Hydropower Generation in the context of the EU WFD

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Abbreviations and units

Unit	Meaning
MW	Megawatt, 1 MW = 1.000 kW
GW	Gigawatt, 1 GW = 1.000.000 kW
TW	Terrawatt, 1 TW = 1.000.000.000 kW
MWh	Megawatt hour (amount of energy produced in 1 hour by a plant with a capacity of 1 MW)
MWh/a	Megawatt hour a year
GWh	Gigawatt hour (amount of energy produced in 1 hour by a plant with a capacity of 1 GW)
TWh	Terrawatt hour (amount of energy produced in 1 hour by a plant with a capacity of 1 TW)
TWh/a	Terrawatt hour a year
ktoe	Kiloton of oil equivalent (amount of energy in 1000 tons of oil)
Mtoe	Megaton of oil equivalent (amount of energy in 1000000 tons of oil)
Gton	Gigaton (1000000000 tons)

Abbreviation	Meaning
BFE	Federal Agency for Energy, Switzerland
ENTSO-E	European Network of Transmission System Operators for Electricity (entsoe.net – the transparency platform of ENTSO-E)
ESHA	European Small Hydropower Association
European countries	
BE	Belgium
BG	Bulgaria
CZ	Czech Republic
DK	Denmark
DE	Germany
EE	Estonia
IE	Ireland
EL	Greece
ES	Spain
FR	France
IT	Italy
CY	Cyprus
LV	Latvia
LT	Lithuania
LU	Luxembourg

Abbreviation	Meaning
HU	Hungary
MT	Malta
NL	Netherlands
AT	Austria
PL	Poland
PT	Portugal
RO	Romania
SI	Slovenia
SK	Slovakia
FI	Finland
SE	Sweden
UK	United Kingdom
HR	Croatia
MK	Macedonia
TR	Turkey
BA	Bosnia & Herzegowina
ME	Montenegro
NO	Norway
CH	Switzerland
IS	Iceland
RS	Serbia
UA	Ukraine
EUROSTAT	Statistical Office of the European Communities
GIS	Geographic information system
HMWB	Heavily modifies water bodies
HP	Hydropower
IEE	Intelligent Energy Europe
LHP	Large hydropower
LHPP	Large hydropower plants
n.a.	Not available
NREAP	National Renewable Energy Action Plan
NVE	Norwegian Water Resources and Energy Directorate
PSP	Pumped storage power
PSPP	Pumped storage power plant
RES	Renewable energy sources
SHERPA	Small Hydropower Energy Efficiency Campaign Action EU funded project in the framework of Intelligent Energy for Europe (IEE), term 9/2006 to 9/2008
SHP	Small hydropower (capacity < 10 MW)

Abbreviation	Meaning
SHPP	Small hydropower plants (capacity < 10 MW)
UCTE	Union for the Coordination of Transmission of Electricity
VEÖ	Verband der Elektrizitätsunternehmen Österreichs, Association of Austrian Electricity Producers

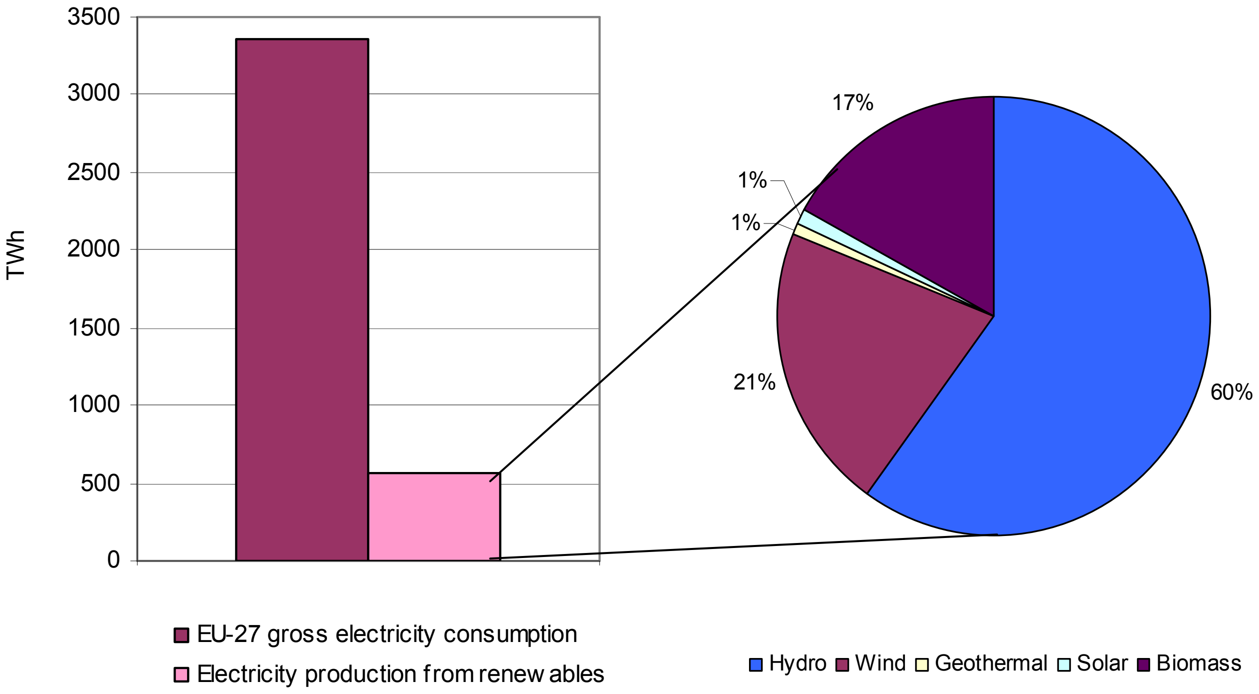
Executive summary

1.1 Energy consumption, electricity consumption and the production by renewable sources

In 2008 renewable energy accounted for 10,3 % of gross final energy consumption (all sectors and sources; thermal, fossil, nuclear, renewable, …) of 1213.9 Mtoe in the EU-27. 16.6% of the gross electricity consumption of 3357 TWh (EU-27) was produced by renewable energy sources (Figure 1). Hydropower covered about 60% of the renewable electricity production.

The total electricity consumption is expected to rise by 8% up to 3530 TWh from 2005 to 2050. With an increasing electricity production of the renewable energy sources of up to 1200 TWh or 34% of total electricity consumption in 2020, the contribution of HP to the electricity production from renewable sources will decrease to about 30%.

Figure 1: Gross electricity consumption and electricity production by renewable sources in 2008 : (Source: EUROSTAT, Statistics in focus 56/2010)



1.2 Energy production and capacity of HP stations

In 2008 the hydropower electricity production amounted to 327 TWh in the EU-27, at an installed capacity of 103 GW. Together with the candidate, associated countries (HR, MK, TR, IS, BA, ME, NO) and Switzerland the generation rises considerably to 554 TWh/a (EUROSTAT 2008), the total installed HP capacity reaching 161 GW (Table 1).

According to the NREAPs for SHP the electricity generation will increase by 11% and the installed capacity by 38% from 2005 to 2020. In the same time the electricity generation from large HP stations is expected to rise by 5% while an additional capacity of 16% will be installed.

Table 1: Hydropower generation and installed capacities for SHP and LHP in 2008

Hydro power		Generation [TWh]			Capacity [GW]		
		total	SHP	LHP	**total**	SHP	LHP
EU-27	2008 (EUROSTAT)	**327**	42.7	284	**103**	12.6	90
	2020 (NREAP)	**370**	55.0	315	**131**	16.7	114
EU-27 (2008, EUROSTAT) candidate, associated countries, CH		**554**	52.7	501	**161**	13.9	147

1.3 Number of HP stations

The total number of HP stations in the EU-27 amounts to about 23000 (Figure 2; Table 2). There are about 10 times more small (SHPP, P < 10 MW) than large HP plants (LHPP, P ≥ 10 MW). However, the generation of SHPP only amounts to 13% of the total generation of HP stations. Figure 2 shows this relation for the EU-27.

Today large HP stations account for 87% of the hydropower generation with only 9% of the stations. This discrepancy will further increase if the development follows the data in the NREAPs. The estimation for 2050 shows an increase in the number HP station by about 10% for large HP stations and by 25% for the number of SHP plants (with a rise in electricity generation of only 11%).

The environmental impacts of hydropower are well known, as are corresponding mitigation measures. Especially the demand for river continuity within a chain of obstacles can only be fulfilled by reducing the number of obstacles, even if well-functioning fishways are built. Hence focus should be placed on development or reburbishment of large power plants. Example: The upgrading of a single LHP station in Iffezheim (Rhine) leads to an additional capacity of 38 MW with an estimated additional electricity generation of 122 GWh. This corresponds to about 190 SHPP of a capacity of 200 kW, a rather common size for SHP, and thus even if they were equipped with fishways to 190 additional obstacles in various rivers.

1.4 Contribution to CO_2 savings

The total CO_2 emission in the EU-27 will decrease from 2005 to 2020 by 12% from 4.25 Gton to 3.71 Gton, while the decrease of CO_2 emission from electricity generation will be 18% from 1.34 Gton to 1.10 Gton.

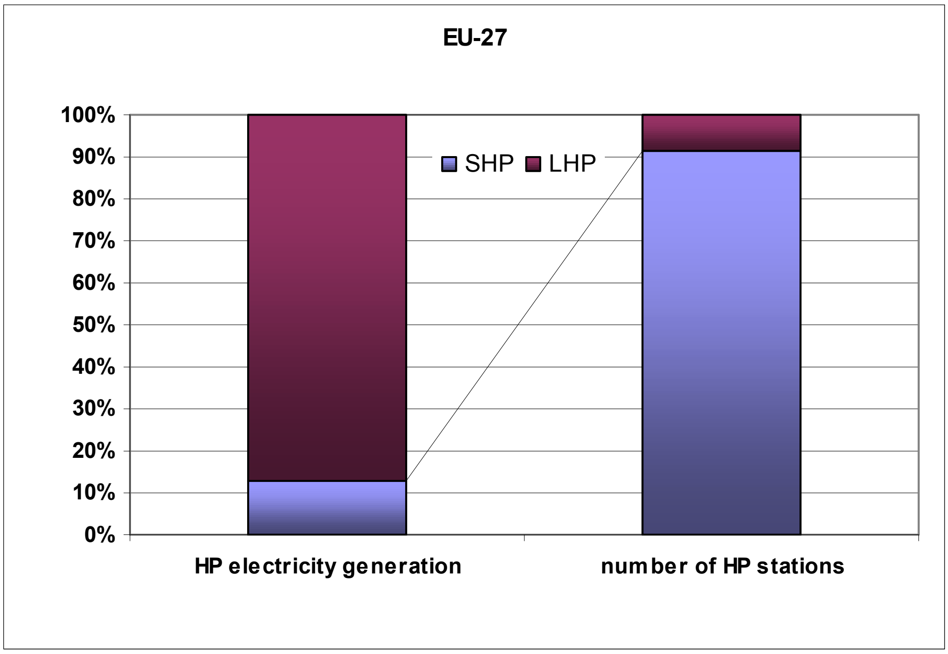
When calculating the change in contribution of SHP and LHP from 2005 to 2020 a slight increase can be recognized. Relative to the total CO_2 emission the contribution of SHP and LHP rise from 0.51% and 3.37% to 0.65% and 3.73% respectively or 0.5% in total.

Relative to direct emissions from electricity generation in the EU-27 the CO_2 savings from SHP and LHP were 1.73% and 11.37% in 2005. These values will rise to 2.20% and 12.60% respectively thus reducing the CO_2 emission together by an additional 1.8% in 2020.

Table 2: Number of small and large hydropower plants, no data on LHP for FI and TR available (sources: SHP – SHERPA 2006; LHP – ENTSO-E statistical yearbook 2009, Melin (SE), NVE (NO), BFE (CH) and EURELECTRIC*)

		Number of HP plants		
		total	SHP	LHP
EU-27	2006 / 2008 (SHERPA, ENTSOE, EURELECTRIC, others)	**22920**	20953	1967 (1978*)
	2020 (NREAP)	**28607**	26392	2215
EU-27, candidate, associated countries, CH		**25259**	22702	2557

Figure 2: Proportion of electricity generation and number of hydropower stations for SHP and LHP in the EU-27



1.5 Energy storage and stabilization of the electricity grid

Future electricity generation demands an increasing flexibility because the share of intermittent renewable energy sources like wind and solar power will rise and sudden power fluctuations within the grid will be the normal situation that has to be handled. Within certain regions the electricity production will temporarily exceed the demand and the secure and optimum operation of the power supply systems can be endangered.

An increasing capacity of energy storage systems will be necessary. When comparing the existing technologies, hydropower storage and pumped storage plants are the largest storage systems used today (Prof. Dötsch, Prof. Görner, E-World 2011, Essen, 15. Congress on Renewable Energies, Forum A).

Pumped storage power (PSP) plants were originally built to face the rapid changes in electricity demand (peak load). In addition PSP facilities are ideal to support grid stabilization (providing voltage stabilization and frequency regulation) because of their short start-up times of about 0.5 to a few minutes, and their relatively large capacities.

40.3 GW or 5% of the total EU-27 electrical capacity of about 800 GW was installed in pumped storage power plants in the EU-27 in 2008. Another 70 GW is being built so that within the next years more than 10% of the total electrical capacity could be covered by pumped storage.

Additional capacities are available by an improved use of existing plants without further environmental impacts. New constructions will not only have impacts on the environment (upsurge operation) but also face social resistance.

1.6 Benefits of HP electricity production

Certain benefits of hydropower as a renewable energy source have been discussed. The following list shows the main benefits.

- Generation of electricity, an energy form that can be converted to any form of end energy (100% energy)
- Well established technology
- Long lifetime of facilities
- Large yield factor (energy production / energy input in facility)
- Large efficiency of electricity generation over a broad capacity band
- Base load and peak load capability
- Grid stabilization
- Electricity storage with large capacity

In addition to the known advantages of HP, large HP stations can offer the following benefits:

- Flood protection
- Infrastructure (shipping, recreation, tourism, water supply)
- Groundwater lifting.

Bavarian electricity suppliers E.ON and BEW (Bavarian Electricity Company) who operate most of the regional large HP stations, argue with these benefits that the environmental efforts should be carried by the multiple users of the rivers (Technische Universität Dresden, Wasserbauliche Mitteilungen Heft 45, 2011, Beitrag Dr. Pöhler).

1.7 Environmental impacts and influence of environmental legislation on hydropower generation

Hydropower schemes form obstacles or barriers in water courses and are known to impact on the aquatic environment. Their construction and operation is linked to unavoidable interconnected up- and downstream impacts on the water bodies and adjacent floodplains and wetlands. Such impacts can be assessed and monitored with a variety of the WFD defined quality elements, which again are decisive for water status classification.

Hydromorphological alterations are amongst the top pressures emerging from the WFD analysis. Amongst others, hydropower and dams have been identified as the main drivers causing the degradations. 16 out of 20 Member States have indicated power generation including hydropower as being a driving force related to hydromorphological pressures. Almost all EU Member States have (provisionally) designated selected surface water bodies as heavily modified or artificial water bodies, whereby they will need to meet the good ecological potential quality criteria. In their initial assessments Member States identified about 20% of the EU's surface water bodies as being heavily modified and a further 4.5% as artificial.

Impacts of hydropower schemes can be distinguished in hydromorphological, physico-chemical and biological impacts and can be considered within a framework of interconnected effects:

- First order impacts: Immediate abiotic effects that occur simultaneously with dam closure and influence the transfer of energy and material into and within the downstream river and connected ecosystems (e.g. changes in flow, water quality and sediment load).
- Second order impacts: Changes of channel and downstream ecosystem structure and primary production, which result from the modification of first order impacts by local conditions and depend upon the characteristics of the river prior to dam closure (e.g. changes in channel and floodplain morphology, changes in plankton, macrophytes and periphyton). These changes may take place over many years.
- Third order impacts: Long-term, biotic, changes resulting from the integrated effect of all the first and second order changes, including the impact on species close to the top of the food chain (e.g. changes in invertebrate communities and fish, birds and mammals).

Many of the impacts can be mitigated with restoration and mitigation measures. There exists a great variety of restoration/ mitigation measures that can be applied to reduce (local) impacts from hydropower, e.g. fish passes, fish protection facilities and downstream fishways, minimum flows and debris and sediment management. Several mitigation measures have already been applied for a long time; pertinent regulations were applicable in some EU Member States well before the WFD was enacted.

Case studies were evaluated to gain an understanding of the energy losses of hydropower schemes due to ecological improvements. The main losses are due to:

- minimum flow requirements,
- fish pass and bypass installations discharges (typically combined with minimum flow requirements),
- head loss at fish protection screens,
- reduced turbine operation during fish migration, and
- requirements on mitigation of surge operation (especially for peak load and storage plants).

Fish passes and bypass systems at large HPP were found to cause losses of a few percent, whereas in small rivers the losses can easily amount to more than 10%. The actual number of European HP stations that apply mitigation measures is not registered and thus not known. Furthermore fishways for upstream migration constructed in recent years have in most cases too small dimensions for the potential fish fauna, are not well functioning and need reconstruction. Assuming that the number of mitigation measures that reasonably function amount to 10 to 20% for SHP and LHP the generation loss relative to the total future HP generation is estimated to be 8 to 9 TWh or 2,3 to 2,6% for the EU-27 countries.

However, the case studies also show that there are many small and large HPP that can be refurbished and upgraded, and that the combination of upgrading together with ecological mitigation measures will probably even increase the HP generation.

The enforcement and implementation of the WFD has impacted and will further impact on the possibility for development of the remaining hydropower potential. Following the transposition of the WFD requirements to national legislation further regulations, protocols, criteria catalogues etc. have been updated or introduced that - taking into account the WFD goals and requirements - a) define the rules for hydropower development and operation in European waters, e.g. ‘no-go’ areas, and b) delineate specific environmental mitigation measures for existing and future hydropower/ dam schemes, However, it has to be highlighted that a number of spatial restrictions and mitigation measures are obligatory because of longstanding national legislation and/ or European nature legislation (e.g. Natura 2000 areas/ Special Areas of Conservation as defined and designated by the EU Habitats Directive).

1.8 Approaches in EU Member States on policy integration

In the course of the Common Implementation Strategy for the EU Water Framework Directive (CIS), specific guidance documents have been jointly developed, aiming at achieving better policy integration between the water and energy sector. The existing guidance calls for a strategic approach in selecting the best places for hydropower development balancing the benefits of the projects (basically renewable energy generation) with the impacts on the aquatic environment. Only such strategic approach will ensure that the best nvironmental option is achieved and that a balance is struck between benefits and impacts.

For this project, ongoing activities in Member States are screened and an assessment is done on how far Member States decided to follow a strategic approach, in accordance with the agreed principles, as stated in the CIS guidance documents.

The analysis has a focus on:

1. Whether strategic planning is taking place e.g. at river basin level or MS level
2. If pre-planning mechanisms are applied for the allocation of suitable and non-suitable areas (or “go” and “no-go” areas”)
3. If this designation is based on a dialogue between different competent authorities, stakeholders and NGOs.

4. If other elements of strategic planning are applied e.g. prior agreement of a catalogue of criteria which informs the judgment on the right balance between the benefits of the hydropower facility and the benefits of protecting the aquatic environment

The analysis, with a focus on 5 EU Member States (France, Austria, Lithuania, United Kingdom and Germany) and 2 non-EU Member States (Switzerland and Norway) has indicated that for some of the countries, strategic approaches have been suggested and have been under public consultation, but the final plan has not been published yet (e.g. Scotland, Austria (Tirol), Norway (regional plans)). For these countries or regions, there is still uncertainty on what will be exactly implemented. Also, suggestions towards strategic planning are made but will be looked at in future (England & Wales, Switzerland). Only for Norway (Master Plan, Protection Plans), Lithuania and France (SDAGE) evidence has been found of already implemented strategic approaches that define suitable and non-suitable areas for hydropower development at a national scale. Evidence has also been found of some strategic approaches applied at a regional basis (e.g. Austria, Italy, Switzerland) but it is often difficult to define how they are applied in practical as for some of these cases only limited information was available and further discussion with authorities would be needed to reveal details. Only France had included a strategic approach as part of its RBMPs in which case the decision process on what is defined as mobilisable potential in a certain river basin is given.

In general, most of the information available is on environmental restrictions included in the country's or region's licensing system. Licensing will happen on a case-by-case basis, but as for example for England & Wales as well as Scotland, a more strategic approach for this is suggested to ensure planning authorities and environmental regulators receive good guidance as well as to allow an overall basin-view on hydropower planning. Further on, individual projects will also be looked at as part of the Art 4.7 exemption applies and mitigations needed.

Due to the scope of this review (limited list of countries to be considered as well as documents to be consulted due to language restrictions), the results need to be interpreted with caution. To allow for a complete review of planned and implemented strategic approaches, relevant authorities and stakeholders would need to be contacted to reveal the diversity of planned strategic approaches on hydropower.

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1 Background

The European Directive 2009/28/EC of 23 April 2009 on the promotion of renewable energy aims at achieving by 2020 a 20% share of energy from renewable sources in the EU's final consumption of energy

To achieve these objectives, the directive for the first time sets for each member state a mandatory national target for the overall share of energy from renewable sources in gross final consumption of energy, taking account of countries' different starting points. The main purpose of mandatory national targets is to provide certainty for investors and to encourage technological development allowing for energy production from all types of renewable sources. To ensure that the mandatory national targets are achieved, member states have to follow an indicative trajectory towards the achievement of their target.

Each EU Member State will adopt a national renewable energy action plan setting out its national targets for the share of energy from renewable sources consumed in transport, electricity, heating and cooling in 2020 and will notify it to the Commission by June 2010 by means of the Renewable Energy Action plans (NREAP). These NREAPs should establish pathways for the development of renewable energy sources.

Hydropower is a mature renewable power generation technology. At present, it accounts for 70% of the electricity generated from renewable energy sources in Europe or 10% of the total electricity production in the EU-27. The large and medium scale hydropower market (>10 MWe) is a well established market in Europe. More than 50% of favorable sites have already been exploited across the EU-27 according to EC SETIS[1]. Today's hydro-power installed capacity in the EU-27 is about 106 GWe (without hydro pumped storage). About 11 GWe of small scale hydropower (<10 MWe) are operating in the EU-25. The largest remaining potential in Europe lies in low head plants (< 15m) and in the refurbishment of existing facilities. About 65% of Small Hydro plants located in Western Europe and 50% in Eastern Europe are more than 40 years old.

The impacts of dams and impoundments in watercourses are well known[2]. However, often plans make very little reference to the assessment of the impacts of each dam in the water environment. Also the accumulated effects in particular river basins are rarely considered or investigated. In the current legislative framework, the impacts on water environment should be assessed against the WFD ecological status classification scheme.

The major impacts of hydropower stations in river basins are the barrier function together with damage and mortality of fish species, modified flows and habitat conditions, the changes in nutrient and physio-chemical conditions, and changed sediment patterns.

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[1] Strategic energy technology plan information system. http://setis.ec.europa.eu/mapping-overview/technology-map/technologies/hydropower

[2] See WFD Common Implementation Strategy Policy Paper "WFD and Hydro-morphological pressures. Focus on hydropower, navigation and flood defence activities. Recommendations for better policy integration" (November 2006) and accompanying documents available at http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive/thematic_documents/hydromorphology

The actual impact will depend on the sensitivity of the river basin, which is mainly depending on its natural characteristics and the range and magnitude of existing pressures. Mitigation measures can be proposed such as the installation of fish passes, the setting of natural flow variations, the application of a minimum flow, the attenuation of hydropeaking, etc. However, the cost-effectiveness of a certain approach on one-hand and its effect on the energy production on the other hand are issues that are often prevailing.

According to the Water Framework Directive (WFD), the deadline for achieving a good status of surface waters is 2015. In the meantime, Member States should avoid taking action that could jeopardize the achievement of the objectives of the directive, notably the general objective of good status of water bodies. Derogations for building new infrastructure projects (notably dams) are possible under Article 4.7, if certain strict conditions are met and an assessment is done according to these conditions. These conditions include amongst others that there are no significantly better environmental options, the benefits of the new infrastructure outweigh the benefits of achieving the WFD environmental objectives and all practicable mitigation measures are taken to address the adverse impact of the status of the water body. Only few plans have made use of the Art 4.7 exemption and new infrastructure dams have often not been mentioned in the RBMP. The reporting on Art 4.7 exemptions should ideally be coordinated with the draft national renewable energy action plan.

This study aims to improve the understanding of both environmental concerns, given by the WFD, and the development of hydropower, encouraged by the Renewable Energy Directive, and the possible approaches for a coordinated implementation of both this water protection policy and energy policy.

1.1 Objectives

The overall objective of the study is to provide a deeper understanding of inter-linkages between WFD implementation and hydropower development, with the aim to support further integration.

Summarising, the expected result of the study is to gain

- Qualitative and quantitative information on the current and potential future contribution of the hydropower sector to the achievement of the renewable energy targets as well as to the reduction of greenhouse gas emissions
- Qualitative and quantitative information on the influence of meeting the objectives of the WFD on the achievement of those objectives
- An overview of strategic planning approaches, as proposed in jointly developed CIS guidance documents, applied by Member States for achieving the objective of better policy integration (between WFD and hydropower development)

2 Benefits, potentials and development of hydropower generation in European countries

2.1 Overall objective

The aim of this task is to provide an overview on hydropower potentials in European countries. The potentials should include those which were already developed and those which are still remaining or are aimed to be developed in the coming years.

The existing studies often distinguish between different categories of potentials (e.g. technical potential, economic potential, environmental compliant potential, already developed potential, etc.). While providing an overview on the different potentials in Europe, the summary should also include a description on how those different potentials are defined respectively on the used methodologies for the calculation in case this information is available.

It is estimated that the Renewable Energy Action Plans will not always, if at all, provide figures on the number of additional large, small and micro hydropower facilities which are intended by the Member States to be constructed in the coming years. In such a case, figures on the number of facilities should be estimated based on available information. This could e.g. be on the basis of existing data, i.e. the number and average size of hydropower stations currently generating a certain amount of electricity. In making these estimates, it should be clearly indicated which assumptions have been made.

The contractor should calculate the current and estimated future contribution (in %) of small and large hydropower to "savings" of greenhouse gas emissions for the EU compared to

- Total greenhouse gas emissions (all sectors and sources)
- Greenhouse gas emissions stemming from electricity generation (all sources)

Finally, largely based on the previously collected information, the following general questions should be answered in a qualitative way:

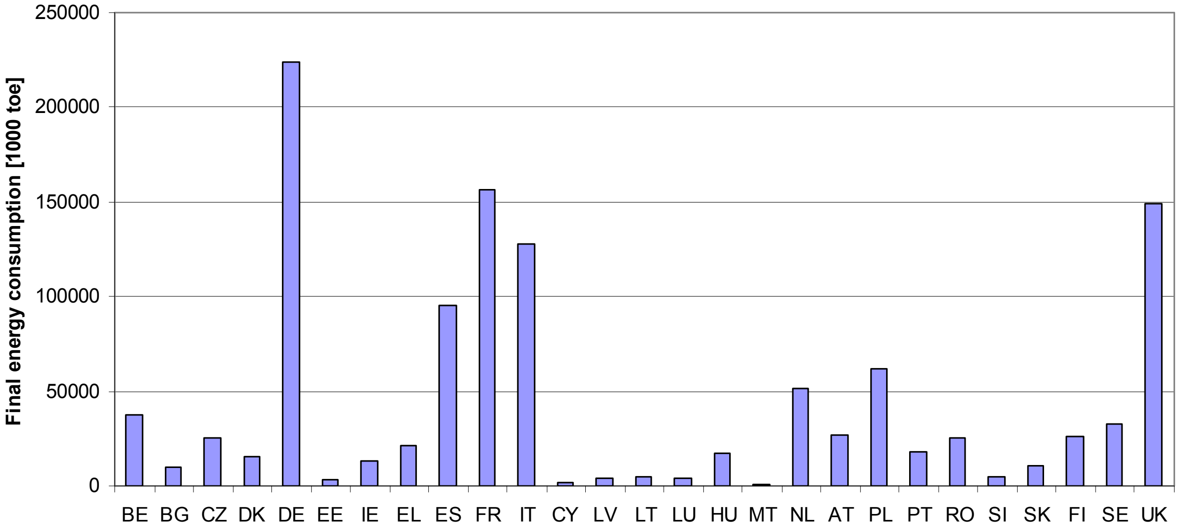
- Role of large and small hydropower generation with regard to the contribution towards the stabilisation of the electricity grid, specifically taking into account upcoming future developments of other forms of renewable energy (e.g. wind and solar).
- Qualitative description on the main benefits of large and small hydropower today and in the future as a form of electricity generation from a renewable source of energy.

2.2 Key figures on the energy and hydropower sector

2.2.1 Energy consumption in the EU-27

In 2008 the final energy consumption in the EU-27 countries was 1168.7 Mtoe. The final energy consumption includes all energy delivered to the final consumer's door (in the industry, transport, households and other sectors) for all energy uses. It excludes deliveries for transformation and/or own use of the energy producing industries, as well as network losses. Germany showed the largest final energy consumption followed by France, the United Kingdom, Italy and Spain (Figure 2.1).

Figure 2.1: Final energy consumption in the EU in 2008
(Source: EUROSTAT http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/main_tables ten00095)



The share of renewable energy sources differs widely within the European countries. For Sweden, it reaches the large value of nearly 45% (Figure 2.2). In total renewable energy sources contributed a share of 10,3 % to the gross final energy consumption in the EU-27. The remaining 89,7% was covered by the use of conventional fuels (Figure 2.3). In 2020 an amount of 20% is aimed at for the contribution of the renewable energy sources.

