flow.

How are you going to integrate the WFD requirements into your future management?
There is a strategy within Vattenfall on how to deal with the River basin management plans.

What is the most important question for your company regarding the implementation of the WFD?
Miljökvalitetsnormer, what aspects that will be regulated by law, like e.g. flow and water levels. At the moment is it only legally binding with good ecological status or potentiall, not exactly given what flow etc. (at least one of the most important one.)

Telephone interview with Peter Sörngård, Naturvårdsverket (EPA), Sweden, 2010-03-18:

How is it possible to upgrade existing hydro power plants and to construct new ones without interfering with good ecological status/potential?
This has to be decided for each separate case. The laws are very clear, but in reality there is a certain amount of uncertainty of how to implement the laws. In each case the costs of a certain measure has to be compared to the benefits and private interests has to be compared to public interests. Measures that are within reasonable costs has to be taken.

Your opinion on HMWB's and HP?
In either case, there will be measures to take. I.e. companies cannot avoid taking certain measures depending on the classification. The definition of a water has to be made in each single case, a water with HP is **not necessary** highly modified.

What is the most urgent issue for the WFD to address in Sweden?
Depends on where in Sweden. Main problems are: eutrophication involving agriculture, sewage, dense population. It involves many components and large economic values. Acidification, this has improved a lot and many measures have been taken, but is still a large problem in many parts of Sweden.

The role of NVV:
NVV is the link between VM and EU, has a prescribing role, guiding role and role as Sweden's representative in the EU. The implementation of the WFD in Sweden has to be coordinated with the other member states to get a similar implementation.
The role of VM:
5 discricts, 1 countybord is responsible for the WFD and is cooperating with the other county boards in the district. Responsible for the whole process from collecting data, organise an administrative plan and measures. VM reports to NVV.

E-mail correspondence with Peter Pollard, Scottish Environmental Protection Agency:

How is it possible to upgrade existing hydro power plants and to construct new ones without interfering with good ecological status/potential?
Upgrading existing power plants can sometimes be undertaken in a way that delivers improvements to the water environment. For example, the upgrade might allow the incorporation of facilities for providing improved river flows downstream of the dam or intake structure; the use of more fish-friendly turbines that cause lower mortality to downstream migrants; etc.

It is SEPA's experience that a large proportion of the new schemes do pose a significant risk to the ecological status of the water environment.
However, if located in the right place and incorporating the appropriate mitigation measures, it is possible to construct new schemes that do not have adverse ecological impacts or whose impacts are sufficiently localised that they do not affect the status of a water body. SEPA is currently consulting on guidance to help developers identify sites and scheme designs that will not cause deterioration [http://www.sepa.org.uk/about_us/consultations.aspx].

What is in your opinion the most urgent issue for the WFD to deal with?
In respect of hydropower, I think the WFD provides an appropriate framework for taking a balanced approach to managing the impacts on the water environment of new and existing hydropower schemes.

The main issues for implementation are:

- improving understanding of ecological impacts (including cumulative impacts and of practicable and effective mitigation;
- sharing experience with other countries on the right balance between renewable energy development and achieving WFD's objectives for the water environment

Would you rather see a development of small-scale or large-scale hydro power plants?
Small-scale and large-scale mean different things in different parts of Europe. Most of the new schemes that have been authorised by SEPA in the last 4 years have an installed capacity of less than 2 megawatts. All but one of the schemes is less than 5 megawatts. Recent changes to the system of feed-in tariffs have encouraged a growing interest in schemes of less than 100 kilowatts.

The UK does not have the combination of high mountains and wet climate that has allowed countries like Norway to produce a large proportion of their electricity from hydropower. Within the UK, Scotland has the most potential for hydropower – but this potential is still very small compared with Norway, Austria, France, etc and concentrated in schemes of up to a few megawatts. An industry estimate in 2008 suggested that there is a further 657 megawatts of financially viable capacity in Scotland [http://www.scotland.gov.uk/Resource/Doc/917/0064958.pdf]. This estimate was revised upwards to 1024 megawatts in 2010 [http://www.scotland.gov.uk/News/Releases/2010/01/21113034]. The revised estimate included schemes of less than 100 kilowatts. The existing installed capacity in Scotland is less than 1,500 megawatts. Industry experts have suggested that there is little potential for large new schemes (e.g. 10s of megawatts).