Figure 2.2: Contribution of renewable energy sources to the gross final energy consumption in the EU
(Source: EUROSTAT http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/main_tables tsdcc110)

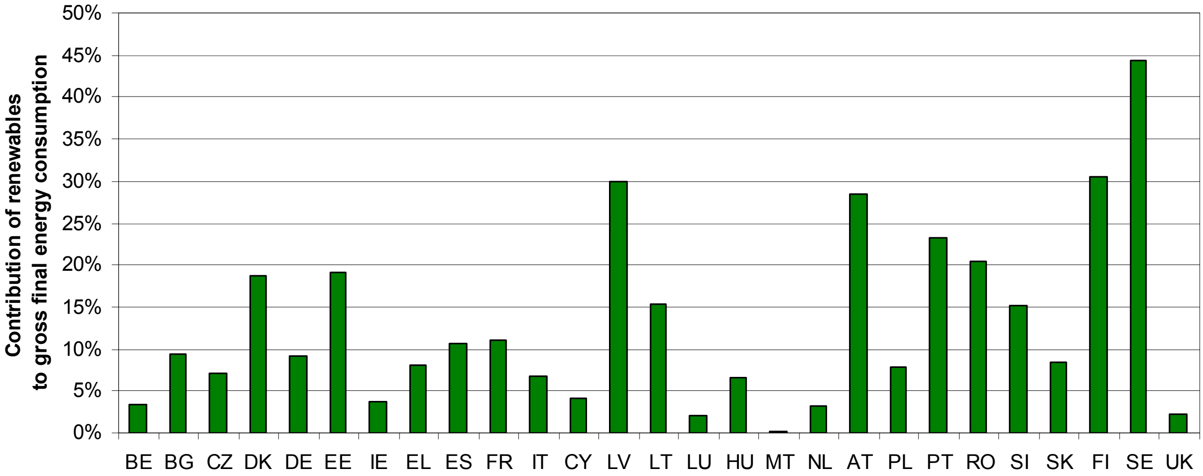
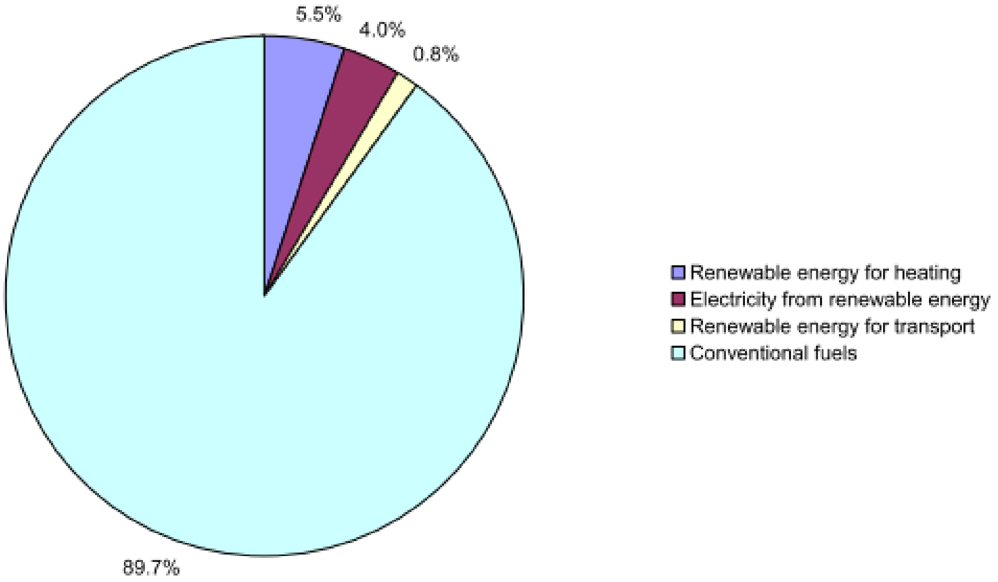


Figure 2.3: Gross final energy consumption in the EU-27 in 2008 (Source: EUROSTAT Statistics in focus 56/2010)

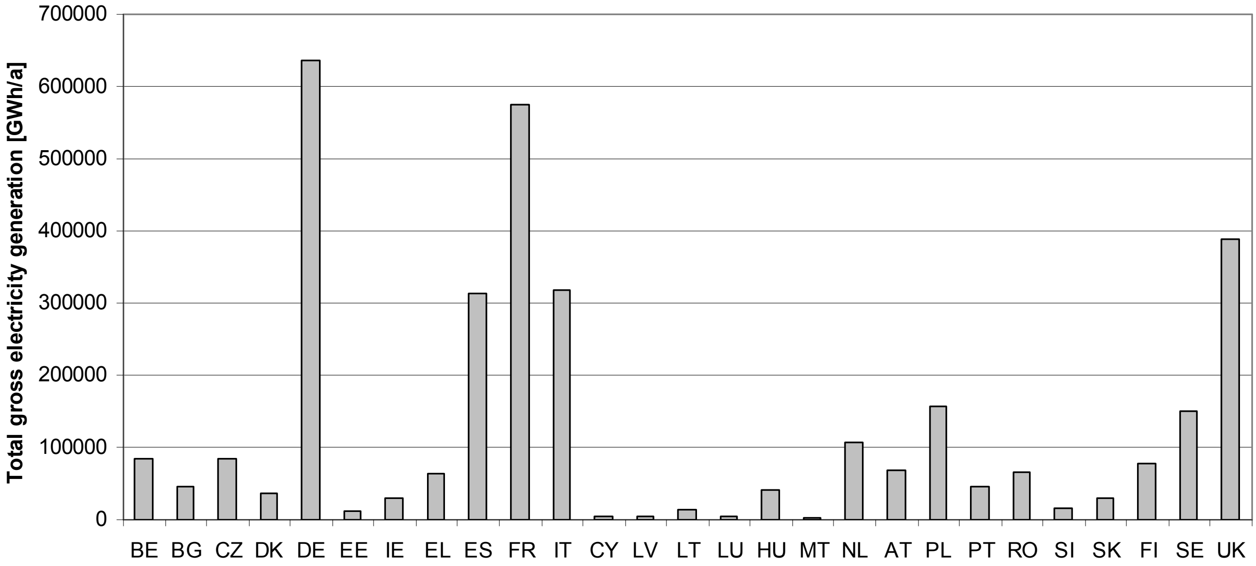


2.2.2 Electricity generation in the EU-27

In 2008 a total gross electricity of 3374 TWh was generated in the EU-27. Total gross electricity generation covers gross electricity generation in all types of power plants. The gross electricity generation at the plant level is defined as the electricity measured at the outlet of the main transformers, i.e. the consumption of electricity in the plant auxiliaries and in transformers are included. Germany, France, the United Kingdom, Italy and Spain showed the largest generation values (Figure 2.4).

Figure 2.4: Total gross electricity generation in the EU

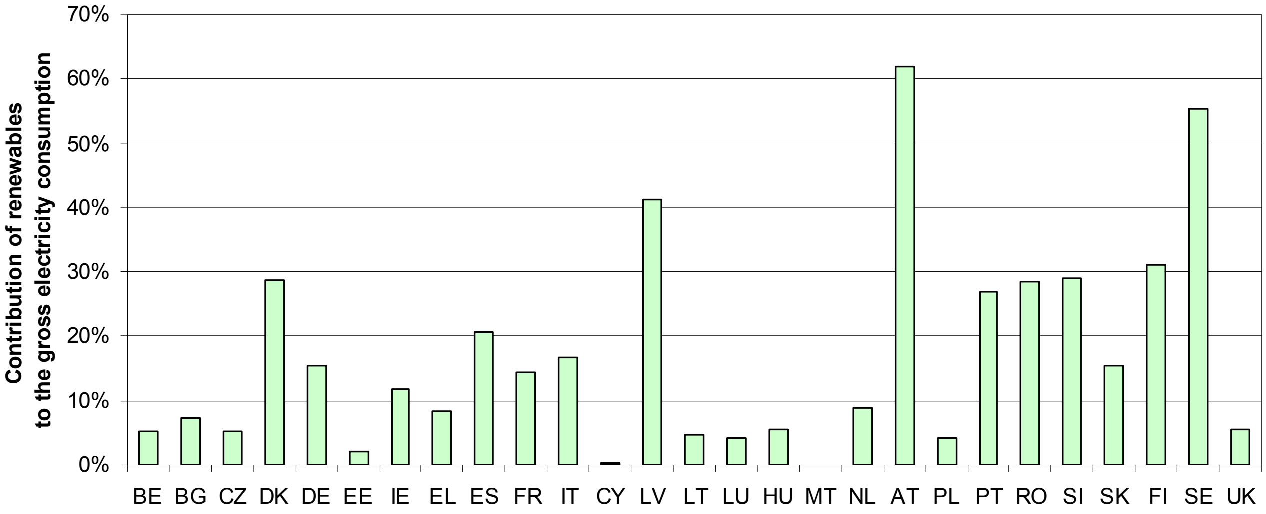
(Source: EUROSTAT http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/main_tables ten00087)



The countries with the largest share of renewable energy sources on the electricity consumption were Austria (62%), Sweden (55%), Latvia (41%) and Finland (31%). In 2008 electricity generation from renewable sources covered 16,6% of gross electricity consumption (Figure 2.5).

Figure 2.5: Share of renewable energy sources to the total gross electricity consumption in the EU

(Source: EUROSTAT http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/main_tables tsdcc330)



2.2.3 Hydropower (HP) in the EU today

Key figures on hydropower in Europe were taken from sources like the Statistical Office of the European Communities EUROSTAT, from the European Small Hydropower Association ESHA, which represent the HP plants with an installed capacity of less than 10 MW, from the Union of the Electricity Industry EURELECTRIC, from individual country studies and the network organization ENTSO-E . When analyzing data from different sources it has to be kept in mind that the countries might have different definitions for small hydropower (SHP). In Germany e.g. SHP comprises HP stations with an installed capacity of less than 1 MW.

Since the ESHA is very active in collecting data, many figures are available for SHP from this particular source. EURELECTRIC, which is an association representing the large hydropower in the frame of the Water Framework Directive (WFD) Common Implementation Strategy (CIS) published much less data for large HP. Data are presented for the EU27, for candidate, associated countries and Switzerland.

2.2.3.1 Types of power stations

Mainly three types of power stations have to be distinguished

- Run-of-the-river stations
- Hydropower stations with storage reservoir
- Pumped storage hydropower plants

2.2.3.1.1 Run-of-the-river stations

This type of installation uses the natural flow of a water course in order to generate electricity. There is no intention to store water and to use it later on. This type is most common for small HP stations but can also be found with large stations.

2.2.3.1.2 Hydropower stations with storage reservoir

A storage reservoir offers the opportunity to store energy and to meet e.g. the peak electricity demands. Such reservoirs can comprise daily, seasonal or yearly storage. Many of the large HP stations operate with a reservoir.

2.2.3.1.3 Pumped storage hydropower plants

Pumped hydropower stations utilize two reservoirs located at different altitudes. Water can be pumped from the lower into the upper reservoir and can be released, if needed, to the lower reservoir producing energy on its way through the turbines.

In times of high demand e.g. during peak hours electricity is produced to satisfy the demand. When there is a surplus of electricity in the system, water can be pumped to the upper reservoir. This may happen during peak production hours from wind and solar energy or at times of low demand.

Pumped storage stations are well suited to serve a reliable electricity supply with fluctuating sources because they can provide balancing power (Deutsche Energie Agentur, dena Studie “NNE Pumpspeicher”, Abschlussbericht 2008-11-24). With the increase of electricity production from wind and solar energy they will therefore play an important role in the electricity management.

2.2.3.2 Installed capacities and electricity generation

The latest data published on hydropower production by the Statistical Office of the European Communities EUROSTAT represent the year 2008. With an HP installed capacity of 102 GW hydropower (PSP excluded) the electricity generation was 327 TWh for the EU-27 (Table 2.1). According to these data there was in 2008 no hydropower production in Cyprus and Malta.

Including pumped storage plants with an installed capacity of 40,3 GW the total gross generation of hydro power was 359.2 TWh in 2008. The consumption of pumped storage plants was 11.3 TWh.

The HP potential is increasing considerably, if the candidate and associated states are included. With 161 GW the total HP capacity increases by 60% and the electricity generation rises by 68% to 550 TWh. This is mainly due to Norway, Switzerland and Turkey with their large potentials.

The data of EUROSTAT are compared to figures of SHERPA for SHP (Table 2.7, Table 2.8), because these will be the basis of the estimations of future SHP production in section 2.2.4.2. The results for the total generation and capacity are shown in Table 2.2. Since the EUROSTAT data do not contain values for Switzerland these data from SHERPA were indicated separately. The figures from the two sources are quite compatible. They also indicate that there have been minor changes in the HP production.

Table 2.1 : Electricity generation and installed capacity of hydropower plants in 2008
(Source: EUROSTAT yearly statistics 2008; for Iceland the only available data from 2006 were taken)

2008	*Generation Ea [GWh/a]*				*Installed capacity P [MW]*			
class	*P < 1 MW*	*1 MW ≤ P < 10 MW*	*10 MW ≤ P*	*all*	*P < 1 MW*	*1 MW ≤ P < 10 MW*	*10 MW ≤ P*	*all*
BE	26	207	176	409	9	50	52	111
BG	108	417	2299	2824	39	191	1890	2120
CZ	492	475	1057	2024	151	141	753	1045
DK	12	14	n.a.	26	3	5	n.a.	8
DE	2060	5286	13596	20942	561	842	2104	3507
EE	28	n.a.	n.a.	28	5	n.a.	n.a.	5
IE	47	85	836	968	23	20	196	239
EL	117	207	2987	3311	44	114	2319	2477
ES	674	2357	20469	23500	267	1605	11232	13104
FR	1582	5342	56802	63726	445	1604	18823	20872
IT	1770	7390	32464	41624	437	2105	11190	13732
CY	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LV	64	6	3038	3108	24	1	1511	1536
LT	51	22	329	402	17	8	90	115
LU	7	126	n.a.	133	2	38	n.a.	40
HU	16	34	163	213	4	10	37	51
MT	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
NL	n.a.	n.a.	102	102	n.a.	n.a.	37	37
AT	1637	3179	33129	37945	454	725	7040	8219
PL	290	605	1257	2152	74	183	672	929
PT	67	670	6060	6797	31	361	3634	4026
RO	99	549	16547	17195	61	292	6009	6362
SI	264	193	3561	4018	117	37	873	1027
SK	58	108	3874	4040	25	65	1542	1632
FI	167	1449	15496	17112	31	285	2786	3102
SE	601	3188	65280	69069	101	815	15436	16352
UK	57	511	4600	5168	65	108	1456	1629
EU-27	10294	32420	284122	326836	2990	9605	89682	102277
HR	1	94	5121	5216	1	32	1749	1782
MK	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
TR	38	472	32760	33270	16	231	13582	13829
IS	48	260	6985	7293	7	49	1107	1163
BA	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
ME	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
NO	235	5402	133917	139554	48	1048	27150	28246
CH	n.a.	n.a.	37935	37935	n.a.	n.a.	13457	13457
All	10616	38648	500840	550104	3062	10065	146727	160754

Table 2.2: HP generation and installed capacities for SHP (Sources: EUROSTAT 2008 and SHERPA 2006)

SHP **Small Hydro Power**	*Generation [TWh]*		*Capacity [GW]*	
	2008 EUROSTAT	*2006 SHERPA*	*2008 EUROSTAT*	*2006 SHERPA*
EU-27	42.7	41.6	12.6	13.2
EU-27, candidate and associated countries	49.3 + 3.4* (CH)	51.6	13.1 + 0.8* (CH)	15.2

The individual values for the European countries on HP electricity generation and on electrical capacity are shown in Figure 2.6 and Figure 2.7. In all countries large hydropower stations (LHPP) with a capacity ≥ 10 MW are the major contributors. They produced 87% of the total generation and comprise 88% of the total capacity with regards to the 27 EU member states.

Figure 2.6: Hydropower electricity generation for different HP plant sizes in the 27 member states, in the candidate and associated states, in Norway and Switzerland in 2008, excluding pumped storage (Source: EUROSTAT yearly statistics 2008; for Iceland the only available data from 2006 were taken)

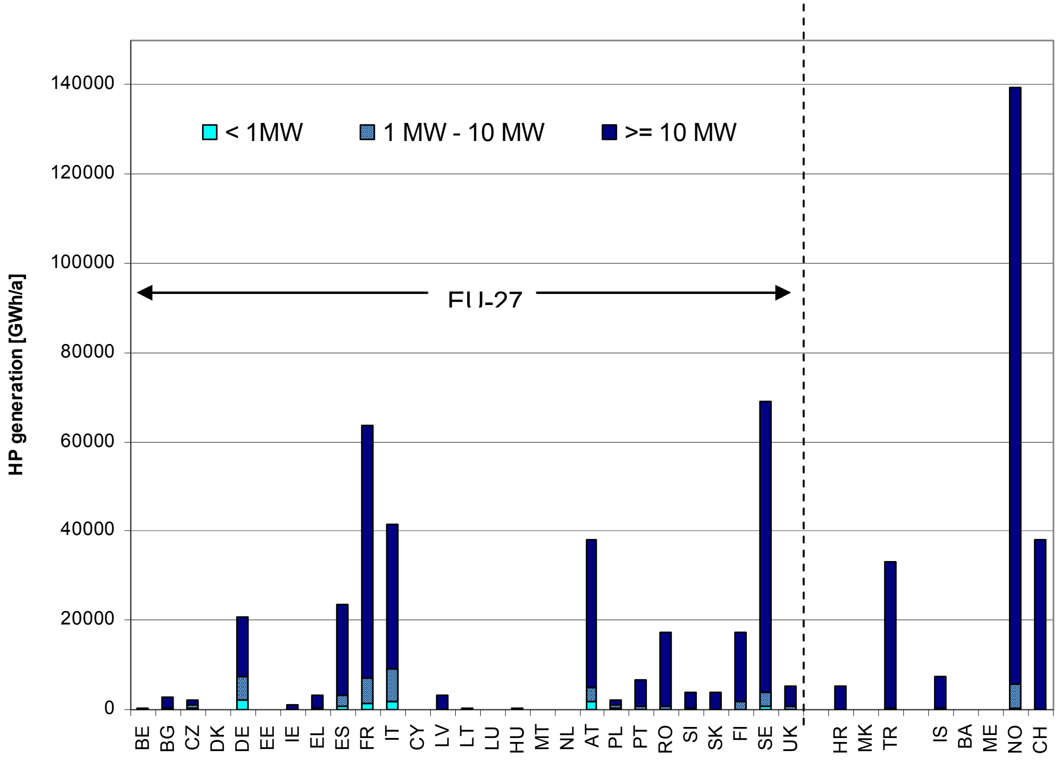
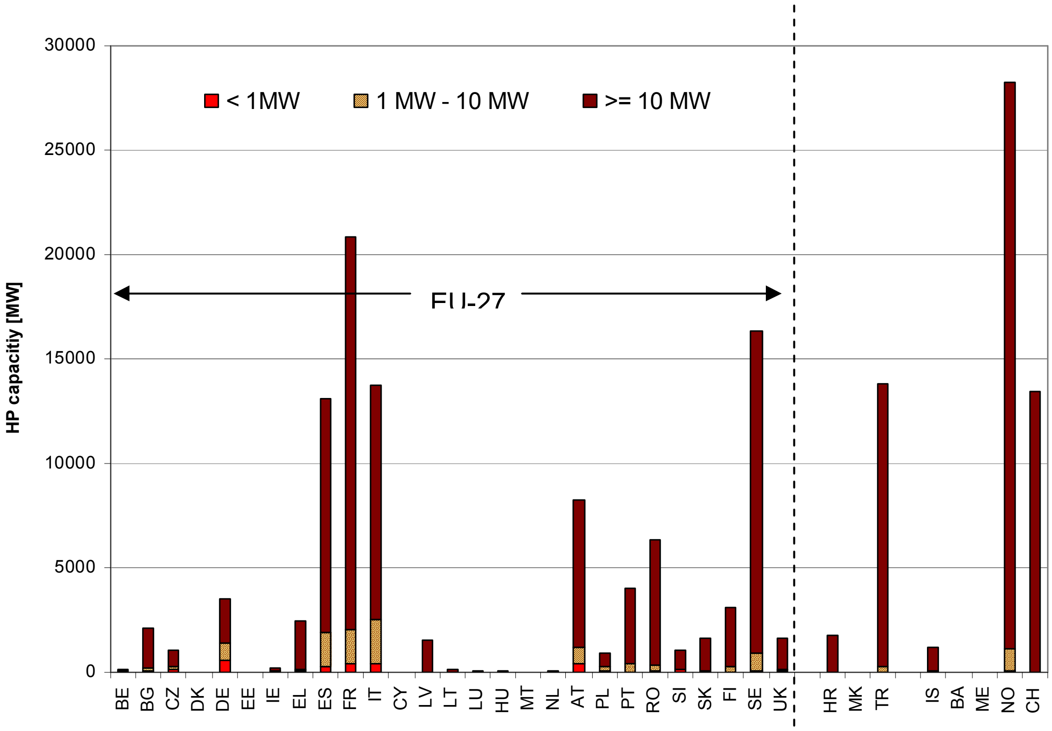


Figure 2.7: Installed electrical capacity of hydropower for different HP plant sizes in the 27 member states, the candidate and associated states, in Norway and Switzerland in 2008, excluding pumped storage (Source: EUROSTAT yearly statistics 2008; for Iceland the only available data from 2006 were taken)



2.2.3.3 Number of existing hydropower stations

Data on the numbers of small HP facilities were compiled in studies by the European Small Hydropower Association (ESHA).

For large HP plants data are available in individual country studies and in the Statistical Yearbook 2009 of the European Network of Transmission System Operators for Electricity (ENTSO-E).

2.2.3.3.1 Number of small HP plants (SHPP)

According to the SHERPA report “Status of SHP policy framework and market development” in 2006 there were about 21000 SHP plants in operation in the EU-27 (Table 2.3) and this number does not seem to increase very much until 2008 because the total capacity of SHP remained nearly constant at 13 GW along this period. Taking the candidate and associated countries into account the number of SHPP increased by about 1700.

The number of SHP plants origin from data collected within the SHERPA project (2006). Within this project questionnaires were sent to main SHP actors in different EU countries as well as Norway, Switzerland, Bosnia & Herzegovina and Montenegro. Information from official databases and existing studies were used as well as from SHP national associations and experts.

Germany shows a remarkably large number of SHP. Hydropower was a driving force for the development of the mining and steel industry. A recent study (WAWi 2010) determined the number of SHP to be about 7400.

This number contains about 5% which do not feed electricity in to a net but produce mechanical or electrical energy for self supply.

More recent data on SHP will be gathered within the Stream Map Project (2009 until 2012), which is coordinated by ESHA and co-funded by the IEE Program of the European Commission under the responsibility of the EACI. One objective of the project is to create a central database (HYDI Hydro Data Initiative) which will compile the relevant information on SHP for the EU-27 on an annual basis from 2007 onwards.

2.2.3.3.2 Number of existing large hydropower plants (LHPP)

A comprehensive source for the number of large HP plants in Europe is the ENTSO-E Statistical Yearbook 2009. ENTSO-E is the European Network of Transmission System Operators for Electricity, representing 42 Transmission System Operators (TSOs) from 34 countries. It replaced all predecessor associations: ATSOI, BALTSO, NORDEL, UCTE, ETSO and UKTSOA. ENTSO-E's mission is to promote important aspects of energy policy in the face of significant challenges like security, adequacy, market and sustainability.

Statistical data are regularly collected by data correspondents at member TSOs. ENTSO-E statistics only describe that part of the electricity supply system, which concerns interconnected system operation. Therefore figures indicated for various countries may differ from some other national statistics.

The following countries are not covered by the ENTSO-E statistics: Estonia, Ireland, Greece, Cyprus (no HP), Latvia, Lithuania, Malta (no HP), Finland, Sweden, United Kingdom, Turkey, Iceland, Norway and Switzerland.

Figure 2.8 shows the total number of HP plants, indicating that SHP comprise most of the stations. For the following countries, numbers of large HP plants were taken from other sources:

- BG: en.wikipedia.org/wiki/Energy_in_Bulgaria lists 11 HPP with a capacity > 100 MW each, of which 2 are pumped stations. The total installed capacity for the 9 (non-pumping) HPP amounts to about 1800 MW. According to the Bulgarian NREAP, the total installed capacity amounts to 2078 MW of which 184 MW according to the SHERPA study correspond to SHP.
- IE: www.industcards.com/hydro_ie.htm lists 3 HPP with a capacity >10 MW with a total installed capacity of about140 MW. According to the Irish NREAP, the total installed capacity for LHPP amounts to 196 MW, so there are at least 4 LHPP in IE.
- EL: www.industcards.com/hydro_greece.htm lists 12 HPP with a capacity > 10 MW with a total installed capacity of about 2230 MW. According to the Greek NREAP, total installed capacity for LHPP amounts to 3018 MW. Taking into account the average capacity of the 12 HPP with know capacity, the total number of LHPP in EL is estimated to be 16.
- FI: www.motiva.fi/en/areas_of_operation/renewable_energy/hydropower mentions 57 HPP with a capacity > 10 MW in FI.

- HU: www.industcards.com/hydro_hungary.htm lists 2 HPP with a capacity > 10 MW and a total installed capacity for LHPP of 41,5 MW. Total installed capacity matches the one reported in the NREAP.
- LV: www.latvenergo.lv mentions 3 HPP with a capacity > 10 MW. Total installed capacity matches the one reported in the NREAP.
- LT: saule.lms.lt/main/hidro_e.html mentions 1 HPP with a capacity >10 MW. Total installed capacity matches the one reported in the NREAP.
- SE: www.svenskvattenkraft.se/default.asp?L=EN mentions 442 HPP with a capacity > 10 MW and a total installed capacity for LHPP of 15200 MW. Total installed capacity closely matches the one reported in the NREAP.
- UK: www.british-hydro.org/installations/installations.html mentions 26 HPP with a capacity between 10 and 20 MW and 17 HPP with a capacity > 20 MW.

Data on numbers of large HP stations where also provided by EURELECTRIC (Table 2.3). Although the numbers turn out to be quite different to those of ENTSO-E and of other sources it can be said that about 1970 large HP plants are installed in EU-27.

Conflicting numbers

When counting the number of HP stations different sources end up with different results. Reasons for this might be that investigations are performed during different periods of time or for slightly different regions. The differences cannot always be solved by studying the sources very thoroughly.

Figure 2.8: Number of large and small HP stations of the 27 member states, candidate and associated countries (Source SHP: SHERPA for 2006; source large HPP: ENTSO-E, Statistical Yearbook 2009 and combination of sources for BG, IE, EL, FI, HU, LV, LT, SE, UK and NO: NVE, CH: BFE)

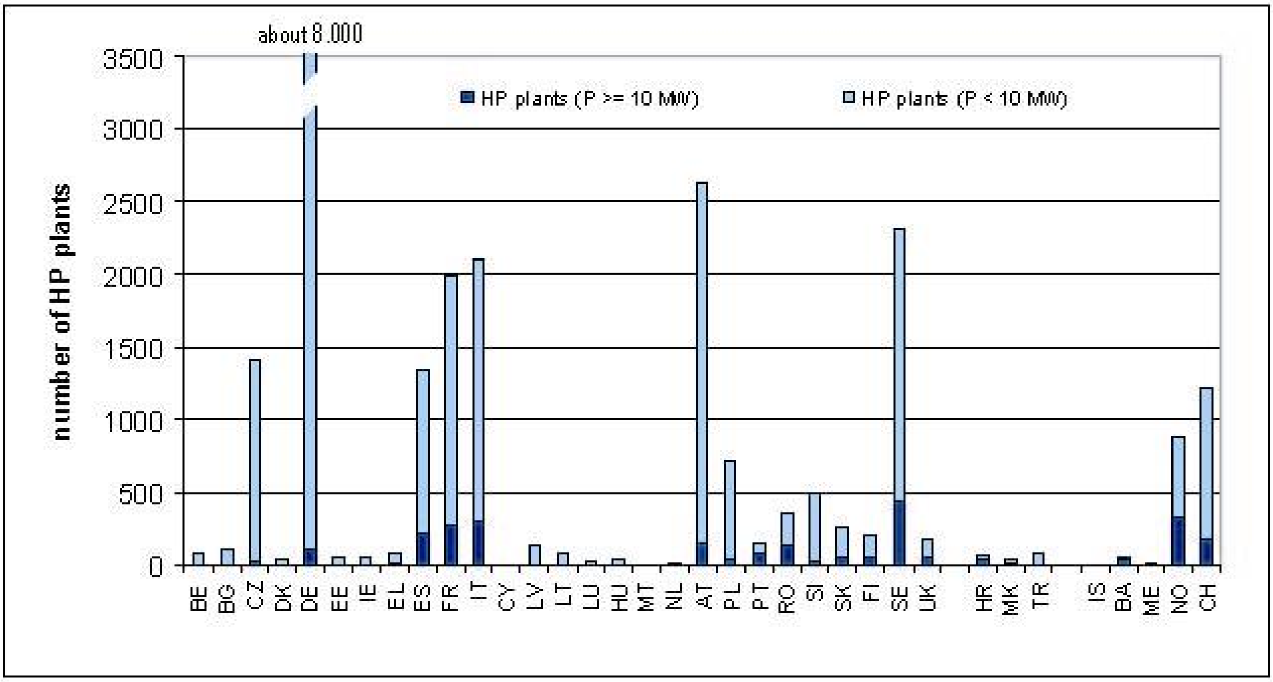


Table 2.3 : Number of hydropower plants (Source: * numbers from SHERPA 2006; ** ENTSO-E Statistical Yearbook 2009 and combination of sources for BG, IE, EL, FI, HU, LV, LT, SE, UK and NO: NVE, CH: BFE), *** data provided by EURELECTRIC

Country code	*Country*	*Number SHPP (P < 10 MW)**	*Number of LHPP** (P >= 10 MW)*	*Number of LHPP*** (P >= 10 MW)*
BE	Belgium	80	4	9
BG	Bulgaria	102	9	28
CZ	Czech Republic	1389	18	20
DK	Denmark	38	0	1
DE	Germany	8000	107	128
EE	Estonia	41	0	0
IE	Ireland	44	4	9
EL	Greece	61	16	27
ES	Spain	1119	220	284
FR	France	1717	273	302
IT	Italy	1799	304	365
CY	Cyprus	n.a.	0	0
LV	Latvia	140	3	4
LT	Lithuania	78	1	3
LU	Luxembourg	24	2	3
HU	Hungary	34	2	2
MT	Malta	n.a.	0	0
NL	Netherlands	10	3	3
AT	Austria	2485	146	191
PL	Poland	676	34	14
PT	Portugal	68	78	60
RO	Romania	221	140	134
SI	Slovenia	478	18	23
SK	Slovakia	202	52	15
FI	Finland	152	57	74
SE	Sweden	1869	442	229
UK	United Kingdom	126	43	50
		20953	**1974**	**1978**
HR	Croatia	32	35	
MK	Macedonia	25	7	
TR	Turkey	76	n.a.	
IS	Island	n.a.	n.a.	
BA	Bosnia & Herzegowina	19	33	
ME	Montenegro	7	2	
NO	Norway	547	336	
CH	Switzerland	1043	177	
		22702	**2564**	

2.2.3.4 Pumped storage hydropower stations and storage hydropower stations

Storage and pumped storage hydropower stations are presently the largest and most cost effective storage systems within Europe (Deutsche Energie Agentur dena, Abschlussbericht NNE-Pumpspeicher, 24.112008). Short start-up times of about 0.5 to a few minutes and high efficiencies and capacities are major advantages. With an efficiency of 75%, PSPP e.g. in Germany are used to supply peak current at peak load times. In contrast to these daily storages with the ability to realize several hundred cycles a day (London Research International (LRI) “Survey of energy storage options in Europe”, 2010: e.g. Kops II, Austria, discharge time 48 h) monthly and seasonal storages prevail in Norway and the Alps. Storages in these countries are filled in summer, when e.g. in the Alps a large amount of melting water is available and consumption and thus prices are low. Within the cold period, electricity is produced and e.g. in Norway used for electric heating. Originally, storage capacity was built to counteract an unsteady electricity demand. With larger shares of wind and solar energy, also for a fluctuant production backup capacities are required.