SEPA's job is to strike the right balance between renewable energy development and achieving Scotland's objectives for the water environment. This is a particular challenge when dealing with applications for very small hydropower schemes. Such schemes make only a small contribution to renewable energy generation. They are often located on smaller waters than larger schemes. This means that the proportion of river flow they take is often equivalent to that of larger schemes. The challenge is therefore managing the risk of cumulative impacts from large numbers of very small schemes. The challenge has been recognized by Scottish Ministers. A policy framework designed to ensure that the cumulative impact of small schemes is appropriately managed has been developed [http://www.scotland.gov.uk/Topics/Environment/Water/WFD/DutiesofMinisters/IAStatement/].

What role is hydro power playing when it comes to achieve the national targets of renewable energy?

The Scottish Government has set targets for renewable energy generation in Scotland [http://www.scotland.gov.uk/Topics/Statistics/Browse/Business/TrenRenEnergy]. Targets have not been set for individual renewable technologies.

In 2008, hydropower schemes in Scotland contributed around 4700 gigawatt hours of renewable energy from an installed capacity of about 1445 megawatts. This represented about 11.5 % of gross electricity consumption. The installed capacity for wind and wave in 2008 was 1708 megawatts with an output of 3330 gigawatt hours (8.1 % of gross consumption). According to industry figures, the installed capacity for hydropower in April 2010 was 1487 megawatts and the installed capacity for wind and wave was 2108 megawatts – wave accounting for less than 1 megawatt).

E-mail correspondence with Veronika Koller-Kreimel, Lebensministerium, Austria.

How is it possible to upgrade existing hydro power plants and to construct new ones without interfering with good ecological status/potential?

Good ecological status is defined in the Ordinance on Ecological Quality objectives (http://wisa.lebensministerium.at/article/archive/29384) : Upgrading or construction new hydropower plants can be easily done in case that the quality objectives for good status set out in the Ordinance are met.

In case that an ecological minimum flow is guaranteed, continuity is maintained via a fish migration aid an that there is only a short backwater area/impoundment usually the new construction will not mean a deterioration of good status.

In case of high status any hydropower use means a deterioration.

Even if there is a deterioration the new construction might be acceptable in case that the prerequisites of Art. 4 (7) WFD are met.

Would you rather see a development of small-scale or large-scale hydro power plants?

Both small-scale and large scale hydropower will be developed in Austria in the future.

What role is hydro power playing when it comes to achieve the national targets of renewable energy?

Hydropower will play an important role. In the Energy strategy which was published by the Minister for Economics and the Minister for Environment in March 2010 you will find a calculation of additional 3500 GWh hydropower generation(see www.energiestrategie.at)

* What is the main obstacle to overcome and what is the most urgent issue for the WFD to deal with in order to achieve good status for the water bodies in Austria?

The water quality in Austria is mostly in good status, we have invested a lot of money in waste water treatment. The main existing problems are the changes in hydromorphology in Austrian rivers due to flood defence (disruption of continuity, straightening of rivers, bank and soil fixation, ...) and hydropower use (no ecological minimum flow, disruption of river continuity, change of a flowing river character to a stagnant/lake character due to impoundments, flow fluctuations due peak load production, ...). As there are so many water bodies whose status has to be improved in the river basin management plan we made a prioritisation of water bodies (mainly rivers > 100 km2 catchment area which are habitats of medium migratory fish species) and where measures have to be set till 2015 concentrating on restoring river continuity, including a two-step-approach for restoring ecological minimum flow restoration and to start improving the morphology of the rivers in the priority rivers (river basin management plan can be down loaded (http://wisa.lebensministerium.at/article/archive/13164).

Karlsdorf -Gössendorf got the consent, because the amount of energy which will be produced by the two power plants plays an important role for the electricity supply in the region and for Austria. That was pointed out in the consent given by the first authorization level.

Austria has part in 3 river basins: "Rhine" (3% of Austrian territory), "Elbe" (> 1 % of territory) and the largest one "Danube" (96% of Austrian territory, which is subdivides into 5 sub basins

(Danube upstream Jochenstein, Danube downstream Jochenstein, Mur, Drau, Leitha -Raab-Rabnitz). Alltogether there are called the 8 Austrian "Planungsräume". As the situation in these 8 Planungsraume (river basin districts) do not differ from each other and therefore do not need a diversification of measures, we did not publish separate RBM-Plans for the 3 river basins or 8 river basins districts, but only one National river basin management plan, which includes the information for all rivers in Austria.

Telephone interview with Martina Pretchtl from Kleinwasserkraft Österreichs, Austria, 2010-04-15:

There will be several consequences of the WFD for the existing SHP in Austria. The plants will have to adapt to present regulations in order to be in line with the objectives of the WFD. When the SHP are being adapted in order to cause less environmental impact, with the installation of fish ladders etc., there will be large economic impacts on the SHP. There will be losses in revenue due to more stringent regulation on residual flow.