Storage and pumped storage power plants fulfil various tasks:

- Shifting of power generation from summer to winter (e.g. Alpine region),
- Peak Load Coverage,
- Storage during low demand times,
- Storage of surplus wind or PV generation.

Furthermore ancillary services like “Black-Start” capabilities (very fast outage reserve for large thermal or nuclear units; PSP stations can be started without a network connection) and frequency control can be performed.

With the increasing amount of renewable energy capacity, storage and grid stabilization will become prominent issues within the next years. According to the SETIS workshop on electricity storage in stationary applications (Petten, 3 December 2008) “one of the main reasons behind the ability of the European grid to cope with the current level of variable power generation is certainly due to past investments in hydropower and in pumped storage plants”.

Pumped storage power plants (PSPP)

Available data on pumped storage capacities were compiled from EUROSTAT and from data compiled by the Technical University of Graz, Institute for Electricity Economics and Energy Innovation (IEE). Figures are also given in the NREAPs (see 2.3).

According to the EUROSTAT yearly statistics, in 2008 a pumped storage capacity of 40.3 GW was installed in the EU-27 (Table 2.4), representing 5% of the total (fossil, nuclear, renewable) electrical capacity of about 800 GW. Data published by the TU Graz (Table 2.4) correspond to the EUROSTAT value for 2008 although these numbers do not include data for Sweden, Finland and the Baltic states. These countries do not report PSP themselves, so no significant mistake is expected for those numbers. Figure 2.9 shows the development of the European PSP stations’ capacity until 2020. Within the next years an additional capacity of about 70 GW is going to be built. This number corresponds to “firm” projects, which definitely will be built (Figure 2.10 , Figure 2.11).

Figure 2.9: Development of installed PSP stations in Europe (source: Huber, Gutschi, TU Graz:Lecture at Andritz headquarter, 27th Oct. 2010)

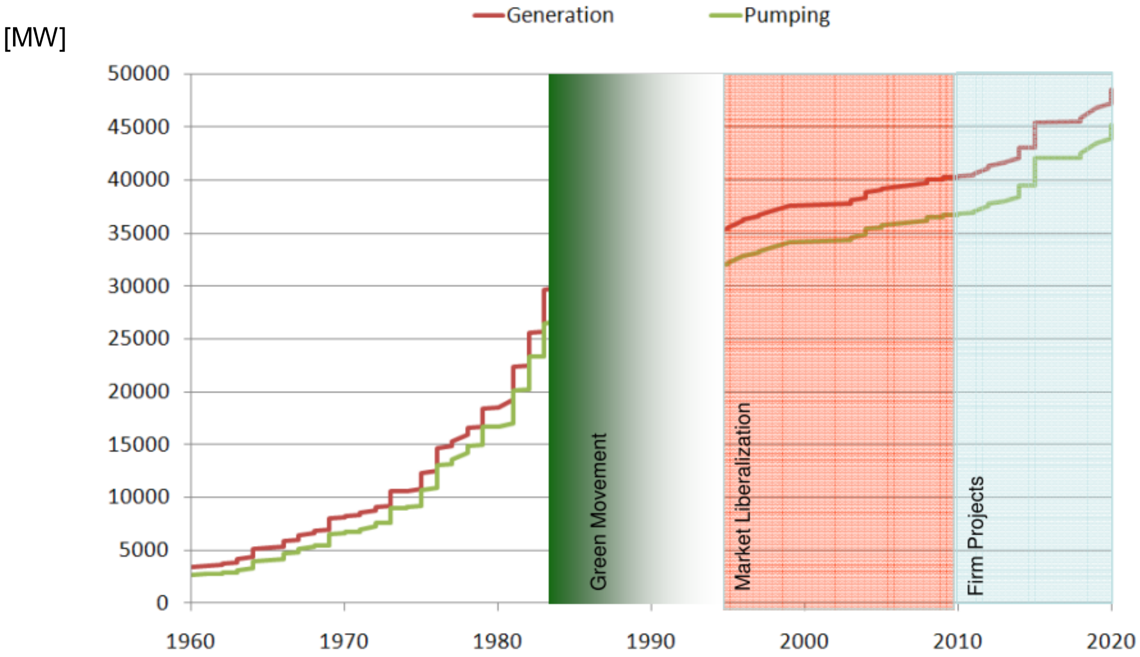


Figure 2.10: PSP stations planned, projected and under construction (Source: Huber CH., Gutschi, CH., 10/2010, IEE , TU Graz, lecture given at Andritz headquater)

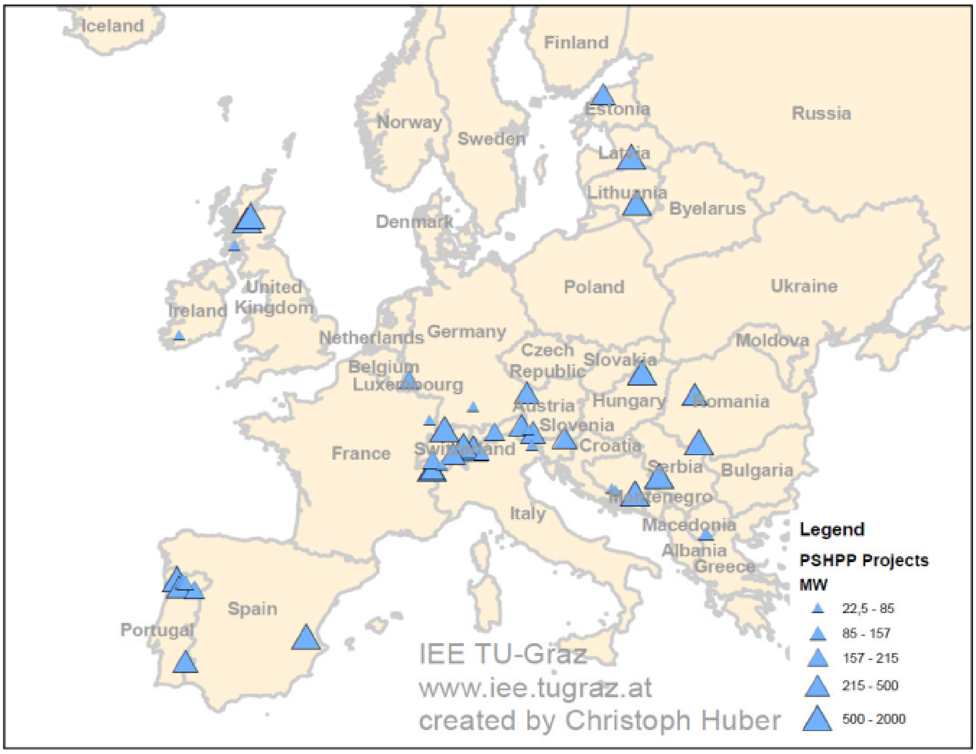


Figure 2.11: PSP stations planned and in construction (Source: Huber CH., Gutschi, CH., 2010, IEE , TU Graz)

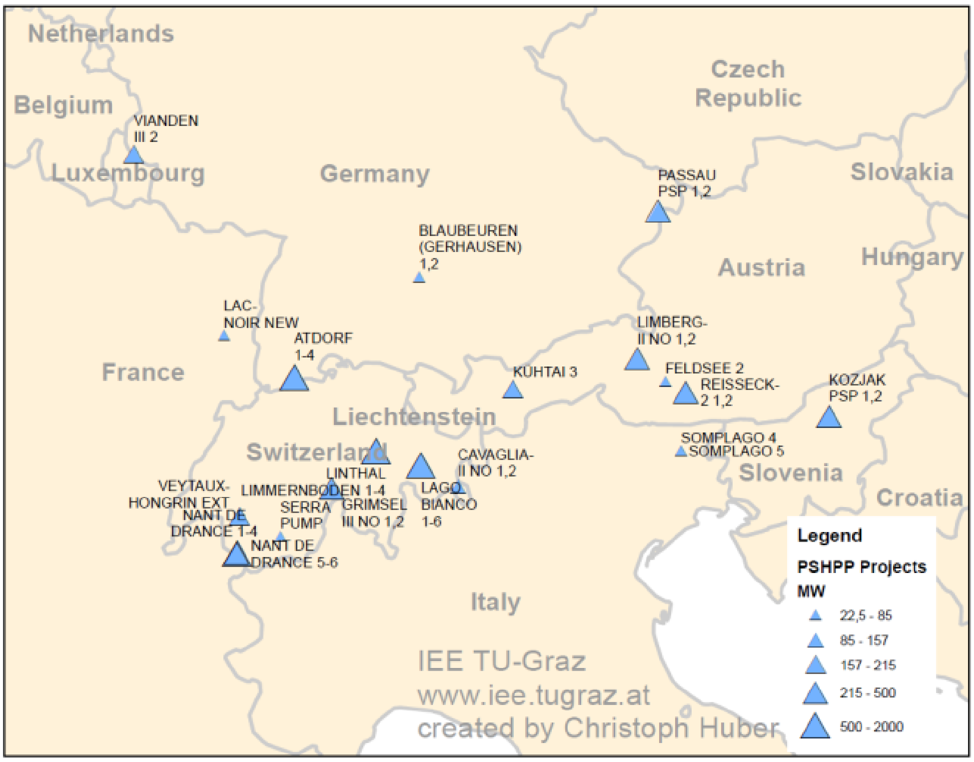


Table 2.4: Comparison of pumped storage to HP capacity

	Pumped storage capacity [GW]	Installed HP capacity without PSP [GW]
EUROSTAT Yearly Statistics 2008, E27	40.3	102.7
TU Graz* (without SE, FI, Baltic states and NO)	40.0** (47.3***)	

*source: Huber, Gutschi, TU Graz:Lecture at Andritz headquarter, 27th Oct. 2010; ** generation (not pumping) capacity; *** forecast 2020

Numbers on the capacity of pumped storage power (PSP) stations are shown in Figure 2.12 on an individual country basis. Capacity data of the TU Graz represent a forecast of 2020, the EUROSTAT values show installed capacities for 2008.

For many countries an increase in PSP capacity can be recognized from 2008 to 2020. For countries with a slight decrease, data are supposed to show minor mistakes.

The numbers in the NREAP of Spain (Table 2.13) show a decrease in PSP from 2005 to 2010 and an increase to 5700 MW is expected until 2020. It is therefore assumed that the EUROSTAT value of 5347 MW probably does not only contain PSP but also storage capacities.

For Italy the numbers of PSP capacity by EUROSTAT and HUBER are about three time the value of the NREAP (Table 2.13). According to Dr. Huber (personal communication) Italy distinguishes between “fluente”, “bacino” and “serbatoio”, the two latter definitions correspond to storage plants and are discriminated according to filling times by natural flow. Thus the numbers of TU Graz and EUROSTAT probably include storage HPP together with PSP stations.

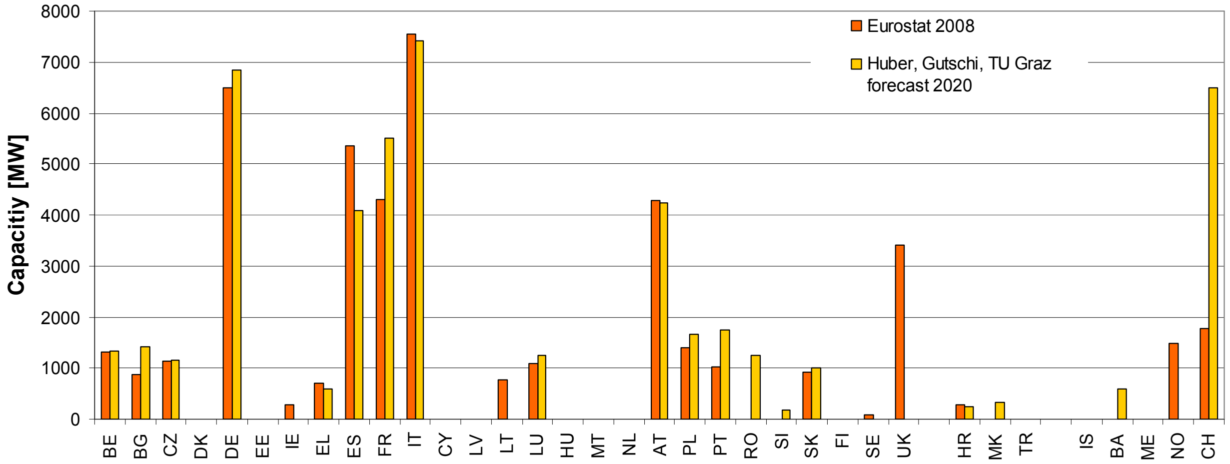
For Switzerland the Federal Agency of Energy (BFE) reported a capacity of 1383 MW for PSP stations (Table 2.5, source: hppt://www.bfe.admin.ch/themen/). The data of Huber and Gutschi predict a considerable rise in PSP capacities.

A comparison with the figures published within the NREAPs is given in section 2.3.

Table 2.5: Installed capacity and generation of 533 HP plants (P > 300 kW) according to different categories

Switzerland CH	*Run-of-the-river stations*	*Storage plant*	*Pumped storage plants*	*Total*
Max. capacity [MW]	3707	8073 (60%)	1383 (10,5%)	13163
Mean generation [GWh/a]	16611	17397	1594	35602

Figure 2.12: Installed PSP in Europe (source: EUROSTAT 2008) and existing and firm projects of PSP (source: Huber, Gutschi, forecast 2020, TU Graz: Lecture at Andritz headquarter, 27th Oct. 2010); values for Spain and Italy exceed those in the NREAPs



Storage power plants and storage capacities

Reservoirs of HP plants possess different sizes of storage volumes. They can be classified according to the cycle of operation for drainage and refill.

Numbers on storage plants were only found in individual country publications. In some countries e.g. Germany daily and monthly storages prevail. Out of 406 HP stations with P > 1 MW, only 18 facilities corresponding to 7% of the total capacity possess a yearly storage. Switzerland e.g. has a high percentage (about 60%) of its total HP capacity installed in (mainly seasonal) storage plants (Table 2.5).

Data on the hydro storage capacity are compiled for some countries in Table 2.6. The storage capacity would be sufficient to store about 4% of the total gross electricity production of 3374 TWh in the EU-27 in 2008 or the total production of the EU-27 wind power plants in 2008 of about 142 TWh.

Today Norway comprises about 50 % of the European hydro storage capacity and doubling is possible according to the Norwegian electricity company Statkraft (neue energie 07/2010). This can be achieved not only by constructing new storages but also by converting existing (storage) HP plants into PSP stations by an increased installation of pumps with a storage management and/or by converting turbines to a pumping mode at existing HP installations with storage basins.

As main drawbacks for the building of new storage power plants environmental impacts and social acceptance have to be considered.

Table 2.6 : Total hydropower storage capacities of different countries (source: neue energie 07/2010, p. 25-31)

	Norway	*Sweden*	*Germany*	*Switzerland*	*Austria*
Capacity of storages [TWh]	84	34	0,04	30	

2.2.4 The hydropower potential

For centuries hydropower has been an important and well developed source of energy in those European countries, which possess hydropower potentials. Therefore the installed capacities only rose moderately. Between 2003 and 2008 the total installed capacity of the HP stations in the EU-27 increased from 137.7 GW to 142.7 TWh, i.e. by 3.6 %.

With the efforts of the countries to enlarge the share of renewable energy sources, an essential question concerns the maximum potential of HP that can be realized under WFD conditions.

Data on still remaining capacities (GW) and additional gross annual production (GWh) in European countries have been compiled in various studies. When comparing numbers, attention has to be paid to the definition of the potential, to the region considered and if the potential of border rivers is totally included.

Also the use of the different terms can change from MS to MS. In Germany e.g. the term “Potential” is often used when referring to power (W, MW, GW…) and not to energy (kWh, MWh, GWh…).

2.2.4.1 Definitions

Values for the hydropower potential can vary drastically depending on the definition, that is used. While the line potential is only a theoretical quantity, indicating the maximum of HP energy of a country, the realizable potential technical takes into account economical and ecological constraints.

Theoretical potential (Line Potential)

The total amount of potential energy contained in inland waters due to geographic high and flow is called the theoretical potential E_L . The theoretical potential is the upper limit of energy stored in surface water running to the sea. It can never be used completely. Flow resistances and losses due to the use of a non-ideal machinery, utilized to convert the water power into electricity reduce the usable potential by at least 30 to 40%. It can be determined by the following calculation:

$E_L = \Sigma\, P_{L,MQ,i} \cdot 8.760\ h$

with $P_{L,MQ,i}$ being the theoretical potential power of a river segment at medium flow MQ for an elevation difference of Δh

$P_{L,MQ} = \Sigma\, MQ_i \cdot \Delta h_i \cdot \rho_W \cdot g$

$\rho_W = 1\ kg/m^3$ (density of water)

$g = 9{,}81\ m/s^2$ (gravitation constant).

Technical potential

The technical potential is the part of the theoretical potential that can technically be exploited considering the head utilization rate and the machine efficiencies. Different definitions are used.

In some publications the technical potential is related to all sections of all stretches of running water (e.g. Wasserwirtschaft 9/2010 for Germany, PÖYRY for Austria). On the other side a technical potential may be determined at specific sites (e.g. Scottish Hydropower Resource Study, Final Report, August 26th 2008 by Nick Forrest Associates Ltd, The Scottish Institute of Sustainable Technology SISTech and Black&Veatch Ltd).

Technical-economical potential

The technical potential can only be developed under certain economical conditions, resulting in the technical-economical potential.

Environmental compliant/compatible, ecological potential

When evaluating studies on HP potential it often is not clear which environmental requirements have been considered. The nomenclature shows variations like e.g. Environmentally compliant potential (complies with good practice guidelines) and Environmentally compatible potential (complies with environmental and legal requirements) and sometimes Ecological potential but the background of potential calculations concerning environmental restrictions often cannot be extracted.

Realisable potential

The environmentally and socially responsible potential is the result if all constraints for the development of the theoretical HP potential are taken into account.

2.2.4.2 The SHP potential

The total capacity and generation of SHP are shown in Figure 2.13 and Figure 2.14. Beside the actual data from 2006, the SHP additional capacity and potential are given accounting for economic and environmental constraints for upgrading old and installing new power plants. The data were gathered within the SHERPA project from different sources: EUROSTAT, reports, from experts, associations and the Internet. From the SHERPA publications it cannot be followed which ecological constraints where considered in the collected data on additional potential. The data collection lists for each country a section “Impact of EU Directives” with a subtitle “WFD” .

For Sweden it is said e.g. “It is already now clear that the WFD will affect the SHP in Sweden in some way. But more precise how it should be interpreted is under discussion..”. Comment on WFD for Spain: “n/a” and for UK: “very negative for SHP”. No indication is found, if these comments relate to the numbers of the potentials for SHP given within the report.

The authors discovered a large variation among the data from different authors. In addition to that official sources do not always present an accurate description of SHP. Not for all member states studies exist that investigated the potential while considering technical, economical and environmental restrictions. Most data on forecasts for SHP are based on assumptions and are presumed to be relatively uncertain.

The resulting total SHP capacity and generation for the different European countries are also shown in Table 2.7 and Table 2.8.

For the EU-27 a total capacity of 23.0 GW is predicted, out of which 13.2 GW are already installed. Installing the additional 10 GW would increase the SHP capacity by 44%. 2 GW or 20% of it are expected to be built until 2010.

In 2006 about 50% or 41.6 TWh of a total, possible generation of 79.4 TWh was produced. According to a forecast from 2006 for 2010 a generation of 66% should be realized until then.

Countries like Germany and Italy would then have a degree of realisation of the potential SHP capacity larger than 80%. For many other countries there is still a large additional SHP capacity that could be realized considering economical and ecological constraints (Figure 2.15).

When including the candidate and associated countries the additional capacity and generation rise considerably. Out of 38.6 GW about 15.2 GW has been installed. The total SHP generation is estimated to be 136.0 TWh with a degree of realisation of 38% in 2006. The additional capacity and generation for SHP are expected to be 23.6 GW and about 84.4 TWh. Norway and Turkey have the largest shares in this potential growth.

Figure 2.13: Total capacity of SHP (Sources: SHERPA-1: report "Strategic Study for the Development of Small Hydro power (SHP) in the European Union" , SHERPA-2 report "Status of SHP policy framework and market development"; in Table 5 of SHERPA-1 for Hungary the data on capacity had to be exchanged with the data on generation for upgrading and new SHP according to SHERPA-2)

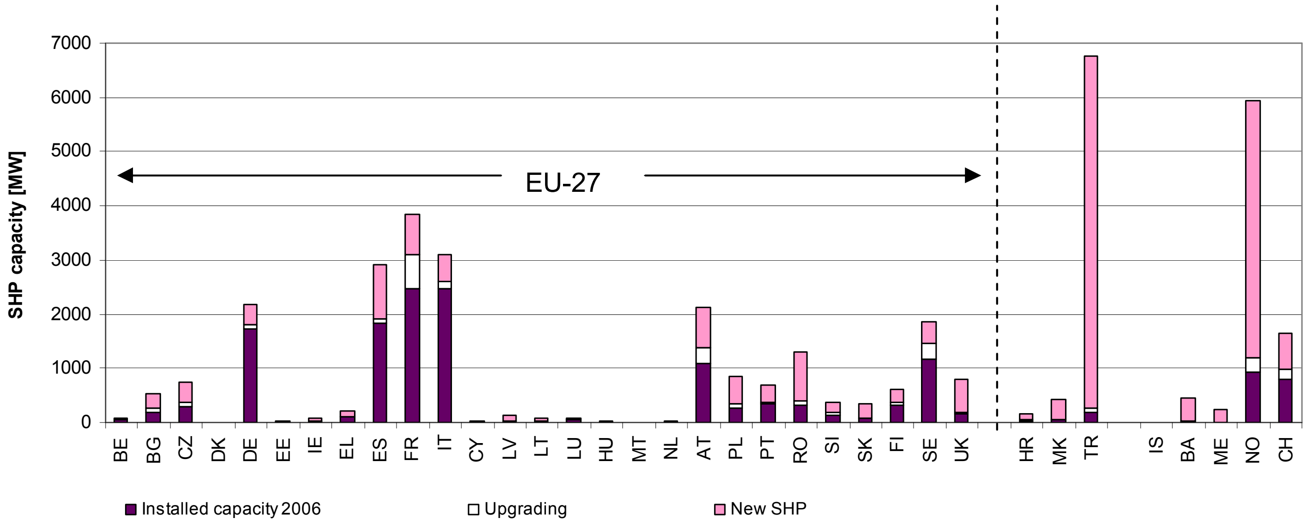


Figure 2.14: Total generation of SHP (Sources: SHERPA-1: report "Strategic Study for the Development of Small Hydro power (SHP) in the European Union" , SHERPA-2 report "Status of SHP policy framework and market development"; in Table 5 of SHERPA-1 the data on capacity had to be exchanged with the data for generation for Hungary for upgrading and new SHP according to SHERPA-2)

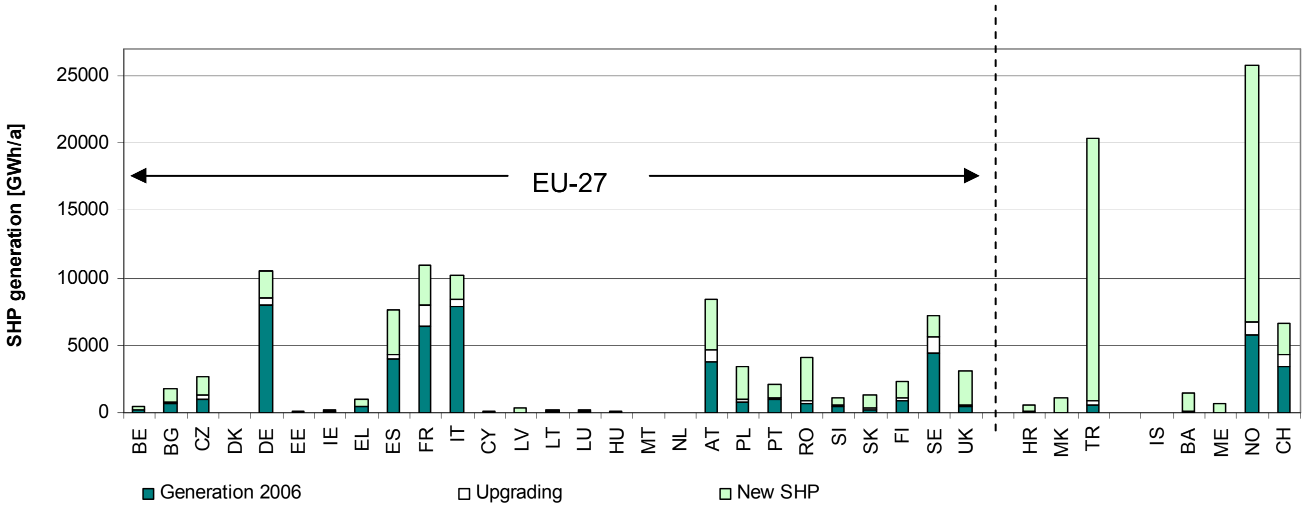


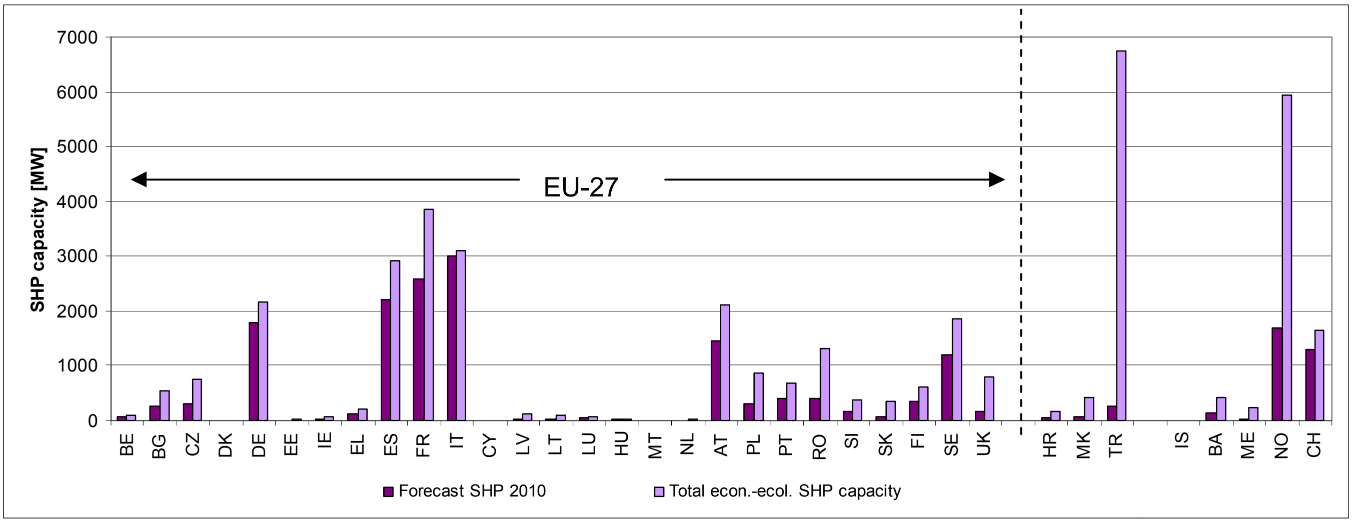
Table 2.7: Capacity data on SHP (Source: *SHERPA 1: summary report, **SHERPA 2: compilation of material collection); degree of realization = Forecast 2010 / total capacity

		Installed capacity 2006**	Additional capacity upgrading*	Additional capacity new SHP*	Total potential SHP capacity	Forecast SHP capacity 2010*	Degree of realization relative to forecast 2010
		[MW]	[MW]	[MW]	[MW]	[MW]	
BE	Belgium	57	5	26	88	60	68%
BG	Bulgaria	196	56	290	542	255	47%
CZ	Czech Republic	287	80	387	754	300	40%
DK	Denmark	9	0	0	9	9	100%
DE	Germany	1714	100	350	2164	1795	83%
EE	Estonia	5,8	3	24	32,8	7	21%
IE	Ireland	32	5	30	67	32	48%
EL	Greece	116	2	100	218	117	54%
ES	Spain	1819	100	1000	2919	2199	75%
FR	France	2473	618	750	3841	2590	67%
IT	Italy	2468	140	500	3108	3000	97%
CY	Cyprus	n.a.	0	20	20	0	0%
LV	Latvia	24	6	95	125	32	26%
LT	Lithuania	27	5	57	89	28	31%
LU	Luxembourg	40	10	19	69	42	61%
HU	Hungary	12	3	16	31	15	48%
MT	Malta	n.a.	n.a.	n.a.	n.a.	n.a.	0%
NL	Netherlands	2,4	0	12	14,4	0	0%
AT	Austria	1099	275	740	2114	1449	69%
PL	Poland	270	68	520	858	305	36%
PT	Portugal	340	20	330	690	400	58%
RO	Romania	325	81	900	1306	400	31%
SI	Slovenia	144	36	194	374	160	43%
SK	Slovakia	68	17	258	343	70	20%
FI	Finland	317	50	238	605	360	60%
SE	Sweden	1171	300	375	1846	1200	65%
UK	UK	153	38	615	806	160	20%
EU-27		13169	2018	7846	23033	14985	
HR	Croatia	33	8	123	164	38	23%
MK	Macedonia	48	12	363	423	80	19%
TR	Turkey	185	80	6485	6750	250	4%
IS	Iceland*	n.a.	n.a.	n.a.	n.a.	n.a.	
BA	Bosnia & Herzegovina	22	7	425	432	150	35%
ME	Montenegro	9	2	220	244	14	6%
NO	Norway	941	250	4750	5941	1700	34%
CH	Switzerland	794	198	650	1642	1300	79%
ALL		15201	2575	20864	38609	18517	

Table 2.8: Generation of SHP (Source: *SHERPA 1: summary report, **SHERPA 2: compilation of material collection)

		SHP generation 2006**	Additional generation upgrading*	Additional generation new SHP*	Total potential SHP generation	Forecast SHP generation 2010*	Degree of realization relative to forecast 2010
		[GWh/a]	[GWh/a]	[GWh/a]	[GWh/a]	[GWh/a]	
BE	Belgium	209	36	156	401	245	61%
BG	Bulgaria	627	158	1000	1785	810	45%
CZ	Czech Republic	964	350	1300	2614	970	37%
DK	Denmark	24	0	0	24	24	100%
DE	Germany	7996	500	2000	10496	9379	89%
EE	Estonia	14	11	95	120	31	26%
IE	Ireland	120	20	100	240	120	50%
EL	Greece	388	5	600	993	495	50%
ES	Spain	4006	350	3224	7580	6692	88%
FR	France	6383	1595	3000	10978	7487	68%
IT	Italy	7875	500	1850	10225	9237	90%
CY	Cyprus	0	0	71	71	0	0%
LV	Latvia	38	14	334	386	70	18%
LT	Lithuania	56	15	203	274	96	35%
LU	Luxembourg	111	27	67	205	130	63%
HU	Hungary	46	12	50	108	57	53%
MT	Malta	0	0	0	0	0	
NL	Netherlands	3,2	0	30	33,2	0	0%
AT	Austria	3731	933	3700	8364	5481	66%
PL	Poland	801	203	2410	3414	924	27%
PT	Portugal	1048	57	943	2048	1200	59%
RO	Romania	693	173	3193	4059	900	22%
SI	Slovenia	425	104	585	1114	452	41%
SK	Slovakia	255	64	965	1284	260	20%
FI	Finland	910	213	1200	2323	1360	59%
SE	Sweden	4457	1200	1500	7157	5000	70%
UK	UK	477	119	2550	3146	559	18%
EU-27		41657	6659	31126	79442	51979	
HR	Croatia	99	28	435	562	120	21%
MK	Macedonia	0	36	1090	1126	240	21%
TR	Turkey	502	350	19520	20372	750	4%
IS	Iceland	n.a.	n.a.	n.a.	n.a.	n.a.	
BA	Bosnia & Herzegovina	125	30	1330	1485	500	34%
ME	Montenegro	19	6	600	625	35	6%
NO	Norway	5800	1000	19000	25800	8000	31%
CH	Switzerland	3439	860	2300	6599	5000	76%
ALL		51641	8969	75401	136011	66624	61%

Figure 2.15: Total economic-ecologic capacity of SHP (total capacity from Figure 2.13) and forecast for 2010 (Sources: SHERPA-1: report “Strategic Study for the Development of Small Hydro power (SHP) in the European Union” , SHERPA-2 report “Status of SHP policy framework and market development”)



2.2.4.3 The total HP potential

Ch. Huber (PhD Thesis, TU Graz, 2010) analyzed various studies on hydro power potentials especially for eastern and southern Europe (Figure 2.16).

Numbers for countries with large additional potential like Sweden, Turkey and Norway were not included in Huber’s evaluation. These numbers were instead added from individual country studies.

The comparison of Huber’s numbers with publications on Germany, France and Austria exposes minor discrepancies:

For Germany Huber cited data from studies conducted around 2003. Recently published results (Anderer et al., Wasserwirtschaft 9/2010) quote a theoretical potential of 92.6 TWh/a (only considering the German proportion of the border rivers´ potential) and a total technical potential of about 30 TWh/a.

The theoretical potential for France is the same in Figure 2.16 in French publications (L´hydroelectricite – Perspective de Developpement, Syndicat des Energie Renouveable, mars 2009; Report on HP potentials in France, Dambrine, March 2006; WFD in France, lecture given by Gh. Weisrock GPAE, ESHA Lausanne, July 2005) while the used potential differs by about 4 % and the technical potential by 14 %.

Huber determined for the investigated 17 European countries a total technical potential of 562 TWh, an actual generation of 353 TWh and thus an additionally available technical potential of 209 TWh (Table 2.9; for Albania, Serbia and Kosovo Huber found an additional technical potential of 15 TWh which is not included in Table 2.9 and Figure 2.16). This potential will reduce due to economical and ecological constraints. It is assumed, that these values will be stated in the NREAPs (chapter 2.3).

Data of Huber do not include the following countries:

- Sweden: with a rather large present potential, the realistic additional potential is estimated to be rather small at present time because ecological constraints have a strong impact;

- Turkey: Turkey actually faces the most rapid increase in HP production within Europe. With a present generation of about 44 TWh the additional techn.-econ. potential of 81 TWh today is the largest within the EU.
- Norway (Figure 3.21): The actual generation of 123 TWh could be increased by 30% with an additional techn.-econ.-ecol. potential of 37 TWh.

Adding the generation of Sweden, Turkey and Norway to the total generation of the 17 EU countries (results by Huber) the value of 584 TWh/a is about 70 TWh larger than the data from EUROSTAT for the same countries. In 2008 EUROSTAT published mean generation values (mean over the last 15 years) and so did Melin and NVE. Huber analyzed data from various sources and different years. This might be the reason for the differences.

Figure 2.16: Hydro power potential in eastern and southern European countries (source: Ch. Huber, PhD Thesis, TU Graz, 2010); different sources for Sweden (Melin, 2010), Turkey (Wasserwirtschaft 4/2010), Norway (NVE, Figure 3.21)

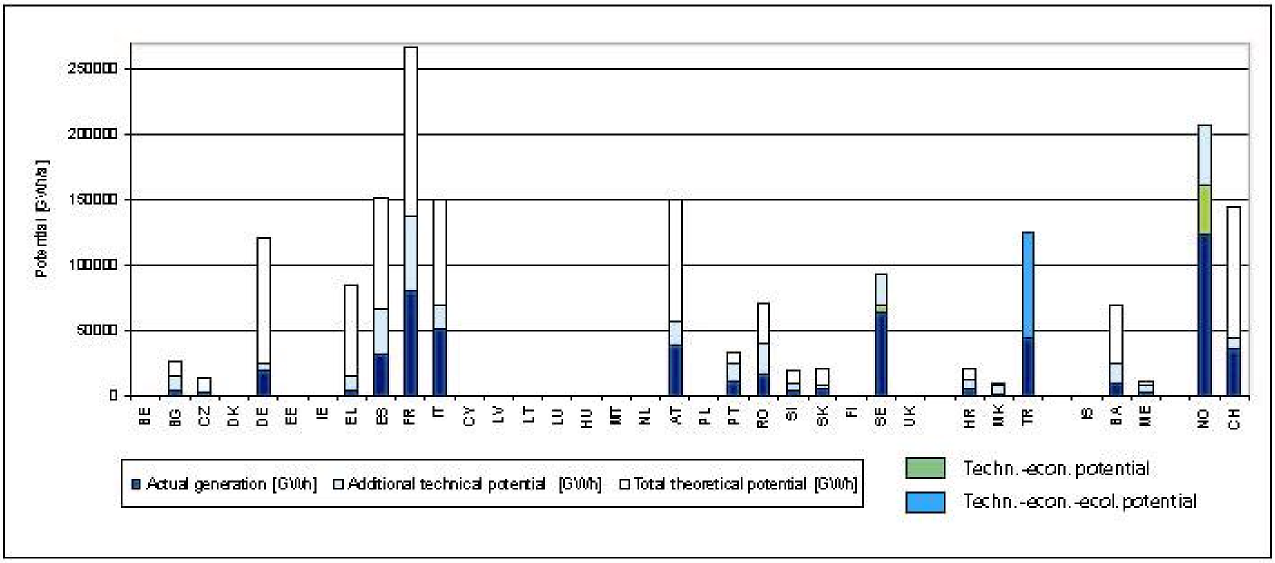


Table 2.9: Data on mean generation and additional potentials (Sources: *Huber PhD thesis; **Melin (2010), ***Wasserwirtschaft 4/2010, #NVE, EUROSTAT 2008)

[TWh]	*Actual generation, different sources*	*Actual generation (EUROSTAT 2008 -Table 2.1)*	*Additional techn. potential*	*Additional techn.-econ. potential*	*Additional techn.-econ.-ecol. potential*
17 EU countries*	353	271	209		
Sweden**	64	69	24		2 - 5
Turkey***	44	33		81	
Norway#	123	140	83		37
total	**584**	**513**			

Today data on additional potentials are best compiled in the NREAPs for the EU-27 (chapter 2.3). The largest additional potentials can be found for the candidate countries in Turkey and for the associated countries in Norway (Table 2.9).

2.2.4.4 Other data sources

The International Journal on Hydropower and Dams yearly publishes the Hydropower & Dams World Atlas, including an overview of installed capacities (both large and small hydropower), capacity under construction, planned capacity and hydropower potential. The distinction is made between the following potentials:

- Gross theoretical hydropower potential (GWh/year): The annual energy potentially available in the country if all natural flows were turbined down to sea level (or the water level of the border of the country if the watercourse extends into another country), with 100% efficiency. It is estimated on the basis of atmospheric precipitation and runoff.
- Technically Feasible hydropower potential (GWh/year): The total hydropower potential of all sites that could be, or have been, developed within the limits of current technology, regardless of economic or other considerations. Calculated based on an inventory of sites, unless otherwise specified.
- Economically feasible hydropower potential (GWh/year): That portion of the gross theoretical hydropower potential that could be, or has been, developed within the limits of the current technology and under the present and expected local economic conditions. The figure usually includes economic potential that would be unacceptable for social or environmental reasons.

Table 2.10 provides an overview of the most recent (2009) data on hydropower capacities and potential in Europe, whereby a distinction is made between the EU27 and other countries on the European continent. The following data are provided:

- Installed capacity (MW);
- Capacity under construction (MW);
- Planned capacity (MW);
- Gross theoretical potential (GWh/year);
- Technically feasible potential (GWh/year);
- Economically feasible potential (GWh/year);
- Most recent data on electricity generation from hydropower (GWh/year)

Table 2.10 shows several data that deviate from data cited before (e.g. gross theoretical potential for Germany, France, Austria and actual generation for EU-27). This reveals the difficulty in compiling the figures on potentials for different countries and keeping them up to date. Individual country studies have to be consulted to elaborate their different definitions of potentials and to distinguish for environmentally compliant potential.

It was not possible within this study to check all these different numbers.

Table 2.10: Hydropower capacities and potentials in Europe (Hydropower & Dams World Atlas, 2009)

	Capacity (MW)			Hydropower potential (GWh/year)			Actual generation Gwh/year
	Installed	Under construction	Planned	Gross theoretical	Technically feasible	Economically feasible	
Austria	12009	100	262	90000	56000	53200	35211
Belgium	107	0	n/a	600	n/a	400	359
Bulgaria	1434	91	1955,5	19810	14800	0	4610
Cyprus	1	0	0	0	23500	0	2
Czech Republic	1029	n/a	n/a	13100	3380	0	2090
Denmark	9	0	0	120	n/a	70	21
Estonia	8	1,3	5,75	1500	375	0	48
Faeroe Islands	31	0	n/a	0	250	150	96
Finland	3049	21	53	22645	16915	16024	13971
France	25400	60	418	200000	n/a	98000	68600
Germany	4310	113	20	120000	24700	20000	16975
Greece	3243	484	160	80000	20000	15000	2254
Greenland	56	15	22,5	550000	17500	0	202
Hungary	54	3	n/a	7446	4590	0	213
Irish Republic	249	n/a	n/a	1400	1180	950	725
Italy	20000	n/a	2100	190000	60000	50000	45511
Latvia	1500	n/a	n/a	7200	4000	3900	2600
Lithuania	120	3	55	6034	2464	1295	451
Luxembourg	40	0	0	175	140	137	111
The Netherlands	38	n/a	7	11396	*	130	110
Poland	839	20	406	25000	12000	7000	2042
Portugal	4959	217	1650	32150	24500	19800	12000
Romania	6422	659	1206	70000	40000	0	17105
Slovenia	1776	0	140	10000	6607	6000	4280
Spain	18559	264	n/a	162000	61000	37000	22888
Sweden	16200	10	n/a	200000	130000	90000	68400
United Kingdom	1539	n/a	n/a	0	**	0	4000
Total EU27	**122981**	**2061,3**	**8460,75**	**1820576**	**523901**	**419056**	**324875**
Albania	1450	n/a	2000	40000	15000	11750	5370
Belarus	13	34	129,5	7500	3000	1300	50
Bosnia-Herzogovina	2380	3,8	570	70128	24000	19000	6200
Croatia	2076	41	670	20000	12000	10500	5023
Iceland	1879	80	382	18400	64000	40000	12427
Kosovo	n/a	n/a	n/a	0	n/a	0	n/a
FYR of Macedonia	528	36	809	8863	5500	0	1220
Moldova	64	n/a	n/a	2000	0	1000	318
Montenegro	658	n/a	711	0	10846	0	2000
Norway	29490	587	3706	600000	205700	205700	122700
Russia	49700	7000	34500	2295000	1670000	852000	180000
Serbia	2820	140	1576	27300	17600	0	10330
Switzerland	13355	146	n/a	125000	41000	0	37590
Turkey	13700	8600	22700	433000	216000	140000	48000
Ukraine	4552	n/a	160	44700	21500	16500	12185
Total non EU27	**122665**	**16667,8**	**67913,5**	**3691891**	**2306146**	**1297750**	**443413**
Total Europe	**245646**	**18729,1**	**76374,25**	**5512467**	**2830047**	**1716806**	**768288**

* < 110 MW
** ~ 4000 MW
n/a not available

2.3 Scan of the renewable energy action plans

2.3.1 Installed capacity and electricity generation from hydropower plants

2.3.1.1 Raw data from the NREAPs

The raw data from the NREAPs have been extracted from the EEA Report 'Renewable Energy Projections as Published in the National Renewable Energy Action Plans of the European Member States - Covering all 27 EU Member States' (Report ECN-E--10-069; February 1, 2011). The only modifications made to the raw data are:

- Data on installed capacities for plants < 1 MW, 1 – 10 MW and > 10 MW for Sweden and France include pumped storage plants. Data on total installed capacity have been corrected for the pumped storage plants.
- Data on production for plants < 1 MW, 1 – 10 MW and > 10 MW for Sweden include production from pumped storage plants. Data on total production for Sweden have been corrected for the production from pumped storage plants.
- An earlier version of the report (December 13, 2010) provided detailed data for Estonia and Poland. These have been included.
- NREAP of Hungary provides detailed data. These have been included.

Table 2.11 provides an overview of the evolution of the total installed capacity of hydropower plants according to the NREAPs. Last line gives an overview of the increase relative to the base year 2005.

Table 2.12 provides an overview of the evolution of the total electricity production from hydropower plants according to the NREAPs. Last line gives an overview of the increase relative to the base year 2005.

2.3.1.2 Adjusted NREAP data

The following data from other sources have been used to modify and complete the raw data:

- Data on installed capacities for plants < 1 MW, 1 – 10 MW and > 10 MW for Sweden and France include pumped storage plants. Data on total installed capacity have been corrected for the pumped storage plants.
- Data on production for plants < 1 MW, 1 – 10 MW and > 10 MW for Sweden include production from pumped storage plants. Data on total production for Sweden have been corrected for the production from pumped storage plants.
- An earlier version of the report (December 13, 2010) provided detailed data on breakdown into capacity ranges for Estonia and Poland. These have been included.
- NREAP of Hungary provides detailed data on breakdown into capacity ranges. These have been included.
- Data on installed capacities and electricity generation for capacity ranges < 1 MW and 1 – 10 MW have been added to yield a 'new' capacity range < 10 MW. This has been done to be able to make use of the results of the SHERPA data, which only deal with capacities < 10 MW.

- Belgium: SHERPA data indicate a total installed capacity of plants with a capacity < 10 MW of 62 MW, generating 166 GWh of electricity in 2005. 2005 data for plants with a capacity > 10 MW have been calculated from the total specified in the NREAP. There are no known plans for new capacity for large hydropower plants (> 10 MW), so all future capacity increase from the NREAP can be attributed to small plants (< 10 MW). Electricity generation for the large plants (> 10 MW) has been assumed equal to generation in 2005 for 2010, 2015 and 2020. Electricity generation for the small plants (< 10MW) have been calculated from the total specified in the NREAP and the estimated generation for the large plants.
- Bulgaria: SHERPA data indicate a total installed capacity of plants with a capacity < 10 MW of 184 MW, generating 588 GWh of electricity in 2005. 2005 data for plants with a capacity > 10 MW have been calculated from the total specified in the NREAP. Wikipedia mentions 3 new large HPP with a respective capacity of 160, 93 and 90 MW to be developed over the coming years (en.wikipedia.org/wiki/Energy_in_Bulgaria). Based on the growth of total hydropower capacity from the NREAP, the hypothesis has been made that an additional 160 MW of large plants will be on stream in 2015 and the remaining 183 MW in 2020. Capacity increase in small plants (< 10 MW) has been calculated from the total specified in the NREAP. Electricity generation from the small plants (< 10 MW) for 2010, 2015 and 2020 has been estimated by correcting the specific generation (GWh/MW) of small plants in 2005 with the specific generation of all plants as calculated from the NREAP for a specific year relative to the specific generation of all plants as calculated from the NREAP for 2005. Electricity generation for the large plants (> 10MW) have been calculated from the total specified in the NREAP and the estimated generation for the small plants.
- Ireland: SHERPA data indicate 103 GWh of electricity generated from the 38 MW of installed capacity for small plants (< 10 WM) in 2005. This installed capacity of small plants in 2005 equals the one specified in the irish NREAP. 2005 electricity generation from plants with a capacity > 10 MW have been calculated from the total specified in the NREAP. Electricity generation from the small plants (< 10 MW) for 2010, 2015 and 2020 has been estimated by correcting the specific generation (GWh/MW) of small plants in 2005 with the specific generation of all plants as calculated from the NREAP for a specific year relative to the specific generation of all plants as calculated from the NREAP for 2005. Electricity generation for the large plants (> 10MW) have been calculated from the total specified in the NREAP and the estimated generation for the small plants.
- Hungary: SHERPA data indicate a total installed capacity of plants with a capacity < 10 MW of 12 MW, generating 50 GWh of electricity in 2005. The total installed capacity of plants with a capacity < 10 MW is equal to the total installed capacity of plants with a capacity < 10 MW specified for 2010 in the NREAP, so the same distribution of installed capacities over the capacity ranges < 1 MW and 1-10 MW as specified in the NREAP for 2010 has been used. 2005 data for plants with a capacity > 10 MW have been calculated from the total specified in the NREAP. Electricity generation from plants with a capacity > 10 MW has been calculated by correcting the specific generation (GWh/MW) of large plants in 2010 with the specific generation of small plants in 2010 as calculated from the NREAP relative to the specific generation of small plants as calculated from the SHERPA data for 2005.

- The Netherlands: SHERPA data indicate a total installed capacity of plants with a capacity < 10 MW of 2,4 MW, generating 3,2 GWh of electricity in 2005. Installed capacity of large plants (> 10 MW) in 2005 has been calculated from the total specified in the NREAP. ECN-BS--09-001 versie 2 (26 januari 2009) specifies an increase of the capacity of large hydropower plants with 135 MW of installed tidal capacity. Based on the growth of total hydropower capacity from the NREAP, the hypothesis has been made that an additional 135 MW of large plants will be on stream in 2020. Capacity increase in small plants (< 10 MW) has been calculated from the total specified in the NREAP. Electricity generation from large plants (> 10 MW) in 2010 and 2015 has been considered equal to the electricity generation from those plants in 2005, which has been calculated from the total electricity generation in 2005 (NREAP) and the SHERPA data on generation from small plants. As installed capacity of small plants in 2020 is equal to installed capacity of small plants in 2015, the hypothesis has been made that electricity generation from small plants in 2020 equals electricity generation from small plants in 2015. Electricity generation from large plants in 2020 has been calculated from the total specified in the NREAP and the estimated generation for the small plants.
- United Kingdom: The Scottish and the England & Wales hydro resource studies by the British Hydropower association pointed out that there was only a potential for development of small plants (< 10 MW) with a potential increase in capacity of 803 – 905 MW. UK NREAP considers an increase in total installed capacity by 2020 with 629 MW, so it has been assumed that this increase was completely due to small plants, keeping the installed capacity of large plants (> 10 MW) constant over the period 2005 – 2020. Electricity generation from large plants for 2010, 2015 and 2020 has been considered equal to electricity generation from large plants in 2005. Electricity generation from small plants in 2020 has been calculated from the total specified in the NREAP and the estimated generation for the large plants.

Table 2.13 provides an overview of the evolution of the total installed capacity of hydropower plants according to the NREAPs. Last line gives an overview of the increase relative to the base year 2005.

Table 2.14 provides an overview of the evolution of the total electricity production from hydropower plants according to the NREAPs. Last line gives an overview of the increase relative to the base year 2005.

2.3.2 Number of hydropower plants

The number of small (< 10 MW) and large (> 10 MW) hydropower plants for 2005 are available from Table 2.3. In case of increasing installed capacity, the NREAPs do not distinguish between refurbishment of existing plants and new plants. In this study, we have made the hypothesis that all additional capacity is due to new plants and the number of new plants have been calculated by dividing the additional capacity for small (< 10 MW) and large (> 10 MW) by the average capacity of each capacity range, calculated for each MS from the available 2005 data. Only exceptions to this methodology are the large hydropower plants in Bulgaria (1 additional plant in 2015 and 2 more in 2020) and The Netherlands (2 additional (tidal) plants in 2020). Figure 2.17 provides an overview of the evolution of the number of small and large hydropower plants in the EU27.

Table 2.11: Evolution of the total installed capacity of hydropower plants according to the NREAPs (raw data)

	Electric capacity < 1MW				1MW < electric capacity < 10MW				Electric capacity < 10MW				Electric capacity > 10MW				Pumped storage				Total hydropower			
	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020
Belgium																					108	112	123	140
Bulgaria																					2078	2090	2280	2549
Czech Republic	123	162	191	194	154	142	147	147	277	304	338	341	743	743	743	743					1020	1047	1099	1125
Denmark	0	0	0	0	10	10	10	10	10	10	10	10	0	0	0	0	0	0	0	0	10	10	10	10
Germany	641	507	534	564	1073	987	1012	1043	1714	1494	1546	1607	2615	2558	2620	2702	4012	6494	6494	7900	4329	4052	4165	4309
Estonia									0	0	0	0								300	5	7	8	8
Ireland	18	18	18	18	20	20	20	20	38	38	38	38	196	196	196	196	0	0	0	0	234	234	234	234
Greece	26	29	34	39	63	154	185	216	89	183	219	255	3018	3054	3396	4276	700	700	700	1580	3107	3237	3615	4531
Spain	239	242	253	268	1534	1603	1764	1917	1773	1845	2017	2185	16447	16842	18032	20177	2727	2546	3700	5700	18220	18687	20049	22362
France	433	441	462	483	1618	1647	1727	1807	2051	2088	2189	2290	18995	19333	20269	21206	4303	4800	5800	6800	25349	25800	27050	28300
Italy	391	444	547	650	1947	2250	2750	3250	2338	2694	3297	3900	13128	13886	13893	13900	1334	2399	2499	2600	15466	16580	17190	17800
Cyprus																								
Latvia	24	24	25	27	1	1	1	1	25	25	26	28	1511	1511	1524	1522					1536	1536	1550	1550
Lithuania					27	26	32	40	27	26	32	40	101	101	101	101	0	0	0	0	128	127	133	141
Luxemburg	2	2	2	3	32	36	36	41	34	38	38	44	0	0	0	0	1100	1100	1300	1300	34	38	38	44
Hungary																						51	52	67
Malta																								
Netherlands																	0	0	0	0	37	47	68	203
Austria	308	455	465	497	692	726	743	794	1000	1181	1208	1291	6907	7053	7215	7707	3929	4285	4285	4285	7907	8235	8423	8997
Poland																	0	0	0	0	915	952	1002	1152
Portugal					323	410	550	750	323	410	550	750	4496	4524	6467	8798	537	1036	2454	4302	4816	4934	7017	9548
Romania	63	63	90	109	262	324	547	620	325	387	637	729	5964	6026	6650	7000	0	0	0	0	6289	6413	7287	7729
Slovenia	108	118	120	120	37	37	52	57	145	155	172	177	836	916	1021	1176	0	0	0	0	981	1071	1193	1354
Slovak Republic	16	25	40	60	46	55	82	122	62	80	122	182	1535	1542	1610	1630	0	0	0	0	1597	1622	1732	1812
Finland	30	30	30	30	280	280	280	280	310	310	310	310	2730	2750	2750	2790	0	0	0	0	3040	3050	3050	3100
Sweden	140	140	140	140	765	765	765	765	905	905	905	905	15397	15402	15407	15412	43	43	43	43	16345	16350	16355	16360
United Kingdom	56				102				158				1343								1501	1710	1920	2130
All MS	2618	2700	2951	3202	8986	9473	10703	11880	11604	12173	13654	15082	95962	96437	101894	109336	18685	23403	27275	34810	115052	117992	125643	135555
Increase		103%	113%	122%		105%	119%	132%		105%	118%	130%		100%	106%	114%						103%	109%	118%

🟨 Pumped storage included in capacities

Table 2.12: Evolution of the total electricity production from hydropower plants according to the NREAPs (raw data)

	Electric capacity < 1MW				1MW < electric capacity < 10MW				Electric capacity < 10MW				Electric capacity > 10MW				Pumped storage				Total hydropower			
	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020
Belgium																					350	362	391	440
Bulgaria																					4336	3260	3534	3951
Czech Republic	343	575	670	724	728	474	490	490	1071	1049	1160	1214	1309	1060	1060	1060					2380	2109	2220	2274
Denmark	0	0	0	0	23	31	31	31	23	31	31	31	0	0	0	0	0	0	0	0	23	31	31	31
Germany	3157	2300	2450	2550	3560	4050	4250	4500	6717	6350	6700	7050	12971	11650	12300	12950	7786	6989	6989	8395	19687	18000	19000	20000
Estonia									0	0	0	0									20	26	30	30
Ireland									0	0	0	0					0	0	0	0	760	701	714	701
Greece	106	112	131	150	218	593	713	833	324	705	844	983	4693	4283	4840	5593	593	776	774	1703	5017	4988	5684	6576
Spain	893	831	715	803	5719	4973	4617	5477	6612	5804	5332	6280	28891	28813	31399	33314	5153	3640	6577	8023	35503	34617	36732	39593
France	1796	1694	1727	1759	6111	5766	5878	5990	7907	7460	7605	7749	62332	61563	62758	63953	4705	5130	6199	7268	70240	69024	70363	71703
Italy	1851	1737	2009	2281	7391	7459	8627	9796	9242	9196	10636	12077	34525	32946	31434	29923	1268	2739	2734	2730	43768	42141	42070	42000
Cyprus																								
Latvia	59	59	63	67	3	3	3	3	62	62	66	70	2880	2844	2899	2981					2942	2906	2965	3051
Lithuania					66	79	93	117	66	79	93	117	385	353	353	353	0	0	0	0	451	432	446	470
Luxemburg	5	6	6	7	93	100	100	117	98	106	106	124	0	0	0	0	785	785	928	928	98	107	107	124
Hungary																						194	196	237
Malta																								
Netherlands																	0	0	0	0	89	128	200	714
Austria	1448	2129	2178	2326	3247	3400	3477	3715	4695	5529	5655	6041	32430	33013	33768	36071	2738	2732	2732	2732	37125	38542	39423	42112
Poland																	0	0	0	0	2201	2279	2439	2969
Portugal					381	827	1108	1511	381	827	1108	1511	4737	8916	9993	12562	387	0	0	0	5118	9742	11101	14074
Romania	61	95	135	164	538	624	1054	1195	599	719	1189	1359	15493	15848	17490	18410	0	0	0	0	16091	16567	18679	19768
Slovenia	451	262	270	270	155	192	247	270	606	454	517	540	3493	3744	4042	4581	0	0	0	0	4099	4198	4559	5121
Slovak Republic	80	75	119	179	198	164	244	364	278	239	363	543	4360	4595	4798	4857	0	0	0	0	4638	4834	5161	5400
Finland	140	150	150	150	1260	1290	1290	1310	1400	1440	1440	1460	12510	12780	12780	12960	0	0	0	0	13910	14210	14210	14410
Sweden	458	458	458	458	3027	3027	3027	3027	3485	3485	3485	3485	69318	67693	66069	64444	71	71	71	71	72874	71249	69625	68000
United Kingdom	44				399				443				4478								4921	5100	5730	6360
All MS	10892	10483	11081	11888	33117	33052	35249	38746	44009	43535	46330	50634	294805	290101	295983	304012	23486	22862	27004	31850	346641	345747	355610	370109
Increase			106%	113%			107%	117%			106%	109%			102%	105%							103%	107%

🟨 Pumped storage included in production

Table 2.13: Evolution of the total installed capacity of hydropower plants according to the NREAPs (adjusted data)

	Electric capacity < 1MW				1MW < electric capacity < 10MW				Electric capacity < 10MW				Electric capacity > 10MW				Pumped storage				Total hydropower			
	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020
Belgium									62	66,1	76,3	93,8	46,2	46,2	46,2	46,2					108,2	112,3	122,5	140
Bulgaria									184	196	226	312	1894	1894	2054	2237					2078	2090	2280	2549
Czech Republic	123	162	191	194	154	142	147	147	277	304	338	341	743	743	743	743					1020	1047	1099	1125
Denmark	0	0	0	0	10	10	10	10	10	10	10	10	0	0	0	0	0	0	0	0	10	10	10	10
Germany	641	507	534	564	1073	987	1012	1043	1714	1494	1546	1607	2615	2558	2620	2702	4012	6494	6494	7900	4329	4052	4165	4309
Estonia	4	6	7	7	1	1	1	1	5	7	8	8								300	5	7	8	8
Ireland	18	18	18	18	20	20	20	20	38	38	38	38	196	196	196	196	0	0	0	0	234	234	234	234
Greece	26	29	34	39	63	154	185	216	89	183	219	255	3018	3054	3396	4276	700	700	700	1580	3107	3237	3615	4531
Spain	239	242	253	268	1534	1603	1764	1917	1773	1845	2017	2185	16447	16842	18032	20177	2727	2546	3700	5700	18220	18687	20049	22362
France	433	441	462	483	1618	1647	1727	1807	2051	2088	2189	2290	18995	19333	20269	21206	4303	4800	5800	6800	21046	21421	22458	23496
Italy	391	444	547	650	1947	2250	2750	3250	2338	2694	3297	3900	13128	13886	13893	13900	1334	2399	2499	2600	15466	16580	17190	17800
Cyprus																								
Latvia	24	24	25	27	1	1	1	1	25	25	26	28	1511	1511	1524	1522					1536	1536	1550	1550
Lithuania					27	26	32	40	27	26	32	40	101	101	101	101	0	0	0	0	128	127	133	141
Luxemburg	2	2	2	3	32	36	36	41	34	38	38	44	0	0	0	0	1100	1100	1300	1300	34	38	38	44
Hungary	3	3	4	6	9	9	9	22	12	12	13	28	39	39	39	39					51	51	52	67
Malta																								
Netherlands									2,4	12,4	33,4	33,4	34,6	34,6	34,6	169,6	0	0	0	0	37	47	68	203
Austria	308	455	465	497	692	726	743	794	1000	1181	1208	1291	6907	7053	7215	7707	3929	4285	4285	4285	7907	8235	8423	8997
Poland	72	102	122	142	174	178	208	238	246	280	330	380	669	672	672	772	0	0	0	0	915	952	1002	1152
Portugal					323	410	550	750	323	410	550	750	4496	4524	6467	8798	537	1036	2454	4302	4816	4934	7017	9548
Romania	63	63	90	109	262	324	547	620	325	387	637	729	5964	6026	6650	7000	0	0	0	0	6289	6413	7287	7729
Slovenia	108	118	120	120	37	37	52	57	145	155	172	177	836	916	1021	1176	0	0	0	0	981	1071	1193	1354
Slovak Republic	16	25	40	60	46	55	82	122	62	80	122	182	1535	1542	1610	1630	0	0	0	0	1597	1622	1732	1812
Finland	30	30	30	30	280	280	280	280	310	310	310	310	2730	2750	2750	2790	0	0	0	0	3040	3050	3050	3100
Sweden	140	140	140	140	765	765	765	765	905	905	905	905	15397	15402	15407	15412	43	43	43	43	16302	16307	16312	16317
United Kingdom	56				102				158	367	577	787	1343	1343	1343	1343					1501	1710	1920	2130
All MS	2697	2811	3084	3357	9170	9661	10921	12141	12115,4	13113,5	14917,7	16724,2	98644,8	100466	106083	113943	18685	23403	27275	34810	110757	113570	121008	130708
Increase		104%	114%	124%		105%	119%	132%		108%	123%	138%		102%	108%	116%						103%	109%	118%