The Kleinwasserkraft association emphasises that they support the WFD and the necessary implementation of measures. They want to ensure that the HP is being run in a way that the environmental impacts are kept as small as possible. In the end it is a delicate balance between conservation of water environments and the generation of renewable electricity.

Involved in two projects with the purpose of support SHP operators to adapt and to improve the measures that has to be taken according to the WFD. The purpose is also to help operators to compensate for losses due to measures taken by technical improvements and increasing efficiency. Some measures are also supported by governmental subsidies.

The future development of HP will have higher investment costs due to extra measures that has to be taken. On the other hand, regulation of HP is not new in Austria, there has been a water law long before the implementation of the WFD. The WFD could though influence the number of feasible sites for HP because of the objective of no deterioration of status.

The future potential of SHP is estimated to 1,5 TWh/year until 2020 due to new installations and 0,7 TWh/ year until 2020 due to upgrading of old installations.

12. Article

The Water Framework Directive – when balancing between interests, where does Hydropower stand?

Global versus local environmental concerns

How do we manage our valuable water environments while at the same time sustain our need for renewable energy in times of diminishing fossil energy sources and global warming? Many of the water bodies in the European countries are in bad ecological conditions, the main reason being the major anthropological impacts from the past centuries. Hydropower is, however, the major renewable energy source in Europe, contributing with about 70% of the renewable electricity production. With clean, relatively cheep energy and no greenhouse gas emissions it is, at present, way ahead of any other renewable energy source. The local environmental impacts are, however, severe and the number of pristine waters in many places in Europe are few. Interestingly lobby groups either for or against hydropower plants both argue that they want to protect the environment.

The WFD – a sustainable way forward

Several other human activities besides the hydropower industry have severely deteriorated the water courses in Europe over the decades. Since watercourses do not follow any political or administrative borders, it is crucial to have inter-border cooperation and management of the water bodies. In 2000 The European Union introduced the Water Framework Directive. The framework has an integrated view of water – involving all stakeholders and provides tools for improving the status of water bodies. At the end of the first management cycle in 2015, the aim is for all water bodies to fulfil "good ecological status", although in some cases water bodies can have this deadline postponed.

Conflicts of interests – how to find the balance?

The morphological alterations caused by hydropower plants will lead to a deterioration of the water course. There are measures in order to decrease the impact of the hydropower plant, such as fish ladders and bypass systems, but the altered watercourse will always have lower ecological values than a pristine water course. This is unavoidable, therefore conflicts of interests occur. The hydropower plants seriously damages local water environments and the number of pristine water courses in Europe are decreasing, however, hydropower is the most prominent renewable energy source available. This conflict has been present since the environmental impacts of human activities started to be debated and highlighted in the 1960's. The Water Framework Directive is set up to protect and improve the status of water bodies and it provides tools in order to balance between different interests. There is a concern from the hydropower industry that the implementation of the WFD will result in less revenue from hydropower as well as fewer available locations for exploitation.

The bigger the better or the smaller the better?

Generally speaking, the larger the hydropower plant the greater the local environmental impact. This often makes small-scale hydropower solutions a popular option when discussing environmentally friendly hydropower plants. However, things are not quite that straightforward. On the one hand smaller plants, generally run-off-the-river plants, cause less impacts then a larger plant. Larger plants, normally with a water reservoir, do on the other hand generate large quantities of electricity. Ideally, it would be most correct to compare the electricity output per environmental damage. It could be possible that one large plant with the capacity of say 10 MW causes less environmental impact then a sum of a number of small-scale plants with the sum of 10 MW of installed capacity. The problem is of course that there is no suitable method of measuring environmental damage in a way that is comparable with different locations. However, it is worth keeping in mind before taking it for granted that small-scale is per definition more environmentally friendly than large-scale plants.

Outlooks for the future

The WFD is still a relatively young directive. The first management cycle finishes in 2015, after this it should be possible to evaluate the success of improving and protecting the water bodies. In a small comparison of the situation for hydropower in Austria, Sweden and Scotland, it is clear that the view of hydropower differ from place to place. Austria and Scotland are commissioning and planning new hydropower plants, while Sweden seems to allow only upgrading of existing plants. The commissioning of new plants are taking place with the regulation of the WFD implemented, however the main question is 'are the water bodies meeting the goals of good status?' we will have to wait until 2015 for an answer.

For the future it is possible that electricity consumption and production will look very different from today, possibly with a smaller need for hydropower. Today, however, hydropower plays an important role which is also why it is so important to control and limit the exploitation of water courses. An integrated approach to the protection of water bodies is essential in order to preserve and protect the natural values for future generations.