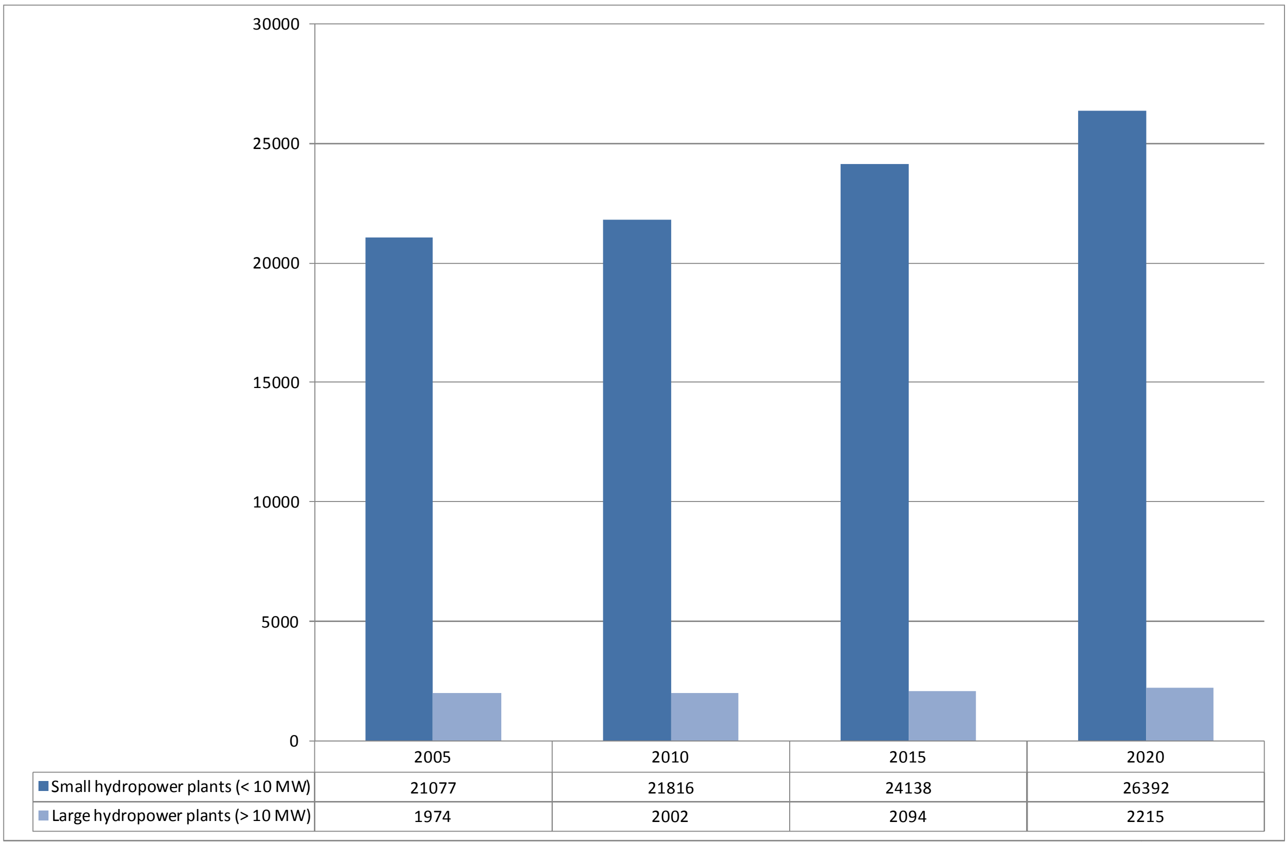
🟨	Pumped storage included in capacities
🟩	Corrected for capacity of pumped storage
🟦	Data from earlier version of report (EE & PL) or NREAP (HU)
🟧	Data from SHERPA study
⬜	Own calculations (see text)

Table 2.14: Evolution of the total electricity production from hydropower plants according to the NREAPs (adjusted data)

	Electric capacity < 1MW				1MW < electric capacity < 10MW				Electric capacity < 10MW				Electric capacity > 10MW				Pumped storage				Total hydropower			
	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020	2005	2010	2015	2020
Belgium									166	178,0	207,0	256,0	184	184,0	184,0	184,0					350	362	391	440
Bulgaria									588	468,2	536,5	740,6	3748	2791,8	2997,5	3210,4					4336	3260	3534	3951
Czech Republic	343	575	670	724	728	474	490	490	1071	1049	1160	1214	1309	1060	1060	1060					2380	2109	2220	2274
Denmark	0	0	0	0	23	31	31	31	23	31	31	31	0	0	0	0	0	0	0	0	23	31	31	31
Germany	3157	2300	2450	2550	3560	4050	4250	4500	6717	6350	6700	7050	12971	11650	12300	12950	7786	6989	6989	8395	19687	18000	19000	20000
Estonia	14	20	24	24	6	6	6	6	20	26	30	30									20	26	30	30
Ireland									103	95,0	96,8	95,0	657	606,0	617,2	606,0	0	0	0	0	760	701	714	701
Greece	106	112	131	150	218	593	713	833	324	705	844	983	4693	4283	4840	5593	593	776	774	1703	5017	4988	5684	6576
Spain	893	831	715	803	5719	4973	4617	5477	6612	5804	5332	6280	28891	28813	31399	33314	5153	3640	6577	8023	35503	34617	36732	39593
France	1796	1694	1727	1759	6111	5766	5878	5990	7907	7460	7605	7749	62332	61563	62758	63953	4705	5130	6199	7268	70240	69024	70363	71703
Italy	1851	1737	2009	2281	7391	7459	8627	9796	9242	9196	10636	12077	34525	32946	31434	29923	1268	2739	2734	2730	43768	42141	42070	42000
Cyprus																								
Latvia	59	59	63	67	3	3	3	3	62	62	66	70	2880	2844	2899	2981					2942	2906	2965	3051
Lithuania					66	79	93	117	66	79	93	117	385	353	353	353	0	0	0	0	451	432	446	470
Luxemburg	5	6	6	7	93	100	100	117	98	106	106	124	0	0	0	0	785	785	928	928	98	107	107	124
Hungary		5,4	8	12		30,4	30	67	50	35,8	38	79	221	158,2	158	158					271	194	196	237
Malta																								
Netherlands									3,2	42,2	114,2	114,2	85,8	85,8	85,8	599,8	0	0	0	0	89	128	200	714
Austria	1448	2129	2178	2326	3247	3400	3477	3715	4695	5529	5655	6041	32430	33013	33768	36071	2738	2732	2732	2732	37125	38542	39423	42112
Poland	358	357	427	497	504	534	624	714	862	891	1051	1211	1339	1388	1388	1758	0	0	0	0	2201	2279	2439	2969
Portugal					381	827	1108	1511	381	827	1108	1511	4737	8916	9993	12562	387	0	0	0	5118	9742	11101	14074
Romania	61	95	135	164	538	624	1054	1195	599	719	1189	1359	15493	15848	17490	18410	0	0	0	0	16091	16567	18679	19768
Slovenia	451	262	270	270	155	192	247	270	606	454	517	540	3493	3744	4042	4581	0	0	0	0	4099	4198	4559	5121
Slovak Republic	80	75	119	179	198	164	244	364	278	239	363	543	4360	4595	4798	4857	0	0	0	0	4638	4834	5161	5400
Finland	140	150	150	150	1260	1290	1290	1310	1400	1440	1440	1460	12510	12780	12780	12960	0	0	0	0	13910	14210	14210	14410
Sweden	458	458	458	458	3027	3027	3027	3027	3485	3485	3485	3485	69318	67693	66069	64444	71	71	71	71	72803	71178	69554	67929
United Kingdom	44				399				443	622	1252	1882	4478	4478	4478	4478					4921	5100	5730	6360
All MS	11264	10865,4	11540	12421	33627	33622,4	35909	39533	45801,2	45893,2	49655,4	55041,8	301040	299793	305892	315006	23486	22862	27004	31850	346841	345676	355539	370038
Increase			106%	114%			107%	118%		100%	108%	111%		100%	102%	105%							103%	107%

🟨	Pumped storage included in capacities
🟩	Corrected for capacity of pumped storage
🟦	Data from earlier version of report (EE & PL) or NREAP (HU)
🟧	Data from SHERPA study
▨	Own calculations (see text)

Figure 2.17: Estimated evolution of the number of small and large hydropower plants according to evolution of the installed capacity specified in the NREAPs



	2005	2010	2015	2020
■ Small hydropower plants (< 10 MW)	21077	21816	24138	26392
■ Large hydropower plants (> 10 MW)	1974	2002	2094	2215

2.3.3 Electricity consumption: total and from renewable sources

Member States also needed to provide data on the total electricity consumption and the electricity generation from renewable sources. Table 46 of the EEA Report ‘Renewable Energy Projections as Published in the National Renewable Energy Action Plans of the European Member States - Covering all 27 EU Member States’ (Report ECN-E--10-069; February 1, 2011) provides an overview of the total electricity consumption per MS over the period 2005 – 2020 for the additional energy efficiency scenario. Data for 2005, 2010, 2015 and 2020 have been extracted from this report, recalculated to GWh and are shown in Table 2.15. Individual 2005 data for Malta and Poland are missing in the report but the sum of both amounts to 12,3 Mtoe. This amount has been redistributed over the two individual MS using the same share as for 2010.

Tables 55-58 of the EEA Report ‘Renewable Energy Projections as Published in the National Renewable Energy Action Plans of the European Member States - Covering all 27 EU Member States’ (Report ECN-E--10-069; February 1, 2011) provides an overview of the electricity generation from renewable sources (RES-E) per MS for 2005, 2010, 2015 and 2020. These have been recalculated to GWh and are shown in Table 2.16. Individual 2005 data for Hungary, Malta and Poland are missing in the report. These have been calculated from Eurostat data on final electricity consumption and share of renewable sources in the gross electricity consumption for these individual MS.

Table 2.15: Total electricity consumption per MS in 2005, 2010, 2015 and 2020 according to NREAPs (GWh)

	2005	2010	2015	2020
Belgium	92017	97355	102681	110787
Bulgaria	36390	36402	36879	36611
Czech Republic	69943	70199	77886	84108
Denmark	36821	36146	37611	37763
Germany	602585	603888	588338	561927
Estonia	8583	9641	10281	10909
Ireland	27226	28761	30657	32715
Greece	63802	58859	61465	68466
Spain	291680	291401	328710	375288
France	527037	533224	539411	545598
Italy	345981	357053	365938	374800
Cyprus	4350	5385	6373	7362
Latvia	6757	6792	7513	8676
Lithuania	11456	10595	12188	13875
Luxemburg	6594	6385	6327	6617
Hungary	41973	42740	47892	51381
Malta	2497	2500	2838	3140
Netherlands	120336	123592	130372	135850
Austria	66582	65523	67652	74165
Poland	140552	140723	152353	169798
Portugal	53010	55010	59034	64512
Romania	53510	62221	65768	73664
Slovenia	14793	13909	15038	15607
Slovak Republic	28052	28610	31180	33332
Finland	87574	87807	95482	101646
Sweden	151039	152225	153411	154598
United Kingdom	373323	368671	373323	376812
All MS	3264460	3295616	3406601	3530007
▨	Sum of MT + PL in 2005 redistributed			
	according to share in sum in 2010			

2.3.4 CO_2 emissions

The total CO_2 emissions in 2005, 2010, 2015 and 2020 have been extracted from the reference scenario of ‘EU-27 Energy Trends to 2030 – Update 2009’. The sum of energy and non-energy related CO_2 emissions have been used for this purpose.

This study also provides data on electricity generation (in GWh) from nuclear, solid, liquid and gaseous fossil fuels and from renewable sources. The fuel input for thermal power generation (solid, liquid and gaseous fossil fuels and renewable) is also specified (in ktoe). The direct CO_2 emissions from fossil fuel consumption for electricity generation have been calculated from the fuel input data, using the IPCC 2006 emission factors. For solid fuels, a distinction has to be made between brown coal/lignite and hard coal and for liquid fuels between residual fuel oil and diesel oil. These data have been taken from the PRIMES_BL2010_REF scenario of the GAINS model (amount of fuel used in power plants). The share of brown coal/lignite in solid fuels and of diesel oil in liquid fuels is fairly constant over the period 2005 – 2020, yielding an average emission factor of 96,2 ton CO_2/TJ for solid fuels and 77,1 ton CO_2/TJ for liquid fuels. The CO_2 emission factor for natural gas was 56,1 ton/TJ. Direct CO_2 emissions from renewable (biomass) are 0 per definition.

Table 2.17 provides an overview of the total CO_2 emissions and the direct CO_2 emissions from electricity generation.

The evolution of the CO_2 emission factor for electricity generation and for electricity generation from classical production is given in Table 2.18. The CO_2 emission factor for electricity generation is obtained by dividing the direct CO_2 emissions from electricity generation by the total electricity generation. The CO_2 emission factor for electricity generation from classical production is obtained by dividing the direct CO_2 emissions from electricity generation by the electricity generated from fossil fuels and nuclear energy.

Table 2.16: Electricity generation from renewable sources per MS in 2005, 2010, 2015 and 2020 according to NREAPs (GWh)

	2005	2010	2015	2020
Belgium	2466	4664	13037	23120
Bulgaria	2396	3873	6129	7536
Czech Republic	3128	5175	10048	12072
Denmark	9886	12409	17178	19597
Germany	61651	104972	157621	216934
Estonia	105	616	1361	1919
Ireland	2093	5862	9944	13909
Greece	5117	7804	16968	27272
Spain	53777	84050	111008	150062
France	71152	82259	109403	148038
Italy	56371	66803	81933	98902
Cyprus	0	233	535	1175
Latvia	3035	3035	3861	5187
Lithuania	442	861	2117	2954
Luxemburg	209	256	570	779
Hungary	1487	2838	3873	5594
Malta	0	12	198	430
Netherlands	7234	10641	27447	50311
Austria	40472	45380	48195	52370
Poland	3045	10618	19876	32401
Portugal	15549	22748	29436	35588
Romania	15666	16689	27133	31006
Slovenia	4210	4512	5327	6129
Slovak Republic	4699	5478	7176	8001
Finland	23609	22679	25586	33378
Sweden	76816	83608	90388	97180
United Kingdom	17515	31634	60348	116986
All MS	482130	639708	886694	1198832

🟧 Calculated based on Eurostat data on final electricity consumption and share of renewables in gross electricity consumption

Table 2.17: Evolution of the total CO_2 emissions and direct CO_2 emissions from electricity generation in the EU27 (kton)

	2005	2010	2015	2020
Total CO2 emission	4251100	4020700	3958900	3713900
Direct CO2 emission from electricity generation	1335696	1260097	1216294	1100918

Table 2.18: Evolution of the CO_2 emission factor for electricity generation and for electricity generation from classical production (ton/GWh_e)

	2005	2010	2015	2020
Emission factor electricity generation	408	381	344	297
Emission factor classical fossil + nuclear	476	471	457	440

2.3.5 Contribution of hydropower to RES targets and CO_2 reduction

The evolution of the contribution of small (< 10 MW) and large (>10 MW) hydropower to the total electricity generation for the EU27 is given in Figure 2.18. Figure 2.19 shows the contribution of small (< 10 MW) and large (>10 MW) hydropower to the total electricity generation per MS in 2005 and 2020.

The share of hydropower electricity generation decreases over the period 2005 -2020 despite the increase in capacity and electricity generation from hydropower. This is due to the fact that hydropower generation is expected to increase at a slower rate than the electricity consumption.

Figure 2.18: Contribution of small (< 10 MW) and large (>10 MW) hydropower to the total electricity generation in the EU27

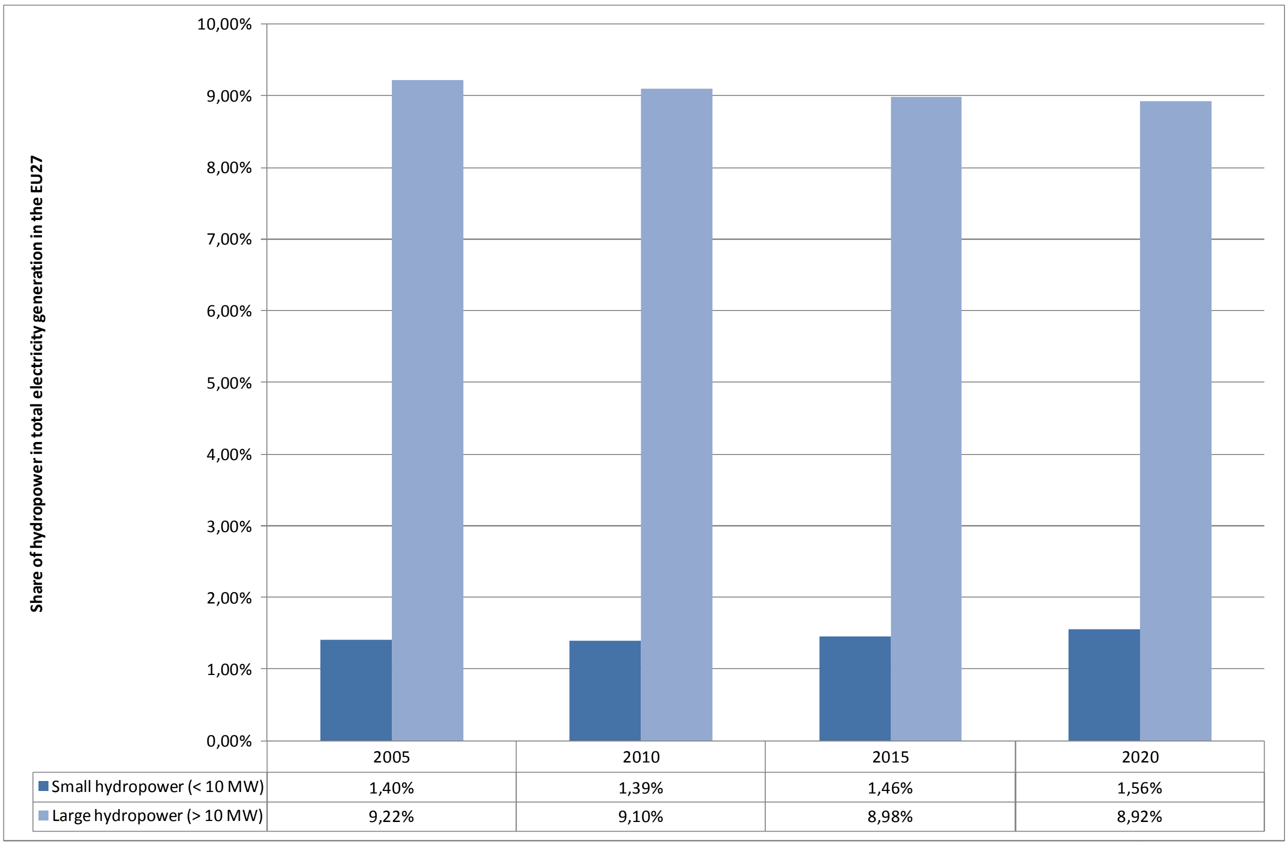
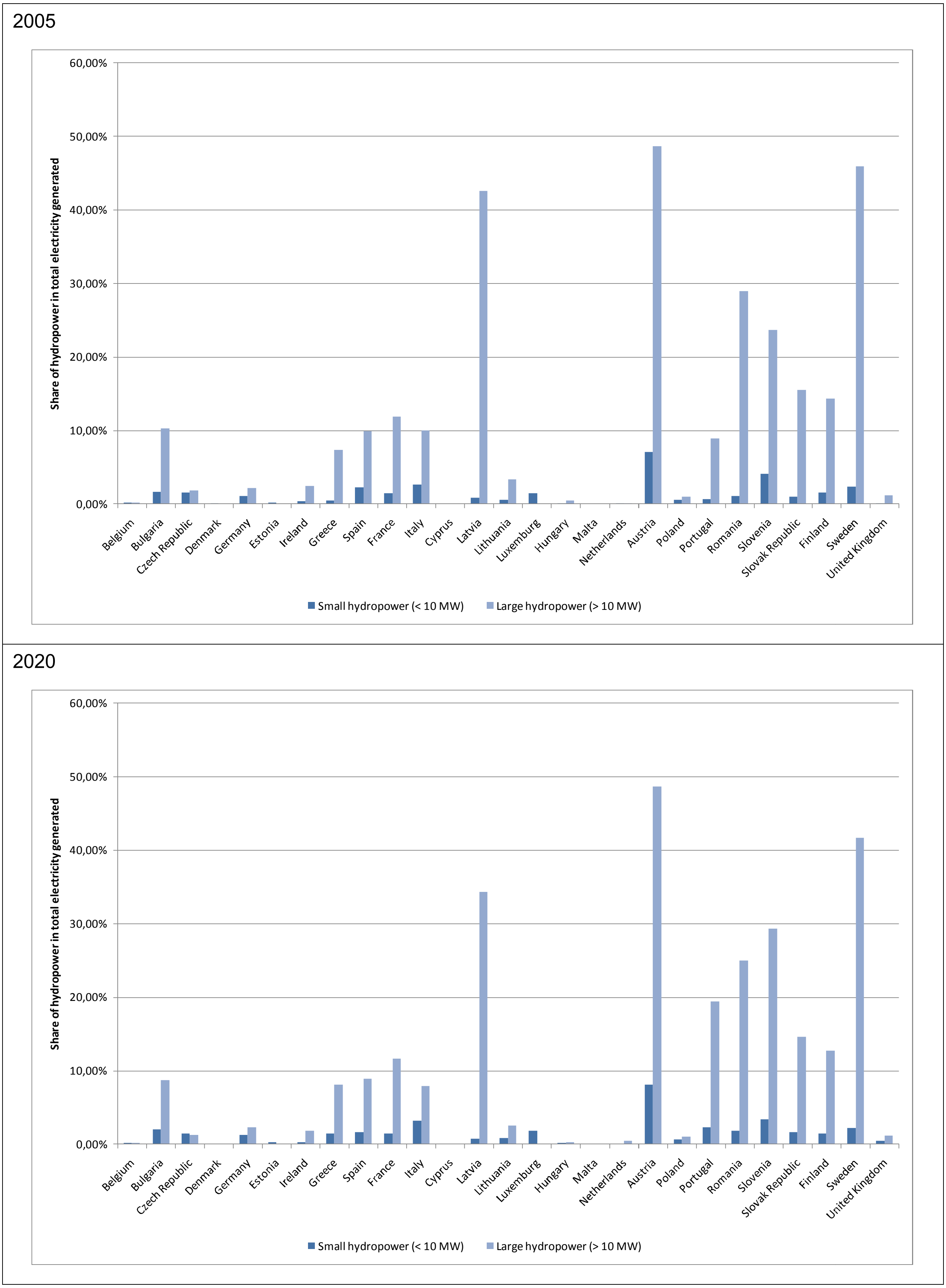
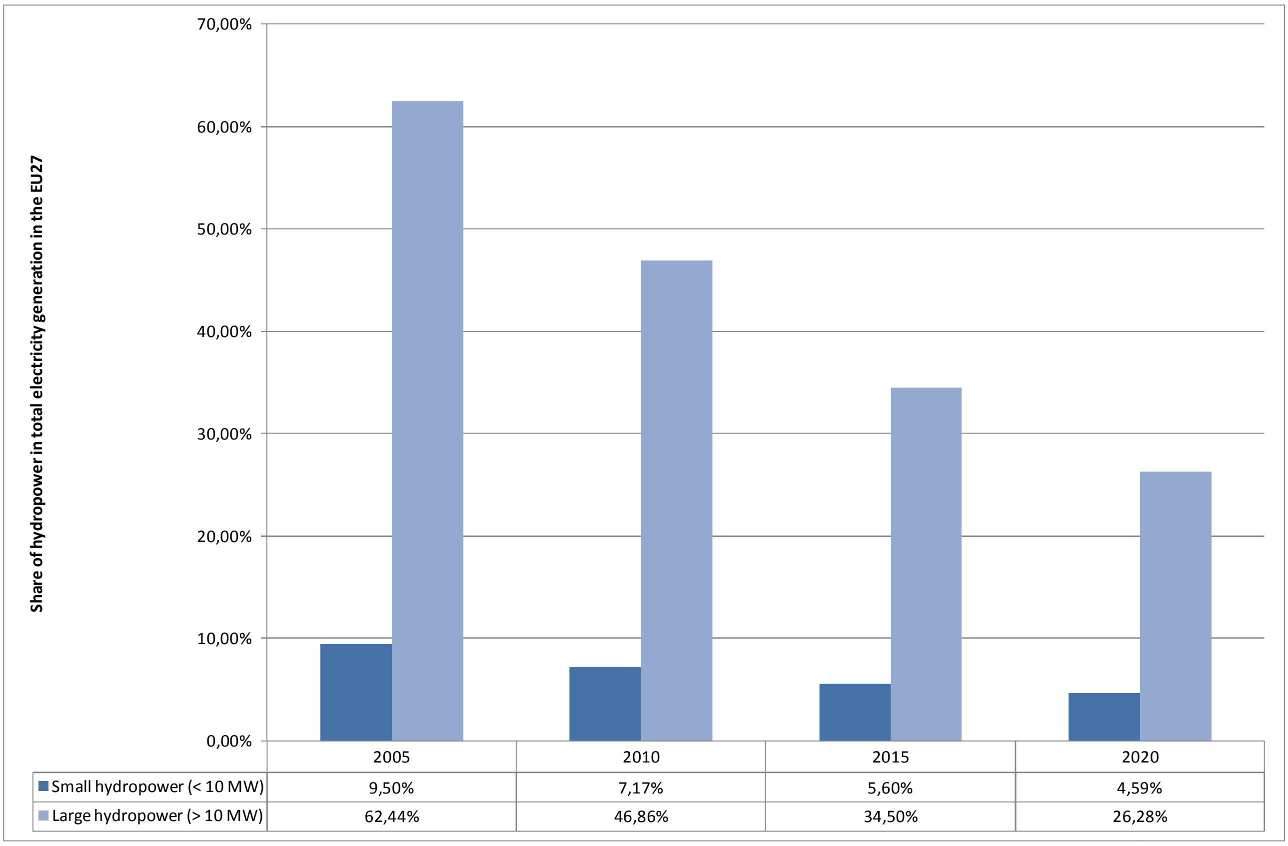


Figure 2.19: Contribution of small (< 10 MW) and large (>10 MW) hydropower to the total electricity generation per MS in 2005 and 2020



The share of hydropower in the total electricity generated from renewable sources decreases significantly over the period 2005 – 2020 as can be seen from the data for the EU 27 (Figure 2.20) and the individual Member States (Figure 2.21). While in 2005, hydropower (small & large) still accounted for over 70% of all electricity generated from renewable sources in the EU27, its share will drop to somewhat over 30% by 2020 according to the NREAPs. by This indicates a stronger growth rate for electricity generation from other renewable sources (wind, biomass, PV and geothermal) than the expected growth rate from hydro.

Figure 2.20: Contribution of small (< 10 MW) and large (>10 MW) hydropower to electricity generation from renewable sources in the EU27

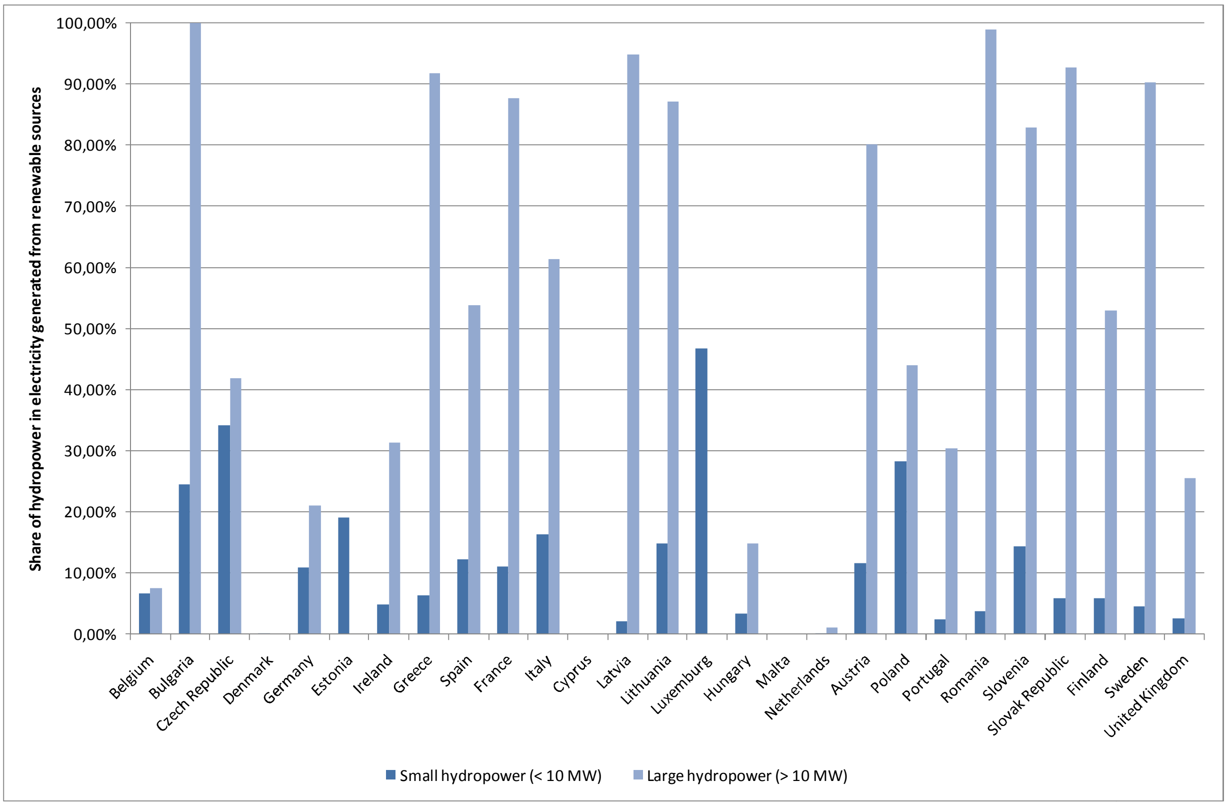


	2005	2010	2015	2020
■ Small hydropower (< 10 MW)	9,50%	7,17%	5,60%	4,59%
■ Large hydropower (> 10 MW)	62,44%	46,86%	34,50%	26,28%

Although the share of small hydropower (< 10 MW) in the total electricity production from hydropower increases from 13.2% in 2005 tot 14.9% in 2020, the largest amount of electricity remains to be generated by a relatively small number of large hydropower plants, as indicated in Figure 2.22. In 2005 8.6% of the plants is responsible for 86.8% of all electricity generated from hydropower plants. In 2020 7.7% of the plants is responsible for 85.1% of all electricity generated from hydropower plants.

Figure 2.21: Contribution of small (< 10 MW) and large (>10 MW) hydropower to electricity generation from renewable sources per MS in 2005 and 2020

2005



2020

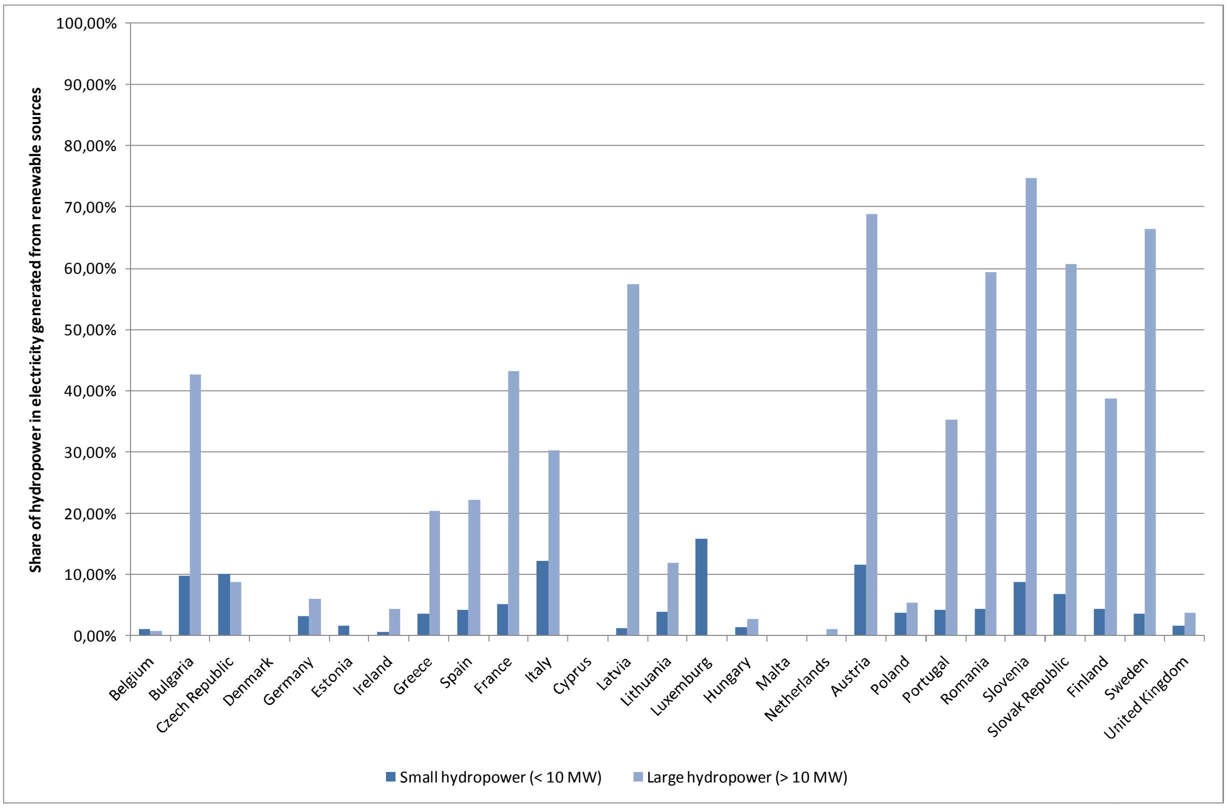
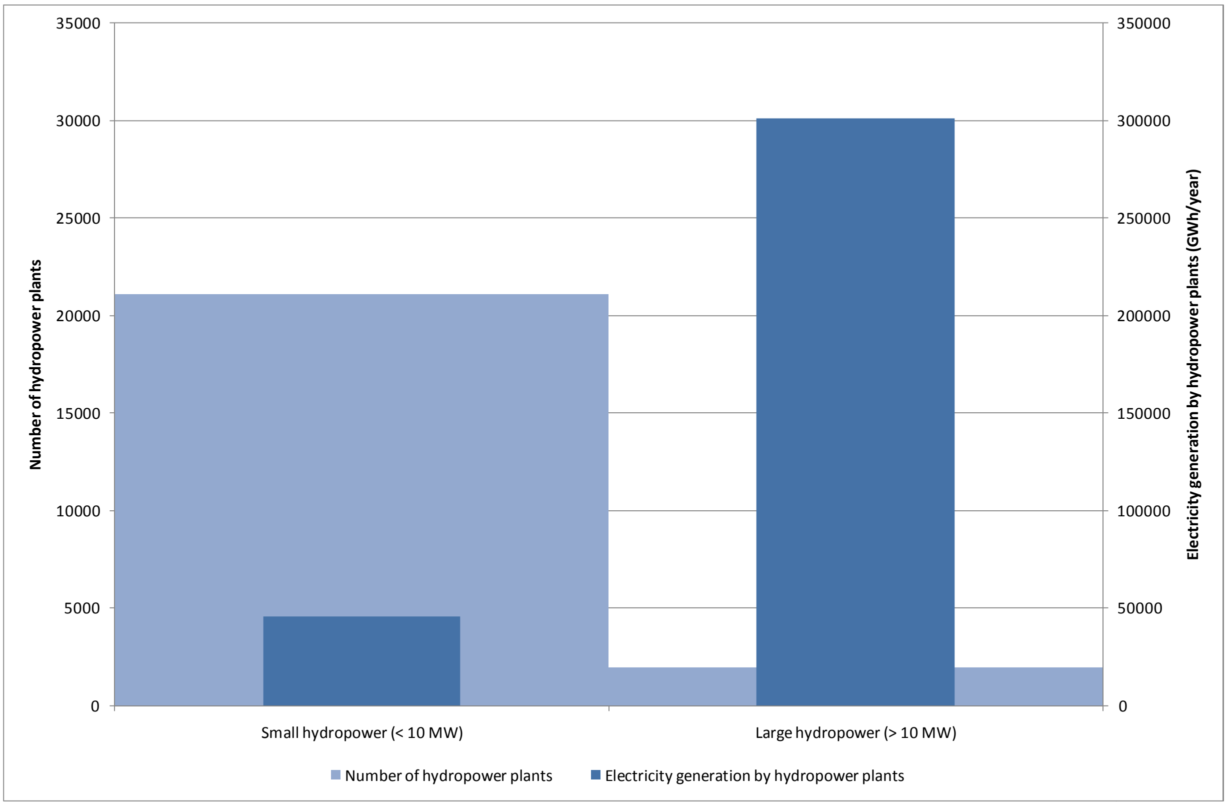
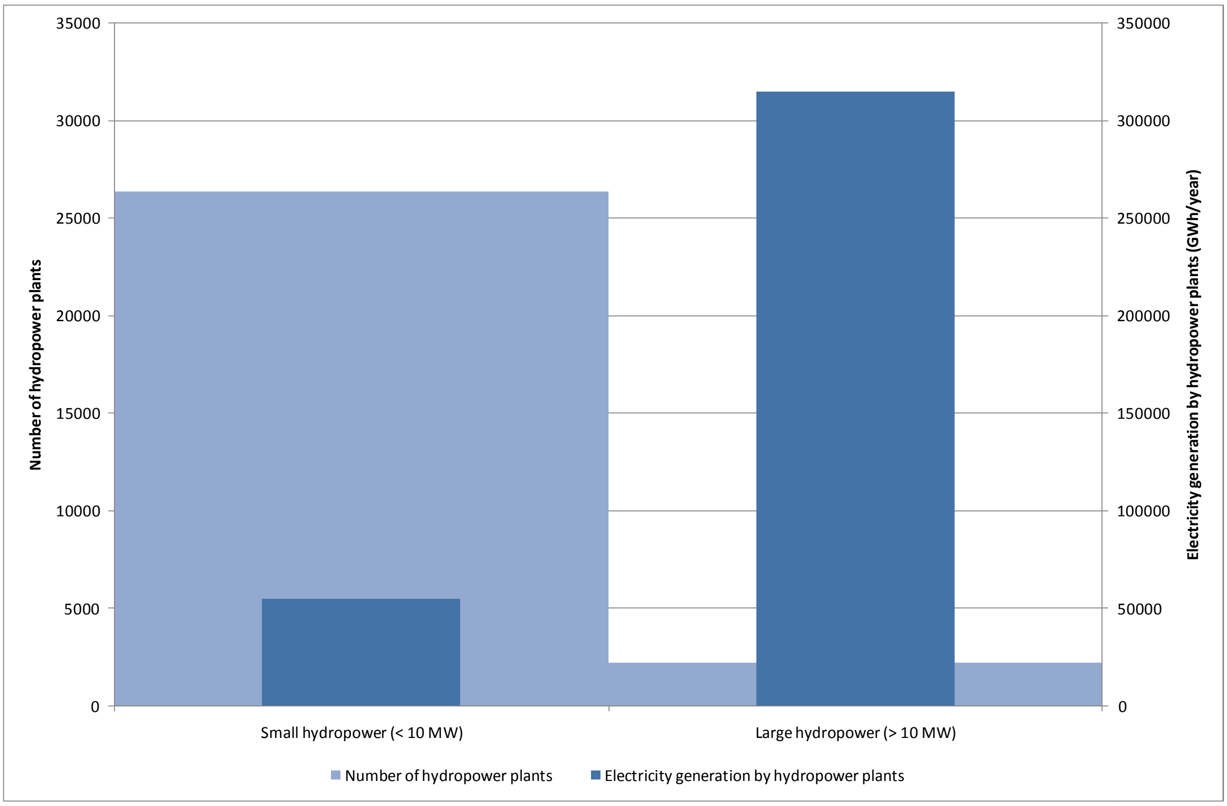


Figure 2.22: Number of small (< 10 MW) and large (>10 MW) plants and electricity generation from small and large hydropower plants in 2005 and 2020

2005



2020



As hydropower (and other renewable) largely replace electricity generation from classical production (both fossil fuels and nuclear), the avoided CO_2 emissions by hydropower electricity have to be calculated based upon the emission factor for classical fossil + nuclear production from Table 2.18. CO_2 savings by electricity generated from hydropower thus accounts for 3.9% of the total CO_2 emissions in 2005 and 4.4% of the total expected CO_2 emissions in 2020 (Figure 2.23). CO_2 savings by electricity generated from hydropower accounts for 13.1% of the direct CO_2 emissions from electricity generation in 2005 and 14.8% of the expected direct CO_2 emissions from electricity generation in 2020 (Figure 2.24). As the emission factor for electricity generation from classical production (fossil fuels and nuclear) decreases over time, due to the decarbonisation of classical electricity generation (increase in plant efficiency, shift to gaseous fuel, use of carbon capture and storage (CCS)), electricity generated from hydropower represents a total saving of 165 Mton of CO_2 in 2005 and is expected to represent a total saving of 163 Mton by 2020.

Figure 2.23: CO_2 savings by electricity generated from hydropower relative to total CO_2 emissions in the EU27

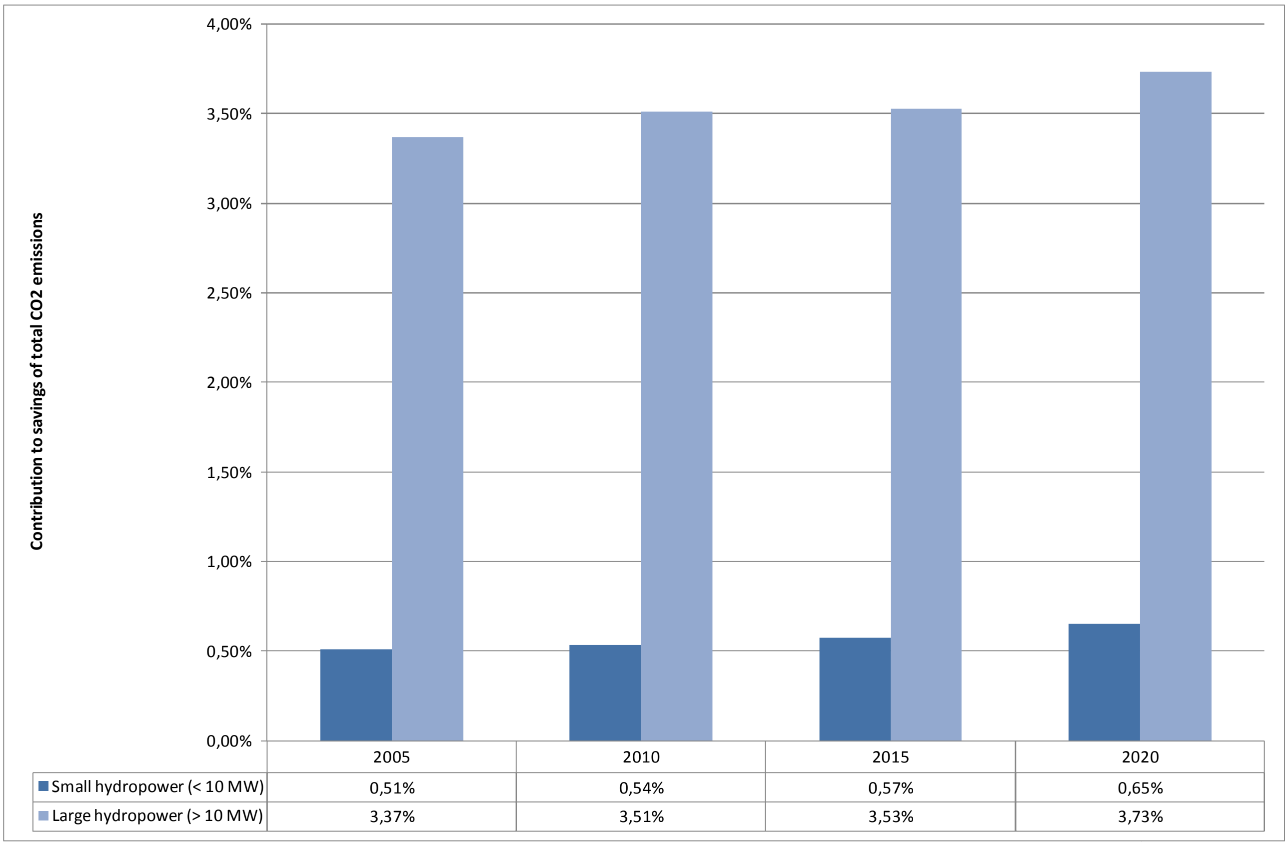
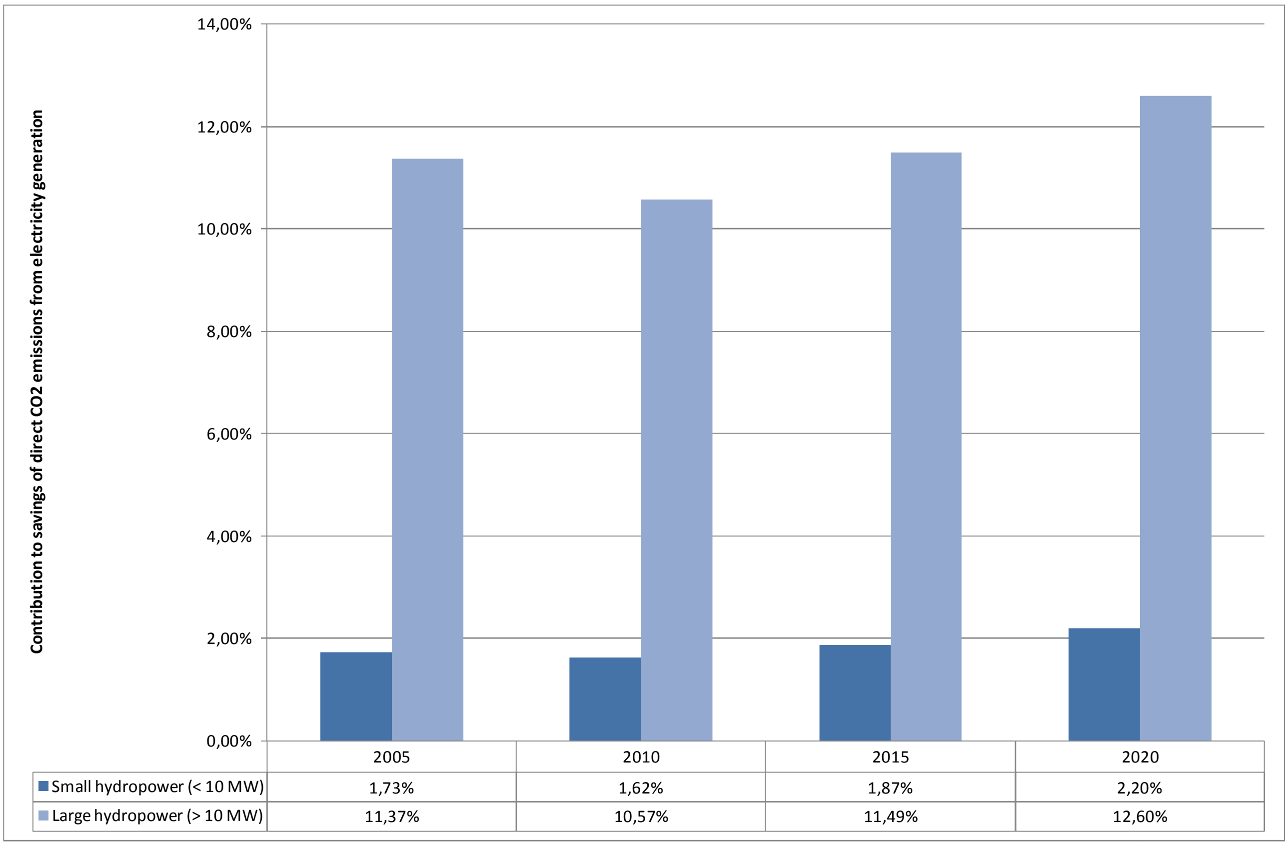


Figure 2.24: CO_2 savings by electricity generated from hydropower relative to direct CO_2 emissions from electricity generation in the EU27



2.4 Power transmission, grid stability and storage

With the increasing amount of intermittent renewable energy production by wind and solar energy facilities, energy storage and grid stabilization will become prominent issues.

Although a large hydro power potential is desired due to its base load ability also the hydropower generation shows relatively strong production variations during the year and over several years time. Production fluctuations according to precipitation and influenced by the geographical position within a discharge regime (e.g. glacial, snow dependant (nival in engl.?) or fluvial) (Figure 2.25, Figure 2.26) are harmonized due a wide spread of geographic positions of HP stations. And since fluctuations occur over hours, are well predictable and weirs and dams have a certain storage capacity most of the hydro power facilities serve as renewable base load stations today.

Several studies are investigating the influence of climate change to the river discharges and the German Ministry of Environment (BMU) and the German Agency on Environment (UBA) had performed studies on the effect on existing German HP stations and possible mitigation strategies (Source: Wolf-Schumann, U.; Dumont, U.:Einfluss der Klimaveränderung auf die Wasserkraftnutzung in Deutschland. In: WasserWirtschaft 100 (2010), Heft 9. BMU- and, UBA-Report, to be published in 2011). As a result in the near future the hydro power production in Germany will decrease about 1 to 4% and in the further future about 15%. Similar values are expected for countries with equivalent discharge regimes. To counterbalance possible minor productions the optimization of existing power plants as well as the improvement of operation and maintenance are recommended.

Figure 2.25: Hydrograph of the German river Main 1961 - 2003 (in m³/s) (source: Anderer et al., BMU-Bericht, to be published in 2011)

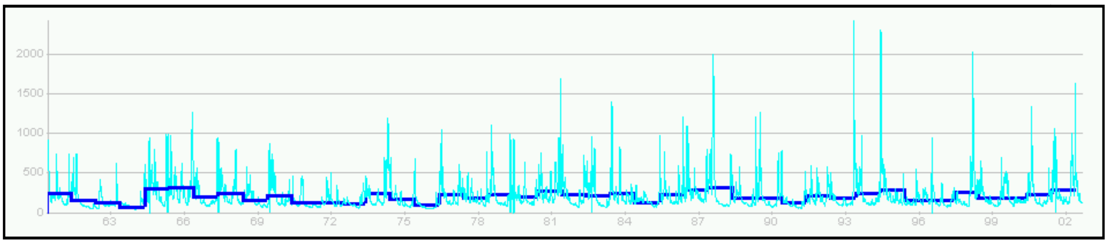
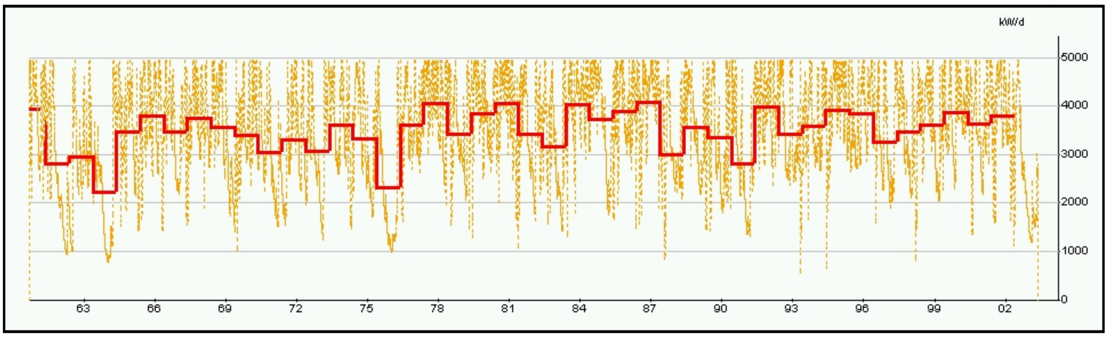


Figure 2.26: Load curve of a HP station in the German low mountain range river Main, modelling 1961 - 2003, daily values (yellow curve) and annual mean (red curve) (source: Anderer et al., BMU-Bericht, to be published in 2011)



2.4.1 Storage

Storage and pumped storage hydro power plants are the most common large storage systems today. Additional capacities are available by an improved use of existing plants and by building new storages. New constructions have to face ecological problems as well as social resistance and investors have to deal with uncertain economical situations.

40.3 GW or 5% of the total electrical capacity of about 800 GW was installed in pumped storage power plants in the EU-27 in 2008. Another 70 GW is being built so that within the next years more than 10% of the total electrical capacity are covered by pumped storage.

Norway comprises the largest European hydro storage capacities (section 2.2.3.4) of 84 TWh. Together with Sweden, Austria and Switzerland in 2008 it would be able to store about 4% of the total gross electricity production of 3374 TWh in the EU-27 or the total production of the EU-27 wind power plants of about 142 TWh.

But the Norwegian storage capacities are not yet prepared to take up the fluctuating European electricity production. The installation of additional turbines and pumps is necessary together with additional basins and grid capacities. It is expected, that storage capacities can reasonably be increased within the existing facilities. Building further large facilities in Norway is assumed to be unlikely due to ecological constraints.

2.4.2 Grid stabilisation

The increased use of renewable energy sources does not only change the composition of primary energies but also the structure of electricity production. A rising share of decentralized power stations will be connected to the existing power supply system (medium-and high voltage).The previously “passive” supply system with a set of large power stations is turned more and more into an “active” supply- and delivery system.

Wind and solar power systems showed in some European countries a rapid capacity increase during recent years and so did their fluctuating electricity production. This leads to situations where the production in certain regions and countries temporarily exceeds the demand and the secure and optimal operation of the power supply systems can be endangered.

Compensation efforts prevailed on a national basis but are reaching their capabilities and an European approach is more and more necessary. Especially pumped storage power plants were used to maintain grid stabilization and to face rapid changes in electricity demand (peak load).

Investigations and modelling of an efficient integration of renewable energy sources are currently performed in national and international projects (DENA 1 and 2: necessary development of grid capacities in Germany; ATLANTIS: Modelling the European Electricity Industry, TU Graz, Austria).

The scenarios show that the use and management of international storage systems would require an expansion of national grids. The utilization of Norwegian storage capacities e.g. would require improved connections between Norway and the off shore wind parks in the northern and eastern sea and to the main consumers in the middle of Europe. First installations have been realized.

Today the Nord-Ned high-voltage cable with a length of 580 km connects Norway and the Netherlands. The Viking-cable between Norway and Germany (Nor Ger project) is planned to be constructed until 2015. Further connections e.g. a second Nord-Ned 2 cable are planned.

The demand on storage capacity rises disproportionately to the electricity consumption. In addition the expansion of grid capacities and of the regions connected by the grid reduces the need for storage considerably. Therefore the present discussion on building new storage capacities deals with several questions:

- What kind of storage is required, when renewable energy sources account for the main part of electricity generation?
- How much storage capacity is needed for the proposed mix of renewable sources?
- By how much could storage capacities be reduced when expanding the transmission lines, increasing (domestic) smart grid solutions and applying an international storage system management?

SUSPLAN (www.susplan.eu, 2008 - 2011)

The development of regional and European-wide guidelines for more efficient integration of renewable energy sources (RES) into future infrastructure is the issue of SUSPLAN (PLANning for SUStainability) a project under the EU 7th Framework Program. Within three years time the following objectives will be addressed:

- Development of grid-based RES integration scenarios for regional (9 European regions) and transnational levels.
- Identification of optimum path for RES integration out of the scenarios.
- Establish implementation strategies for decision makers.
- Establish a knowledge base and publish SUSPLAN results.

The aim is to connect EU targets and national objectives to (investment) decisions for new energy infrastructure and technology which mostly are taken on a regional or local basis. The project focuses on the development within the period from 2030 to 2050. Results will be published by the end of 2011.

3 Environmental impacts and influence of environmental legislation, specifically the WFD, on hydropower generation

3.1 Overall objective

This section comprises qualitative and quantitative information on the influence of meeting the objectives of the WFD on the achievement of those objectives.

3.2 Overview on environmental impacts

3.2.1 Introduction

Hydropower schemes in freshwater environments commonly consist of a hydropower station and an impounding structure (dam or weir) that creates the difference in height (head) between the source water and the turbine outflow. Both elements have impacts on the aquatic environment.

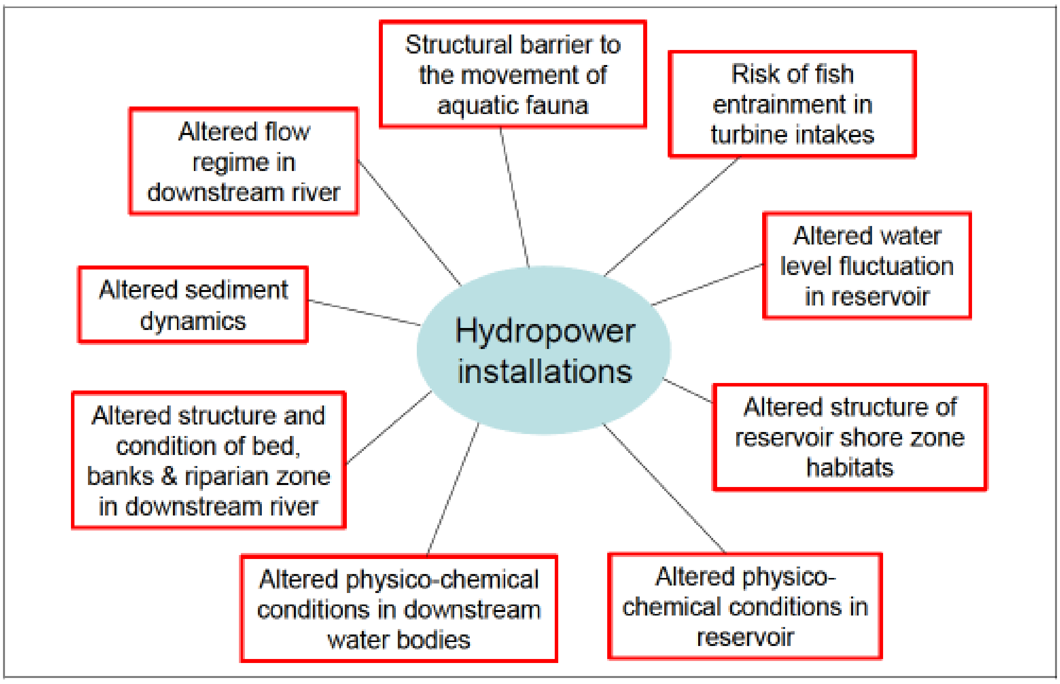
Typically run-of-the-river plants are facilities with small(er) reservoir capacities, whereas hydropower plants with dams store large(r) volumes of water in upstream reservoirs. Diversion plants channel a portion of a river through a canal or penstock, which may or may not (e.g. at waterfalls) require an impounding structure. Pumped storage plants store energy in the form of water, pumped from a low elevation reservoir to a high elevation reservoir, from where the stored water is released through turbines during periods of high electrical demand.

In general, hydropower schemes form obstacles and/ or barriers in water courses. Their construction and operation is linked to unavoidable impacts on the water bodies and adjacent floodplains and wetlands (Figure 3.1). Dams and weirs in particular constitute obstacles for longitudinal exchanges along fluvial systems and as such result in the fragmentation, i.e. reduced connectivity of ecosystems (Ward and Stanford, 1995; Nilsson et al., 2005).

Impounding structures are anthropogenic alterations that disrupt dynamic processes and so impact on the ecological integrity of natural systems. Large dams not only alter the pattern of downstream flow (i.e. intensity, timing and frequency) they also change sediment and nutrient regimes and can alter water temperature and chemistry. The environmental impact of dams on river ecosystems has been studied extensively, at least in temperate climates. These have shown that dams disrupt the river continuum and cause upstream and downstream shifts in abiotic and biotic parameters and processes. For example, the environmental impacts of large dams were evaluated and summarized by Bergkamp et al. (2000) in preparation of the World Commission on Dams Report (2000).

The most obvious effect of large storage reservoirs is the permanent destruction of terrestrial ecosystems through inundation. Terrestrial biotopes are completely destroyed - all terrestrial plants and animals disappear from the submerged areas. Large reservoirs and associated infrastructure (e.g. roads, pipelines and powerlines) can disrupt natural migration corridors. Terrestrial ecosystems are replaced by aquatic ecosystems, and mass water circulations replace riverine flow patterns. These may be good for some species (e.g. pelagophilic fish) and in some areas (e.g. in arid areas). However, because a river represent a more varied habitat than a large lake there is usually a decline in the total number of species (Bardach and Dussart, 1973).

Figure 3.1: Range of possible alterations typically associated with hydropower dams with subsequent biological alterations (CIS, 2006).



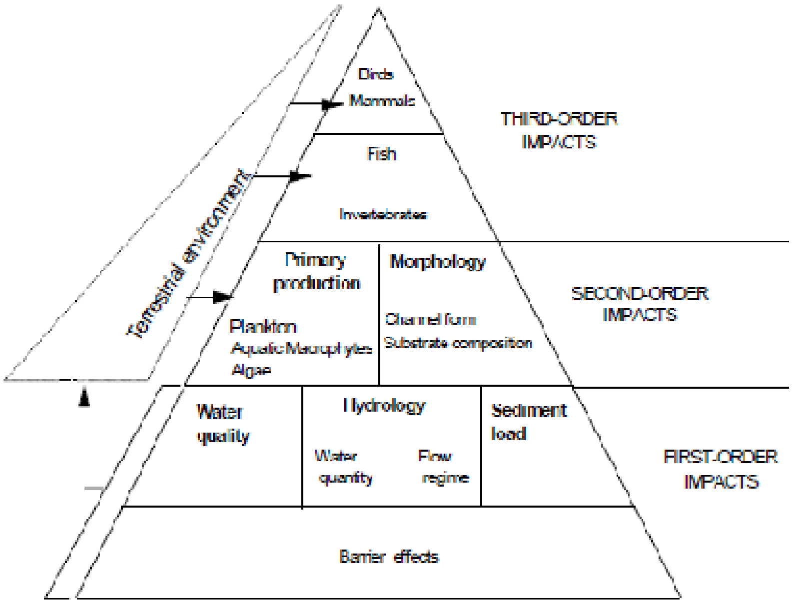
The most common downstream effect of large dams is that variability in water discharge over the year is reduced. High flows are decreased and low flows are increased. Reduction of flood peaks reduces the frequency, extent and duration of floodplain inundation. Reduction of channel-forming flows reduces channel migration. Reduced sediment transport (i.e. sedimentation within the reservoir) results in complex changes in degradation and aggregation below the dam. The temporal pattern of flooding is altered by regulation, one effect of which is to desynchronise annual flow and temperature regimes (Sparks et al., 1990). These changes and others directly and indirectly influence dynamic factors that again affect habitat heterogeneity and ultimately the ecological integrity of river ecosystems (Ward and Stanford, 1995).

3.2.2 Framework of interconnected effects

Nowadays the environmental consequences of impoundments are not considered in isolation but in view of the whole river ecosystem. To this end, impacts can be considered within a hierarchical framework of interconnected effects (Petts, 1984, Figure 3.2). Within this framework, first, second and third order impacts are identified (McCartney et al., 2000). In general terms the complexity of interacting processes increases from first to third order impacts:

- First order impacts: These are the immediate abiotic effects that occur simultaneously with dam closure and influence the transfer of energy, and material, into and within the downstream river and connected ecosystems (e.g. changes in flow, water quality and sediment load).
- Second order impacts: These are the changes of channel and downstream ecosystem structure and primary production, which result from the modification of first order impacts by local conditions and depend upon the characteristics of the river prior to dam closure (e.g. changes in channel and floodplain morphology, changes in plankton, macrophytes and periphyton). These changes may take place over many years.
- Third order impacts: These are the long-term, biotic, changes resulting from the integrated effect of all the first and second order changes, including the impact on species close to the top of the food chain (e.g. changes in invertebrate communities and fish, birds and mammals). Complex interactions may take place over many years before a new “ecological equilibrium” is achieved.

Figure 3.2: A framework for assessing the impact of dams on river ecosystems, modified from Petts, 1984 (in: McCartney et al., 2000).



3.2.3 Upstream and downstream impacts of impounding structures on ecosystems

The impacts of impounding structures on ecosystems are complex, varied and multiple. The impact of each dam/ weir is unique and dependent not only on the structure and its operation but also local sediment supplies, geomorphic constraints, climate, and the key attributes of the local biota. The proximity of catchments of contrasting topography, geology, land use, soil characteristics and possibly different meteorological inputs, typically results in areal variations in catchment dynamics. Furthermore, fluvial processes will operate differentially even within an individual catchment. Thus, predicting the precise magnitude and nature of impacts arising from the construction of a dam is highly challenging and usually not possible given current levels of understanding.

However, climate and topography exert general and pronounced influences over the basic pattern of catchment processes. Therefore, it provides a basis for attempts to generalise the impact of dams on ecosystems. Subsequently a brief and simple overview of possible differences in the ecosystem impact of dams is given (acc. McCartney et al., 2000 and Bergkamp et al., 2000).

3.2.3.1 Upstream impacts

3.2.3.1.1 First order impacts:

3.2.3.1.1.1 Modification of the thermal regime

Large mass of still water in reservoirs allows heat storage and produces a characteristic seasonal pattern of thermal behaviour. Depending on geographical location, water retained in deep reservoirs can become thermally stratified.

In large artificial reservoirs the development of thermal stratification is influenced by a) the pattern of inflows and outflows and b) the change of water level (more variable in a reservoir than in a natural lake, so that advective heat transfer and vertical movement/ mixing of the water-mass are significant).

3.2.3.1.1.2 Accumulation of sediment in the reservoir

Reservoirs can store significant proportions of the sediment load supplied by the drainage basin (even the entire sediment load in large reservoirs).

The “trap efficiency” of a reservoir depends on a) the size of the reservoir’s catchment, b) the characteristics of the catchment that effect the sediment yield (i.e. geology, soils, topography and vegetation) and c) the ratio of the reservoir’s storage-capacity to the river flows into them.

Sediment transport shows considerable temporal variation; both seasonally and annually. The amount of sediment transported into reservoirs is greatest during floods.

3.2.3.1.1.3 Increase in evaporation

Reservoirs multiply the total surface area of freshwater from which evaporation occurs. The additional water evaporated from a reservoir, over and above that which would occur under natural conditions, depends on both the surface area of the reservoir and the climatic conditions which control potential evaporation (i.e. predominantly radiation and temperature). Evaporation is greatest from reservoirs with large surface areas, located in hot arid climates.

3.2.3.1.1.4 Release of greenhouse gases

A point that has recently gained considerable attention is the potential release of greenhouse gases from reservoirs, especially methane as a result of the submersion of biomass and organic soils. However this issue does not relate so much to Europe, as to other continents.

3.2.3.1.1.5 Changes in water quality

Water storage, especially in large reservoirs, induces physical, chemical and biological changes in the stored water all of which can affect water quality. The chemical composition of water within a reservoir can be significantly different to that of the inflows. The size of the dam, its location in the river system, its geographical location with respect to altitude and latitude, the storage detention time of the water and the source(s) of the water all influence the way that storage detention modifies water quality.

Major biologically induced changes occur within thermally stratified reservoirs.

Predominantly in large reservoirs, nutrients, particularly phosphorous, can be released biologically and leached from flooded vegetation and soil.

Eutrophication of reservoirs may occur as a consequence of large influxes of organic loading and/ or nutrients. For example, the Vir Reservoir in the Czech Republic has become more eutrophic over the last 30 years as a consenquence of increased input of fertilisers in the catchment (Zakova et al., 1993).

3.2.3.1.2 Second order impacts:

3.2.3.1.2.1 Changes in channel/ basin form and substrate

Impoundments and reservoirs trap sediment as soon as they are operational. Sedimentation progressively alters the character of a reservoir storage and the basin substrate. The exact changes differ according to catchment specific conditions (e.g. catchment area, topography and geology), as well as the initial reservoir capacity, inflow characteristics and reservoir management. However, the process of sedimentation is essentially the same for all reservoirs. As the water of rivers draining into a reservoir are slowed within it, the sediment load is deposited. Sediment is deposited both in the reservoir and, as a result of backwater effects, in the channel and valley bottom upstream.

The distribution of accreted material in a reservoir varies appreciably. In large reservoirs the actual pattern of deposition can influence the movement of water within the reservoir and so have implications for stratification and water quality. The depletion of storage space in reservoirs, is also significant in ecological terms, because the progressive loss of storage capacity influences both the character of discharges and the suspended loads passing the dam. As a result of extensive sediment accumulation, water currents during floods can reactivate sediment transport and carry material through outflow gates.

3.2.3.1.2.2 Changes in Primary Production: Plankton and Periphyton

Man-made reservoirs in river systems, particularly as a result of impoundment in headwater areas, can alter the plankton component of river systems. Typically, phytoplankton production is often negligible within natural systems. The hydrological characteristics and thermal and chemical regimes of artificial reservoir are unique and so the character of primary production within reservoirs is highly site specific. However, in all reservoirs, the primary production is mainly derived from the activity of phytoplankton.

Periphyton are layers of algae attached to any submerged object, including larger plants. Diatoms normally dominate the attached algae of river systems. Conversion from a river to a lake environment will provide opportunity for some species of periphyton, whilst destroying the habitat for others. Periphyton is most likely to proliferate, where light penetrates, in the shallow water close to the reservoir edge. The exact species composition will be determined by the nature of the substrate, the presence or absence of aquatic macrophytes, the temperature and chemistry of the reservoir water and the operation of the dam.

3.2.3.1.2.3 Growth of aquatic macrophytes

Aquatic macrophytes can increase in the littoral and sub-littoral zone of reservoirs. The build up of delta deposits near river inlets to a large reservoir reduces water depths and can encourage macrophyte growth. However, their ability to colonise these areas may be limited if there are large changes in reservoir level.

A specific and serious problem of reservoirs is the mass development of aquatic weeds, as is currently the case in some reservoirs on the lower Ruhr River in Germany (Figure 3.3), where the operation of several run-of-the-river plants and the pumped storage plant Koepchenwerk is impeded.

Figure 3.3: Mass development of western waterweed Elodea nuttallii in Lake Harkort, Ruhr River, Germany (Photo: Ruhrverband).

3.2.3.1.2.4 Invasive species

Modified habitats resulting from reservoirs can create environments that are more conducive to non-native and exotic plant, fish, snail, insect and animal species. These resulting non-native species often out-compete the native species and end up developing ecosystems that are unstable.

3.2.3.1.2.5 Riparian vegetation

Riparian vegetation changes when its’ adjoining aquatic environment changes. Shallow groundwater in the vicinity of a reservoir provides opportunity for vegetation that requires access to water throughout the year.

Variation in the water levels of reservoirs can have a negative impact on plants in the immediate vicinity of the reservoir. For example, in Sweden, regulated water-level fluctuations may exceed 30 m in height. This has resulted in riparian corridors that are several hundred meters wide. However, because the pattern of water-level fluctuations is not synchronised with the natural regime, the riparian vegetation cover is extremely sparse (Nilsson and Jansson, 1995).

3.2.3.1.3 Third order impacts:

3.2.3.1.3.1 Invertebrates, Fish, Birds and Mammals

Filling of a large reservoir results in permanent flooding of riverine and terrestrial habitat, and depending upon the topography and habitats of the river valley upstream of a dam site these impacts can vary greatly in extent and severity. The effects of inundation are especially severe when the reservoirs are situated in lowland areas (large backwater effect/ inundation due to the shallow gradient of the water course), in dry areas, or at higher latitudes where the river valleys are usually the most productive landscape elements.

Reservoirs can block or delay the downstream movement of migratory species, notably fish (Hansen et al., 1984). Broodstock can be prevented from reaching their spawning grounds during the breeding seasons, resulting in massive failure of recruitment and eventual extinction of the stock above the dam. Diadromous species, i.e. species that use both marine and freshwater habitats during their life cycle, are particularly vulnerable.

Hydropower stations/ turbines and spillways can inflict serious injuries or even mortalities to downstream migrating fish (Monten, 1985, Holzner, 1999, Larinier et al., 2002, Bruijs et al., 2003, DWA, 2005 and Keuneke & Dumont, 2010). Fish can be a) impinged onto intake screens (Figure 3.4) and/ or injured by their cleaning machines (Figure 3.5), b) suffer from the pressure fluctuations during turbine passage, c) be injured or killed by physical impact or abrasion with the guide vanes, turbine runner or turbine casing (Figure 3.6) and d) become prone to predation downstream due to disorientation from turbine passage. The degree of injury or mortality can vary from 0 to 100% (e.g. in Pelton turbines) at a single hydropower station and depends on a) the fish itself (species, size, body shape and fitness), b) intake screen (approach velocity and screen spacing), c) turbine (type, size, rotation speed, flow and turbine setting/ operation mode) and d) turbine outlet/ stilling basin (exit velocity, turbulence and water depth).

A man-made impoundment creates a new ecosystem, which can vary significantly in ecological value and productivity according to the physical and biological characteristics of the site and the management regime of the hydropower plant/ dam. Riverine species can become trapped behind the structure and may survive, although many riverine species cannot tolerate lake-type conditions. Exotic or lentic species are often introduced to fill these niches. Usually the fisheries are purposely managed.

Figure 3.4: Haematoma on eels as a result of intake screen impingement (Photo: Institut für angewandte Ökologie)

Figure 3.5: Dead eels and fish in a hydropower intake screen cleaning machine (Photo: Institut für angewandte Ökologie)

Figure 3.6: A Francis runner clogged with dead fish (Photo: Alex Haro)

3.2.3.2 Downstream impacts

3.2.3.2.1 First order impacts:

3.2.3.2.1.1 Daily, seasonal and annual flows

Flow regimes (including volume, duration, timing, frequency and lapse time since last flooding) are key driving variables for downstream aquatic ecosystems and are critical for the survival of communities of plants and animals living downstream. Small flood events can act as biological triggers for fish and invertebrate migration, major events create and maintain habitats, and the natural variability of most river systems sustains complex biological communities that are very different from those adapted to the stable flows and conditions of a regulated river. In general, discharge control resulting from the operation of large (storage) hydropower plants/ dams in particular changes daily, seasonal and annual flow variability downstream, i.e. intensity, timing and frequency and therewith can impact on the aquatic environment.

Operational procedures can result in fluctuations in discharge that occur at non-natural rates on a daily, weekly, seasonal or annual basis. Hydropower (e.g. hydro-peaking, i.e. when reservoirs are used for generating peak power) and irrigation demands are the most usual causes, but peak-discharge waves are also been utilised for navigational purposes and to meet recreational needs (e.g. white water kayaking and rafting in some Scottish (e.g. River Conon) and French (e.g. Verdon River) rivers). Flow fluctuations can have several consequential effects, such as stranding of fish in drawdown zones in the river channel, isolation of fish in pools (with a risk of suffocation due to decreasing concentration of oxygen), drift of aquatic organisms, or river bank erosion due to (fluctuating) groundwater table-induced shear failure. (see: CIS Workshop (2007): Issues Paper, WFD Hydromorphology). This problem can also be exacerbated when the effects unleashed by a chain of power plants overlap on a single river section (Bratrich & Truffer, 2001).

Typically the magnitude of flood peaks is reduced and their timing is delayed by large (storage) hydropower plant/ dam operation. A consequence of reduced flood peaks is reduction in the frequency of overbank (floodplain) flooding and reduced extent of flooding when it does occur. For major floodplain rivers, dams may rarely increase flood peaks by altering the timing of the flood peak to coincide with flood peaks from tributaries downstream.

Reservoirs/ dams can affect the total volume of runoff. These changes can be both temporary (e.g. during reservoir filling) and permanent (e.g. water loss/ removal for direct human consumption (drinking water supply), irrigation and through evaporation).

The hydrological effects of a dam become less significant the greater the distance downstream, i.e. as the proportion of the uncontrolled catchment increases. The frequency of tributary confluences below a hydropower plant/ dam and the relative magnitude of the tributary streams, play a large part in determining the length of river affected by an impoundment.

3.2.3.2.1.2 Water quality

Water storage in large reservoirs induces physical, chemical and biological changes in the stored water (see section 3.2.3.1). As a result, the water discharged from reservoirs can be of different composition and/ or show a different seasonal pattern to that of the natural river.

Reservoirs act as thermal regulators and nutrient sinks so that seasonal and short-term fluctuations in water quality are regulated.

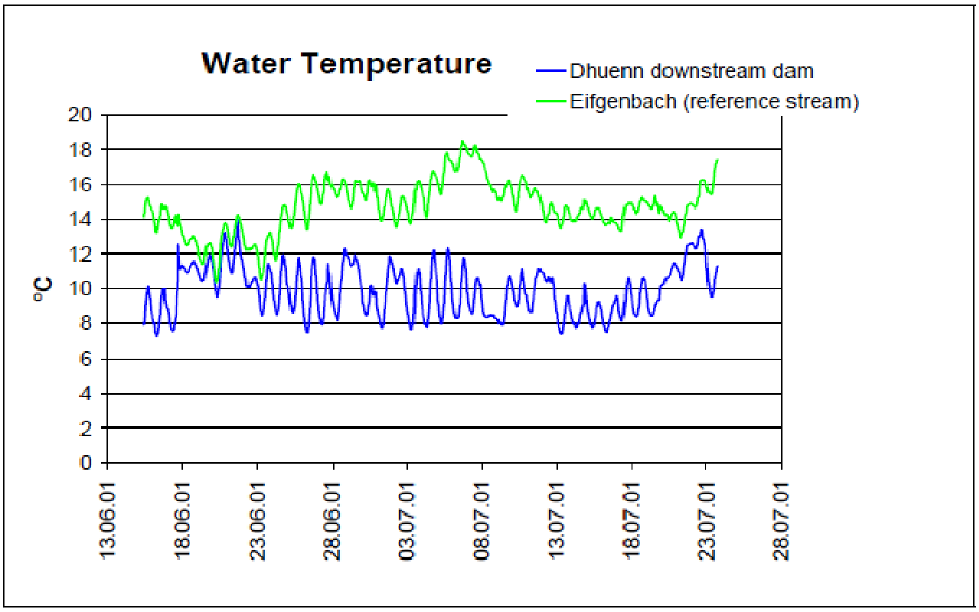
Thermally altered reservoir outflow influences many important physical, chemical and biological processes downstream. It is known that thermal changes caused by water storage can have significant effects on in-stream biota, e.g. delay in spawning activity of fish or change in fish species distribution (river reaches below large dams resemble rhithron regions, i.e. salmonid reaches, of rivers from a temperature point of view (Figure 3.7).

Water discharged from thermally stratified reservoirs is typically a) of a constant low temperature (close to 4° C throughout the year) and b) low in oxygen (or even oxygen-depleted) and may be nutrient-rich (high in hydrogen sulphide, iron and/or manganese). This is due to the fact that hydropower intakes and bottom outlets usually extract water from the hypolimnion.

Even without stratification of the storage, water released from hydropower plant/ dams may be thermally out of phase with the natural temperature regime of the river.

Changing the turbidity of (flood) outflow water can have downstream environmental effects.

Figure 3.7: Water temperature of the Dhünn River downstream of the Dhünn Dam and the reference water body Eifgenbach, Germany (Umweltbundesamt, 2002, Case study A4)



3.2.3.2.1.3 Sediment transport

Under natural conditions sediment feeds floodplains, creates dynamic successions, and maintains ecosystem variability and instability. Changes in sediment transport have been identified as one of the most important environmental impacts of dams. The reduction in sediment transport in rivers downstream of large reservoirs not only has impacts on channel, floodplain and even coastal delta morphology, and so alters habitat for fish and other groups of plants and animals, but through changes in river water turbidity may affect biota directly. For example, if turbidity is reduced as a consequence of impoundment, plankton development may be enhanced.

3.2.3.2.2 Second order impacts:

3.2.3.2.2.1 Channel morphology and sedimentation

Large reservoirs alter the hydro-morphological processes operating in the downstream river system, by isolating upstream sediment sources, controlling floods and regulating the annual flow regime.

The change in channel reach below an impoundment depends upon the interaction of four factors: a) degree of sediment reduction in the reservoir, b) the degree of flow regulation, c) the resistance of the channel bed and bank materials to erosion, and d) the quantity and nature of downstream sediment sources.

If the post-regulation flows remain competent to move bed material, as is typically the case with run-of-the-river plants, the initial effect is degradation downstream of the impoundments, because the entrained sediment is no longer or not sufficiently replaced by material arriving from upstream. For example, this has been the long-term case in the Rhine River. According to the relative erodibility of the streambed and banks, degradation may be accompanied by either narrowing or widening of the channel. Another typical result of degradation is a coarsening in the texture of material left in the streambed; in many instances a change from sand to gravel is observed.

As a consequence of the reduction in sediment transport, channel patterns may ultimately be changed near the point of regulation, e.g. from braided to split or single thread.

Further downstream, increased sedimentation (aggradation) may occur because material mobilised below a dam and material entrained from tributaries cannot be moved so quickly through the channel system by regulated flows.

3.2.3.2.2.2 Floodplains

Damming a river can alter the character of floodplains as the reduction in flood flows reduces the number of occasions and extension of floodplain inundation. The river becomes divorced from it floodplain. Effects on floodplain ecosystems are specifically critical as they often are matured systems with a large biological diversity and complicated food-web structures that are difficult to restore once lost (if at all).

3.2.3.2.2.3 Coastal deltas

In contrast to the impact on river and floodplain morphology, where aggradation may occur, impounding rivers invariably results in increased degradation of at least part of coastal deltas, as a consequence of the reduction in sediment input. An example is the Rhone River, where a series of hydropower dams retain much of the sediment that was historically transported into the Mediterranean and fed the dynamic processes of coastal accretion there. It is estimated that these dams and associated management of the Rhone and its tributaries have reduced the quantity of sediment transported by the river to 12 million tons in the 1960s and only 4-5 million tons today. This has contributed to erosion rates of up to 5 meters per year for the beaches in the regions of the Camargue and the Languedoc (Balland, 1991), requiring a coastal defence budget running into millions of Euros.

3.2.3.2.2.4 Plankton and Periphyton

Large impoundments can markedly alter the plankton component of river systems below dams in two ways: a) by changing the conditions affecting the development of riverine plankton (e.g. through modification of the flow regime and alteration of chemical, thermal and turbidity regimes) and b) by usually, but not always, augmenting the supply of plankton into the downstream system. These changes affect not only plankton abundance, but also plankton composition. Three factors govern the contribution of lentic plankton to the river downstream: a) the retention time, b) the seasonal pattern of lentic plankton development and c) the character of outflows from the reservoir.

Within impounded water bodies, in temperate climates, the maintenance of higher summer discharges, the reduction of flood magnitude and frequency, reduced turbidities and the regulation of the thermal regime (i.e. higher winter temperatures) often promotes algal growth (Petts, 1994).

The periodic disruption of periphytic communities under, natural, variable flow conditions may be eliminated, or decreased in frequency, as a result of flow regulation. This allows full development of a periphyton assemblage, at least in channels of relatively steep slope where moderate current speeds can be maintained.

Downstream from deep release reservoirs the composition of the attached algae and the proportion of the substrate covered changes as temperature, turbidity and substrate stability vary in response to tributary and anthropogenic inputs. Typically, algal growth occurs in the channel immediately downstream from dams because of the nutrient loading of the reservoir releases, and diminishes downstream due to processes of self-purification. Increased algal density has been observed immediately below the Veyriers dam, on the Fontaulière River (France). However, although algal biomass was up to 30 times greater than at an upstream reference site, species composition was considerably altered. The differences have been attributed to nutrient pollution, lowered water temperature, flow constancy and substrate stability (Valentin et al., 1995).

3.2.3.2.2.5 Growth of Aquatic Macrophytes

Compared with the situation in a natural river, the root systems of plants experience reduced effects of scour downstream of large dams. The plants suffer less stress from high discharges and the rate of channel migration is reduced, so that typically areas of the channel-bed are available for the development of aquatic plants.

Flow regulation not only decreases the competence of discharges and inhibits bed-material movement, but also induces the deposition of finer sediments where supplies are available from tributary or effluent sources. Channel sedimentation, particularly involving nutrient-rich silt, can markedly alter plant distributions. The complex feedback processes that link water and matter fluxes with vegetation and how these change as a consequence of river impoundment, have been illustrated by studies conducted in the Upper Rhone River (Girel and Patou, 1996).

The elimination of high discharges to flush systems has allowed the extensive development of aquatic weeds downstream of large dams in some cases.

3.2.3.2.2.6 Riparian vegetation

Riparian tree species are dependent on river flows and a shallow aquifer, and the community and population structure of riparian forests is related to the spatial and temporal patterns of flooding at a site. Conversely, artificial pulses generated by dam releases at the wrong time – in ecological terms – have been recognised as a cause of forest damage.

3.2.3.2.3 Third order impacts on fauna:

3.2.3.2.3.1 Freshwater Species Diversity Changes

Reduction a) in variability of water discharge over the year, b) of flood peaks, c) of channel-forming flows and d) of sediment transport result in complex changes in degradation and aggregation below dams. These changes and others directly and indirectly influence dynamic factors that affect the diversity and abundance of invertebrates, fish, birds and mammals downstream of hydropower plants and dams.

Complete closure of river flow below hydropower plants and dams (e.g. for hydro-peaking), reduces downstream populations. However some populations may manage to hang on in pools or tributaries. These effects can lead to declines in downstream fisheries.

Most aquatic species require minimal flows in which to navigate, feed, etc. Such species may be seriously affected by reduced flows which mean reduction of area of habitat. Habitat reduction may mean simply smaller populations or reduced growth rates, or where populations are already at risk, it may lead to loss of a population or even extinction of entire species.

Diadromous (e.g. salmon and eels) and potamodromous (e.g. barbel, pike etc.) fish species have migratory patterns. Migrations occur between marine and freshwater ecosystems and within freshwater ecosystems (linearly and laterally, i.e. into floodplains). Hydropower plants, dams and weirs block or impede these migrations to varying degrees. The blockage of fish movements upstream is the most significant and negative impact of instream obstacles on fish survival and biodiversity. Many stocks of Salmonidae (e.g. salmon), Acipenseridae (e.g. sturgeon) and Clupeidae (e.g. shads) have been lost as a consequence.

Even when fish passes have been installed successfully, migrations can be delayed, e.g. by the absence of navigational cues such as strong currents in reservoirs. This causes stress on the energy reserves of the fish as, for example, anadromous fish (e.g. salmonids) do not feed during migration.

Mortality resulting from fish passage through hydraulic turbines or over spillways during their downstream migration can be significant (section 3.2.3.1). Problems associated with downstream migration can also be a major factor affecting anadromous or catadromous fish stocks. Habitat loss or alteration, discharge modifications, changes in water quality and temperature, increased predation pressure, and delays in migration caused by hydropower plants and dams are significant issues.

The control of floodwaters by large dams, which usually reduces flow during natural flood periods and increases flow during dry periods, leads to a discontinuity in the river system. This together with the associated loss of floodplain habitats has a negative impact on fish diversity and productivity. The connection between the river and floodplain or backwater habitats is essential in the life history of many riverine fishes that have evolved to take advantage of the seasonal floods and use the inundated areas for spawning and feeding (e.g. pike and tench). Loss of this connection can lead to a rapid decline in productivity of the local fishery and to extinction of some species.

Dams can deteriorate riverine fisheries downstream. If discharge is from the hypolimnion of a reservoir, lowered temperatures in the receiving tailwater can curtail or eliminate warmwater river fisheries and may require stocking of coldwater species such as salmonids (assuming that the water is sufficiently oxygenated).

3.2.4 Cumulative impacts of dams

Many of the major river catchments in Europe contain multiple dams. Within a basin, the greater the number of dams the greater the fragmentation of river ecosystems. It is estimated that 61% of the worlds river basins are highly or moderately fragmented (Nilsson et al., 2005).

The magnitude of river fragmentation can be very high. In Sweden, for example, only four major (longer than 150 km) and six minor (70-150 km) first order rivers have not been affected by dams (Bergkamp et al., 2000).

River impoundment affects the downstream environment, so dams built in the same catchment, either in series (i.e. along the same river) or in parallel (i.e. on different tributaries) will inevitably result in cumulative impacts. A cumulative impact is defined as the incremental effect of an impact added to other impacts. An individually insignificant impact may, when combined with others, produce a major change within a river ecosystem. The total effect on a river ecosystem of cumulative impacts may be greater than the sum of each individual impact. This is particularly the case for those second and third order impacts that are dependent on a number of lower order impacts.

There has been relatively little research into the cumulative effects of dams. The most frequently mentioned type of cumulative impact is the combined effects of multiple dams on river discharge and water quality. Cada and Hunsaker (1990) investigated the cumulative effects of hydropower development and grouped the impacts into four potential pathways ranging from simple, additive effects of a single project to synergistic effects arising from multiple projects.

Further, successive plants can result in:

- change in sediment pattern,
- change in habitat conditions,
- barrier function for fish migration, and
- eutrophication.

The specific effects depend largely on the type and vulnerability of the river system, and the size and the distance between each of the hydropower plants/ dams.

In several countries, the importance of cumulative impacts is increasingly recognised. Several of them, most notably the United States and Canada have made efforts to study and define cumulative impacts for incorporation of their impacts assessment into legal guidelines for environmental impact assessment. Consideration of cumulative impacts became a formal requirement in the National Environmental Policy Act in the United States in the late 1970s and in Canada in 1992 (Bergkamp et al., 2000). In Europe this issue has so far only been addressed in a qualitative and theoretical fashion, for example in Germany in the States of North Rhine-Westfalia and Rhineland-Palatinate (Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrhein-Westfalen, 2005 and Anderer et al., 2010).

A major constraint on assessing the cumulative effects on higher order impacts is the paucity and low quality of available data. However, research has been conducted that demonstrates cumulative impacts at all three levels of impact caused by impoundments. A third order cumulative impact often cited is that of mortality of migratory fish. On the Columbia River, USA between 5% and 14% of adult salmon are killed at each of the eight dams through which they pass. Consequently, the cumulative mortality is 70% to 90% in every salmon run (Bergkamp et al., 2000).

3.2.5 Information Constraints

Over the last 30 years, the findings of numerous scientific studies relating to the environmental impacts of hydropower facilities and dams have been reported in the scientific literature. Some of these findings have been summarised within wide-ranging compilations (e.g. ICOLD, 1981, 1988, 1994 and WCD, 2000).

Research continues and research findings are constantly being up-dated. Other sources of information include a significant body of grey literature, usually written during the planning of a river impoundment. Most of these case studies consist of pre-regulation investigations. Finally, there is now an increasing amount of information and related position papers published by various organisations. However, to an extent the perspective of the people and organisations involved cloud the latter and the information presented may be selective in nature.

In order to effect a thorough investigation of the impacts of dams on ecosystems, data are required on both the abiotic and the biotic components of ecosystems. Pre- and post-impoundment information is required on: the hydrology of the river (both at the site of the dam and downstream); hydraulic characteristics of the river; water quality; geomorphological characteristics (i.e. sediment transport); aquatic biota and their habitat requirements; riparian vegetation and associated fauna; vegetation and associated fauna in the upper watershed; and the direct use of the river and its associated resources by local people.

To date, most studies have investigated the impact of one dam or a few dams on specific components of ecosystems rather than on the ecosystem as a whole. Most studies are focussed primarily on the abiotic, primarily first-order impacts. Relatively few studies have assessed second and third-order impacts, possibly because of the longer time frame required before new equilibrium states are attained and total change becomes apparent. At higher trophic levels (e.g. impact on fish), very limited amounts of data relate to long-term change caused by dam construction, though possible impacts are subject to much speculation (Nilsson and Dynesius, 1994).

3.2.6 Impacts of hydropower plants and dams on the aquatic environment in view of the WFD requirements

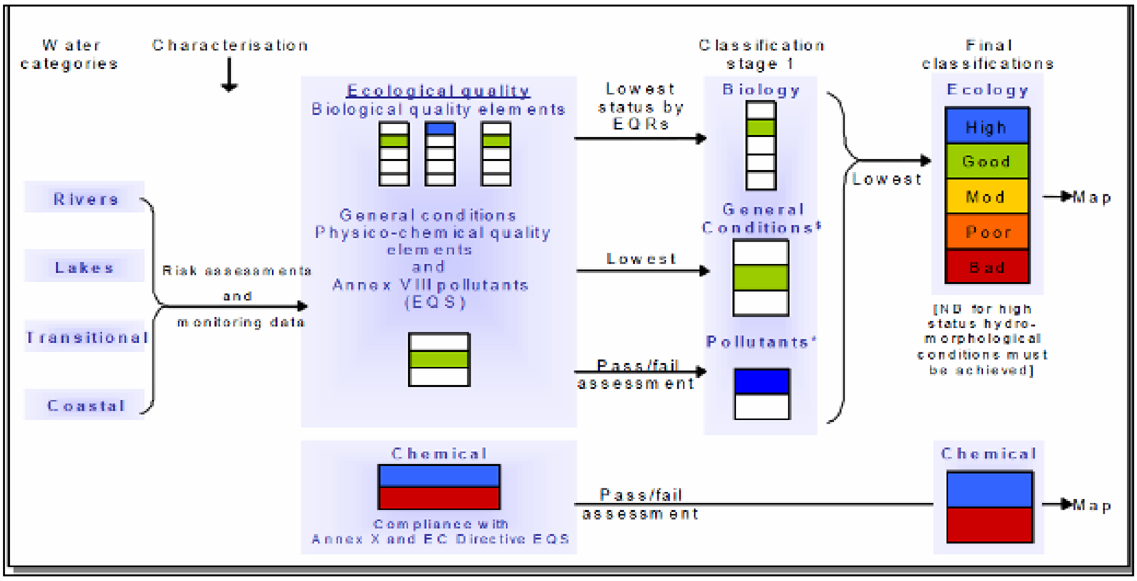
3.2.6.1 WFD requirements and hydromorphological pressures

The environmental objective of the WFD is to achieve ‘good status’ for all groundwaters and surface waters by 2015 at the latest. ‘Good status’ is a concept that on the one hand ensures protection of all water bodies in a holistic way, and on the other hand integrates quality objectives for specific bodies of water derived from other legislation (e.g. the Drinking Water Directive). For surface water, it consists of a general requirement for ecological protection (“good ecological status”), and a low level of chemical pollution (“good chemical status”).

Good ecological status is defined in terms of the quality of the biological community (e.g. phytoplankton, macrophytes and phytobenthos, benthic invertebrate fauna and fish fauna), the hydromorphological characteristics (supporting the biological community e.g. hydrological regime, river continuity, channel patterns, width and depth variations, flow velocities, substrate conditions, and both the structure and condition of the riparian zones), and the chemical and physico-chemical characteristics (e.g. thermal conditions, oxygenation conditions, salinity, acidification status, nutrient conditions) (see Annex V WFD and Figure 3.8). The controls are specified as allowing only a slight variance from the biological community that would be expected in conditions of minimal anthropogenic impact, thus accounting for ecological variability between different waters.

The analysis of pressures and impacts (end 2004) showed that a significant number of surface water bodies across Europe are at risk of failing to achieve good ecological status. The information in the Article 5 reports shows differences in the importance of different pressures between the EU Member States. In general waste water discharges are less important in EU15 than in the new EU12 Member States, agriculture appears as most relevant to water quality in some EU15 Member States and hydromorphology is considered significant all over EU27.

Figure 3.8: Classification of surface water bodies (CIS, 2005)



Hydromorphological alterations, i.e. modifications to the structural characteristics and associated impacts on the hydrological characteristics, are amongst the top pressures emerging from the WFD analysis. Amongst others, hydropower and dams have been identified as the main drivers causing the degradations (European Commission, 2007,). 16 out of 20 Member States have indicated power generation including hydropower as being a driving force related to hydromorphological pressures (Figure 3.9).

Table 3.1 (CIS, 2006) summarises typical hydromorphological alterations associated with different water uses and their subsequent impacts on hydromorphology.

Almost all Member States have (provisionally) designated selected surface water bodies as heavily modified or artificial water bodies, whereby they will need to meet the good ecological potential quality criteria. In their initial assessments Member States identified about 20% of the EU's surface water bodies as being heavily modified and a further 4.5% as artificial (CIS, 2006). The situation varies widely between Member States. Belgium, the Czech Republic, the Netherlands and Slovakia designated over 40% of their surface water bodies as heavily modified. In contrast, Latvia and Ireland indicated that less than 2% of their water bodies are heavily modified or artificial.

Figure 3.9: Percentage of 20 Member States indicating a driving force related to hydromorphological pressures as significant (European Commission, 2007)

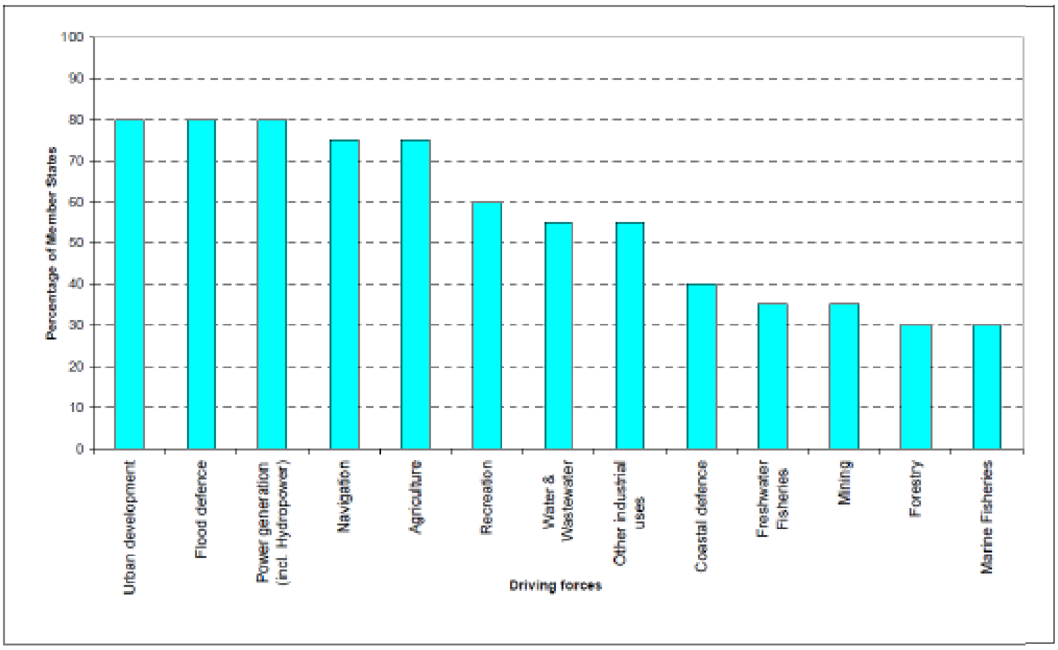


Table 3.1: Overview of hydromorphological alterations typically associated with different water uses and their subsequent impacts, x = more relevant, (x) = less relevant (CIS, 2006)

	Specified uses (= driving force)					**Impacts on hydromorphology: deteriorations, impairments of hydromorphological conditions (= deficit parameters)**						
Physical modifications (= pressure)	Navigation	Water regulation, flood protection	Activities for which water is stored, transferred or bypassed			Disruption in river or estuary continuum & sediment profile	Change in hydrological regime: low / reduced or increased flow, artificial discharge and level regime	Change in (soil) erosion / sediment transport / silting	Change in river profile (length and transverse profile)	Disruption in lateral connectivity, detachment of oxbow lakes / wetlands	Restriction / loss of flood plains or intertidal area	Change in connection with groundwater, alteration of groundwater level
			Power generation	Water supply	Irrigation							
Cross profile construction (dams, weirs, locks, impoundments)	x	x	x	x	x	x	x	x	x	x	x[1]	x
Longitudinal profile construction (dykes)	(x)	x					x		x	x	x	x
Channelisation, straightening	x	(x)	(x)	x	x	(x)	x	x	x	x	(x)	x
Bank reinforcement, bank fixation, embankments (training wall, breakwater, groynes etc.)	x	(x)	(x)	(x)		x	x	x	x	x		
Deepening (channel maintenance, dredging, removal or replacement of material)	x	(x)	(x)		(x)	(x)	x	x	x			x
Intakes, transfers and bypasses of water (tunnels etc.)			x	x	x	x	x					

3.2.6.2 WFD quality elements sensitive to pressures related to hydropower

For WFD surveillance monitoring all relevant quality elements must be monitored. However, for the operational monitoring programmes required under the WFD, the Member States do not necessarily need to use all biological quality elements for assessing the ecological status of a water body. According to the WFD, Member States shall monitor parameters that are “indicative of the status of each relevant quality element” (Annex V.1.3). Appropriate parameters for these biological quality elements need to be identified to obtain adequate confidence and precision in the classification of the quality elements (CIS N°13, 2005). It is suggested that the parameters indicative of the quality elements most sensitive to the pressures to which the water bodies are subject are selected. According to CIS guidance N°13 the sensitivity of biological elements and of the parameters monitored to estimate their condition may be considered in terms of (a) their actual sensitivity to the pressure and (b) the degree of confidence that can be achieved in monitoring results. There are no agreed (CIS) guidelines on the elements considered sensitive for certain pressures. However, UKTag (the body coordinating WFD implementation in the UK) includes guidelines in its monitoring guidance (UK Tag 12a, 2005). Quality elements most sensitive to hydro-morphological pressures affecting rivers are macrophytes, macroinvertebrates and fish. For the assessment of pressures in lakes, eutrophication is considered to be the main pressure with phytoplankton and macrophytes as main indicators.

The greenhydro method (Bratrich & Truffer, 2001), developed to address the trade-off between hydropower use and the protection and ecological enhancement of highly affected river systems, uses 2 of the WFD biological elements, namely fish and macroinvertebrates. These are used in similar ways to the WFD. Phytoplankton and macrophytes do not form key criteria to assess the impact of hydropower use according to the greenhydro method, but it is recognised in Ruef & Bratrich (2007) that the method is complementary with the requirements of the WFD.

3.2.7 European mitigation practice to reduce impacts on the aquatic environment

Many of the impacts described in Sections 3.2.3 and 3.2.6 can be mitigated with restoration and mitigation measures (refer CIS Workshop, 2007). The summary ‘Good practice in managing the ecological impacts of hydropower schemes, flood protection and works designed to facilitate navigation’ (CIS, 2006), prepared as part of the CIS activity on WFD & Hydromorphology, includes several case studies that demonstrate measures that can improve the ecological status/ potential by means of restoration/ mitigation measures.

There exists a great variety of restoration/ mitigation measures that can be applied to reduce (local) impacts from hydropower. Measures are generally chosen in view of the site-specific impacts/ adverse ecological effects and the particular characteristics of the affected water bodies. More recently they are also selected based on the regional water management goals (e.g. river basin/ sub-catchment management plans).

Today there exist several documents that contain a range of generic mitigation measures and strategies for specific ecological impacts or - more general - for water bodies impacted by hydropower, e.g.

- International Hydropower Association (2004) and CIS (2006) Figures 5 to 7
- Environment Agency (2009)
- Scottish Environment Protection Agency (2010)
- European Small Hydropower Association / SHERPA (?)

The subsequent sections outline European mitigation practices to reduce impacts on the aquatic environment, state relevant guidelines and standards and comment on the state of the art.

3.2.7.1 Upstream fish passage

Most fish species need to migrate during certain life stages. As explained in Section 3.2.3.1, dams and weirs act as barriers to fish migration. Worldwide upstream fish passage has been restored (in particular during the last two decades) by equipping new dams/ weirs and retrofitting existing impassable barriers with fishways (fish passes). These facilities provide access to spawning grounds and for feeding migrations, habitat shifts, re-colonisation after floods, and restoring fragmented populations. There exist various types of fishways for upstream migration (Table 3.2).

Table 3.2: Classification of upstream fish passage structures (DWA, 2010)

Fish passes / fishways				**Bottom structures, waterway crossings and other hydraulic structures modified to allow for fish passage**
at or integrated into the migration barrier			**extend extensively around migration barrier**	
Pool-type passes	**Channel-type passes**	**Special technical constructions**	**Bypass channels**	
Vertical slot pass Pool and weir-type pass Pool and orifice-type pass Nature-like boulder-type pass	Baffle/Denil pass Eel pass Bristle-type pass	Fish lock Fish lift (fish elevators)	Nature-like channel e.g. with perturbation boulders	Rock ramp Fish-friendly culvert Duct Sluice gate Flood gate Ship lock Gauging station Flood detention dam

Design guidelines for different types of fishways are available in various European countries, for example:

- Germany: DVWK (1996), Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz NRW (2005), Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Wuerttemberg (2006), DWA (2010)
- France: Larinier et al. (2002)
- United Kingdom: UK Environment Agency (2004)
- Netherlands and Belgium: Kroes & Monden (2005)
- Italy: Provincia di Modena (2006)

Moreover there exist numerous international fishway design guidelines, standards and recommendations, such as Pavlov (1989), Clay (1995) and DVWK/FAO (2002).

Whereas some design guidelines formerly only focussed on certain target species requirements, e.g. of Salmonids, fishways are nowadays designed for the entire (potentially natural/ type-specific) fish fauna in a water body, i.e. for various species, life stages and respective sizes (DWA, 2010). For example, the recently inaugurated vertical slot fish pass in Geesthacht (Figure 3.10) was designed to enable passage of sturgeon (that can grow up to 3 m in length) that are being restored in the Elbe River basin. Therewith Geesthacht fish pass represents Europe’s largest fish pass.

Figure 3.10: Vertical slot fish pass Geesthacht, Elbe River, Germany (Photo: Vattenfall)

The design of fish facilities always requires knowledge of the swimming performance and ability as well as the behaviour of the species concerned so that the fish pass does not present an impediment for example to juveniles, weak swimmers or large fish. In principle two prerequisites are decisive for the effectiveness and efficiency of fish passes (DWA, 2010):

1. traceability, i. e. the fish pass location, entrance position, hydraulic conditions at the entrance and attraction flow, and
2. passability, i. e. the fish pass design e. g. design discharge, flow velocities and patterns, water depths, pool dimensions, slot spacings etc.

Whereas the passability of fish passes depends on the actual construction type and the respective hydraulic and geometric conditions prevailing within the pass, the requirements of the fish passes traceability rather refer to their general layout. The various aspects that apply to all types of fish pass constructions are illustrated in the aforementioned design publications.

Today pool-type passes (Figure 3.11), channel-type passes and bypass channels (Figure 3.12) are common solutions for low-head barriers (up to around 10 m height), such as weirs or small dams. Fish locks and fish lifts (Figure 3.13) are technologies for high barriers (> 10 m). Rock ramps are popular nature-like structures to restore fish passage at bottom structures or in weir decommissioning projects.

In general, fishways are internationally considered as being well-developed for a wide range of diadromous and potamodromous fish species. Their construction and operation is considered common practice at low-head barriers. However, pool-type passes, channel-type passes and bypass channels are usually not applicable for high barriers due to spacial constraints; the comparatively small slope of these facilities would result in significant construction lengths that regularly are not available on site. For example, the length of the nature-like bypass channel at the Harkortsee hydropower station (Figure 3.12) with a head of 7,80 m amounts to 370 m. Solutions for high barriers, e.g. fish locks and fish lifts, are technically complex and comparatively expensive facilities (both, in construction and operation). Due to their non-continuous rotational operation, additional features, such as entry chambers with fish crowders, are necessary, so that they function effectively. Therefore, and because of other reasons, their number worldwide is limited (Redeker, 2005).

Figure 3.11: Pool-type fish pass, Pitlochry Dam and hydropower station, River Tummel, Scotland (Photo: Marq Redeker)

Water and/or fisheries legislation in several European countries incorporate fish passage requirements. Today, hydropower master plans and individual consents/ licences for new hydropower plants and dams/ weirs typically entail fishways to mitigate the upstream barrier effect in almost all European countries (e.g. Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz NRW (2009), Environment Agency (2009), Scottish Environment Protection Agency (2010), Halleraker (2011)). This is also the case for re-consenting/ re-licensing processes.

Figure 3.12: Nature-like bypass channel Harkortsee hydropower station, Ruhr River, Germany (Photo: Ruhrverband)

Figure 3.13: Fish lift at Tuilières hydropower station, Dordogne River, France (Photo: Marq Redeker)

3.2.7.2 Downstream fish passage and fish protection

The issues related to downstream fish migration are outlined in Section 3.2.3. Hydropower stations/ turbines and spillways can inflict serious injuries or even mortalities to downstream migrating fish.

In general, fish protection and downstream passage issues are not as well studied as those associated with upstream migration. The development of effective protection facilities is more complex than with upstream fishways and requires taking into account the varying swimming ability and behaviour of fish species and their life-stages, as well as site-specific conditions (e.g. water temperature). Therefore fish protection technologies are much less advanced than upstream fishways.

However, several types of fish protection facilities exist and have been in operation for decades. They can be categorised into

- mechanical barriers (e.g. inclined bar racks, mesh and wedge wire screens (Figure 3.14), drum screens, perforated plates, louvres etc) and
- behavioural / guidance devices (repulsion with electricity, light, sound etc).

The facilities are commonly equipped with additional bypass systems to convey fish safely downstream of the hydropower plant.

Design guidelines are available in Europe and overseas, e.g.

- France: Larinier et al. (2002)
- Germany: DWA (2005), Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz NRW (2005)
- United Kingdom: Turnpenny et al. (1998) and UK Environment Agency (2005)

Internationally it is accepted that mechanical barriers that physically prevent fish from being entrained into intakes, pumps or turbines, are the only effective fish protection systems. The behavioural devices have not performed successfully; their effectiveness varies considerably and is species, life-stage and/or site specific. (DWA, 2005)

For mechanical barriers to be effective and efficient they must

- have sufficiently small bar spacing / mesh to prevent fish from passing through;
- provide low approach flow / sweep velocities to avoid fish impingement and allow fish to escape from the screen surface (which usually requires larger screen areas); and
- preferably guide fish to safe areas, e.g. by installing additional bypass systems.

There are two principal issues associated with fish protection and downstream passage (Redeker, 2010):

1. Realistically it is impossible to provide protection for all life stages of fish, e.g. for larvae and fry. Therefore prescribing specific screen aperture represents a conscious decision on which fish sizes / life stages one intends to protect, or not. This determination that essentially defines what proportion of fish need to be excluded to meet both environmental targets and water users objectives, is always a mutual compromise and controversially debated. In Europe, screen aperture and mesh size requirements/ recommendations lie between 10 to max. 20 mm depending on the (target) fish species and size (i.e. life-stage) to be protected.

2. The technical and economical challenge with mechanical barriers lies in their operation and maintenance (in particular screen cleaning and sediment management), and not so much in their design and installation. Currently fine screen facilities (< 15 mm) are only expected to be technically feasible at hydropower plants with design discharges of around 40 - 50 m³/s.

Figure 3.14: Retrofitted inclined wedge wire screen pilot facility (5 mm spacing) with surface bypass and cleaner in an intake channel of a German mini-hydropower plant (design flow: 1.7 m³/s) (Photo: Marq Redeker)

Other known issues are:

- Fish protection facilities for hydropower plants at large dams with low-lying intakes and penstocks are very difficult to retrofit and operate (Redeker, 2005).
- Fine screen facilities are generally expensive to install and operate.

In all, fish protection issues have only really been considered in the last two decades. As yet, no country has found an entirely satisfactory solution. Issues have been examined and addressed in Northern America and Europe with regards to salmonid fish species and eels only. Comparatively little information is available on other species.

Countries are tackling this problem by pursuing joint and staged approaches including:

- Intensification of scientific research, e.g. of fish behaviour and swimming performance.
- Interdisciplinary discussions and preliminary determination and endorsement of fish screen design parameters (e.g. aperture and sweep velocities) based on agreed criteria, such as long-term resource management (e.g. WFD) and fish conservation objectives.

- Expert design, construction, operation, and intensive and professional monitoring and evaluation (including environmental and cost effectiveness) of multiple pilot facilities of varying sizes in different environments. These are usually publicly funded.
- Review of preliminary design criteria, formulation of guidelines / decision support systems etc. and adoption by the regulator.
- Commitment to an ongoing improvement process.

These approaches can

- identify sensible and practical solutions that are continually optimised;
- produce best practice guidelines that are regularly revised as the experience and knowledge of fish protection technology advances; and
- contribute to establishing and extending international fish protection know-how.

‘Trap & truck’ and ‘trap & barge’ are alternative approaches to fish protection facilities. These techniques involve trapping migrant fish at a barrier and transporting them up- or downstream in trucks or barges. The approaches are controversial. The lack of (a) conventional fishway(s) or fish protection facilities and the cost of installing one or more facilities are typical reasons for using these alternative means of fish transport. Some practitioners have concerns regarding the effect that handling and transport have on fish behaviour and health. On the other hand, trap and truck operations are successfully being used in some cases to move fish up-/downstream of long reservoirs, and/ or multiple hydropower/ dam schemes; fish can then be released close to spawning grounds or the sea. In Europe trap & truck is being executed on the Garonne River in France (for downstream passage of salmon smolts) (DWA, 2005, Figure 3.15 and Figure 3.16) and on the Moselle River in Germany (for downstream passage of eels). Trap & truck’ and ‘trap & barge’ is also performed in the USA, e.g. in the Columbia River Basin.

Possible adverse impacts of trapping & trucking fish include disorientation, disease and mortality, delay in migration, and interruption of the homing instinct, which can lead to straying.

Early warning systems are another alternative fish protection technology. There exist

- abiotic early warning systems (based on the mathematic correlation between meteorological / hydrological parameters and on the information of the migratory activities of the target species concerned),
- technical early warning systems (recognition of fish migration by using detectors, e.g. underwater cameras for visual monitoring, echo sounding systems and hydrophones), and
- biological early warning systems (based on the assumption that monitored fish kept in a holding tank show the same behavioural patterns as members of the same species in a water body, e.g. the MIGROMAT®-system (Adam & Schwevers, 2006).

Early warning systems and their development stages and effectiveness are described in Bruijs et al. (2003), DWA (2005), Moltrecht (2010) and others. Early warning systems usually form an element of turbine management practices. For example, at Wahnhausen hydropower plant (Fulda River, Germany) a MIGROMAT®-system monitors downstream migration activities of eels since 2002. In case a high migration activity is detected, the local hydropower operator temporarily reduces turbine discharge and simultaneously opens the neighbouring weir gate in order to provide a safe downstream passage route (Pöhler, 2006).

Figure 3.15: Trapping station for downstream migrating salmon smolts in Camon, Garonne River, France (Photo: Marq Redeker)

Figure 3.16: Truck of the Garonne River trap & truck scheme. The fish are transported 200 km downstream and released below the lowermost Golfech dam. (Photo: Marq Redeker)

3.2.7.3 Sediment and debris management

Mitigation measures include:

- Artificial scouring floods to clear mud and vegetation in downstream reaches, e.g. to create adequate spawning conditions (e.g. expose gravel substrates).
- Reservoir drawdowns during high flow periods in order to pass bed- and washload.
- Flushing flows intend to wash away detrimental sediment accumulations.
- Introduction of sediment bypassing structures or procedures to restore downstream sediment supply or to limit upstream aggradation.
- Regulation of material removal and sediment (gravel) extraction.
- Moderate and focused watercourse maintenance.

For ecologically based sediment management it is advisable and sensible to undertake a combined set of measures for an entire chain of power plants (similar to fish migration) (Bratrich & Truffer, 2001).

3.2.7.4 Mitigation of disruption of flow dynamics

Artificial discharge regimes should be avoided for ecological reasons. However, if artificial discharge regimes cannot be avoided entirely, the ecological status of the water bodies affected can still be improved through operational modifications that, for example, attenuate the volume and frequency of artificially generated abrupt waves and avoid unduly precipitous water level fluctuations (Bratrich & Truffer, 2001).

Hydro-peaking is known to have serious ecological consequences (e.g. flushing and stranding effects, temperature alterations etc., see Section 3.2.3.2). However there are still knowledge gaps with regards to its impacts. Mitigation options are limited and often involve high costs due to the loss of peak-load capacity. However, examples for successful implementation of mitigation measures exist (CIS Workshop, 2007 - conclusions):

- application of minimum flow (see separate paragraph)
- dampening of peak flow
- alteration of hydropower operation
- compensation reservoirs (examples: Möhne and Sorpe Dams, Ruhr River Basin, Germany)
- coordination of multiple power plants

Following goals must be achieved by measures to mitigate flow changes (Bratrich & Truffer, 2001):

- Attenuation of discharge fluctuations: attenuation in regard to the frequency (on a seasonal basis, particularly in the case of spawning and migration periods) and in terms of quantity, sufficiently to ensure that no lasting qualitative and quantitative damage is caused to the naturally occurring diversity of the fish and benthic fauna in the river reaches involved. In particular, care must be taken that the water level does not fall too swiftly in the reduced-flow period and does not rise abruptly in the peak generation-flow period. The Austrian regulation on hydro-peaking is an example.

- No dry-out in return flow sections, so that a minimum functional habitat diversity for flora and fauna is assured (minimum flow regulations).
- No critical effects of temperature.
- No isolation of fish and benthic fauna outside the main channel: The gradient of the water level change in the receding-flow phase must be attenuated adequately to ensure that widespread isolation of the fish and benthic fauna in their refugial habitats outside the main channel is avoided. No isolated pools should be created, in which the oxygen concentration falls below critical levels.
- Preservation of habitat diversity and characteristic landscape features.
- Preservation of fish habitats, particularly spawning grounds and juvenile fish habitats. No irreversible loss in the variety of fish habitat may occur, nor any serious disruption to the naturally occurring diversity and age class distribution of fish populations. Suitable spawning grounds and habitat for juvenile fish may not dry out, particularly during low flow periods.

Minimum flows can cause significant changes to the abiotic and biotic conditions in and around river systems. The aim of ecologically compatible minimum flows is to ensure a discharge regime that closely reflects the natural characteristics of the river system involved. It is often impossible to make general statements on evaluating its impact, since many of the factors relevant to the assessment are dependent on local circumstances. Individual studies are therefore useful for the determination of minimum flow regulation that optimises ecological and economic imperatives. It is important to know which discharge in particular river stretch is actually significant ecologically (Green Power Publications, Issue 7).

In order to meet the criteria of good ecological status or potential, ecologically an acceptable minimum flow should remain in a river downstream of a hydropower scheme (except in a river that naturally and temporarily falls dry) and aim at maintaining and restoring the river's type-specific aquatic community:

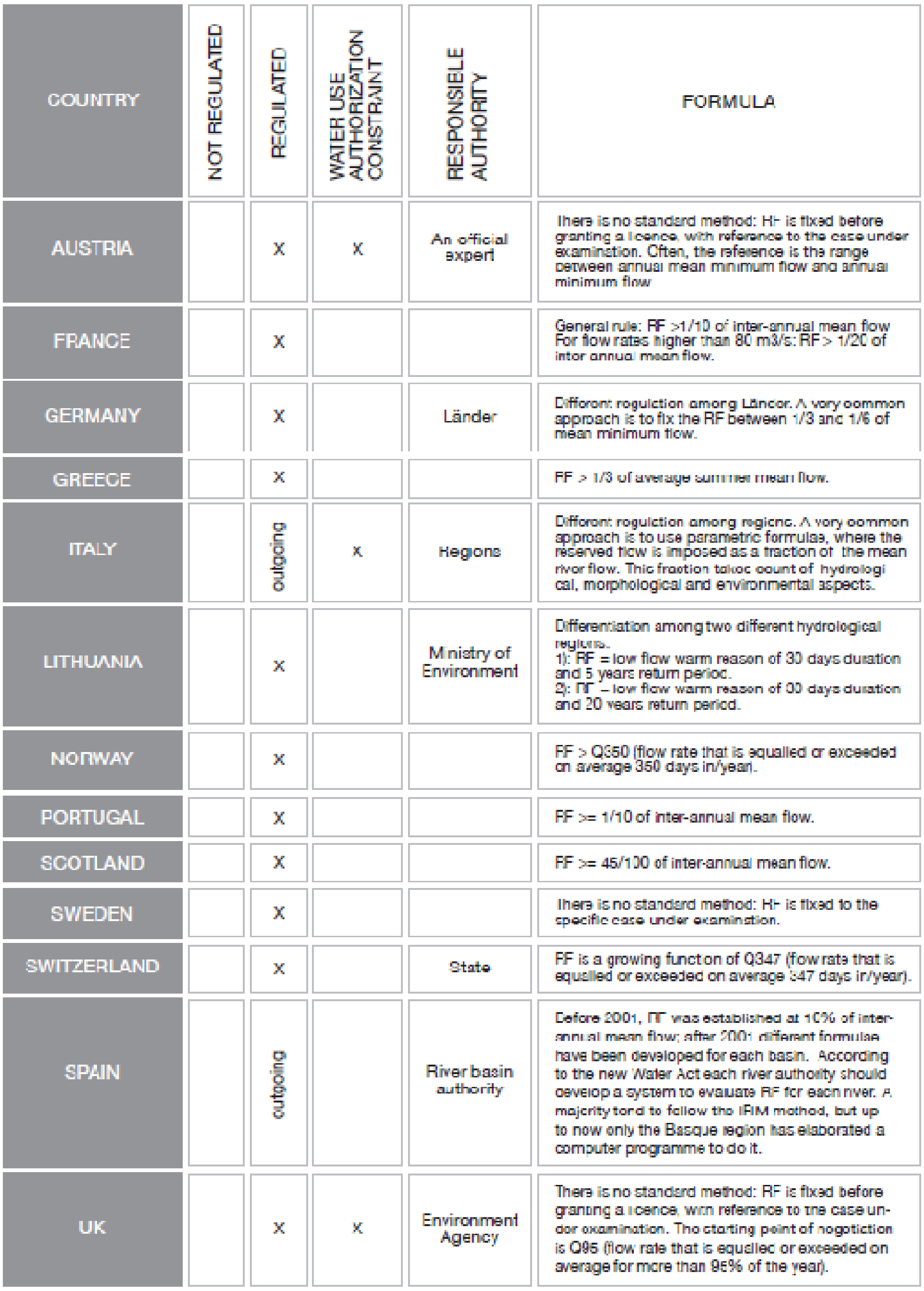
- stable flow over summer, or
- variable flows designed for downstream ecology.

Several European countries have developed different minimum flow standards/ requirements (European Small Hydropower Association / SHERPA, Table 3.3). There is no one-size-fits-all approach - a combination with other mitigation measures (e.g. fish pass) is often necessary.

Instream flow requirements, often expressed as percentages of the annual flow, usually give little consideration to the importance of natural seasonal flow variations (e.g. flow releases which raise levels during normally dry spells can even do more harm than good). Instream flow requirements also rarely allow for releases of occasional large flood flows which form part of fluvial ecosystems. In general, instream flows can mitigate the effects of dams but cannot recreate the variability and dynamics of natural rivers.

Extensive research on minimum flows is being conducted in different EU Member States, but there are still gaps mainly as to the ecological responses to minimum flows and interaction with morphology. It is recognised that European standards at general level are needed (CIS Workshop, 2007).

Table 3.3: Some of the current European minimum flow (RF) regulations (European Small Hydropower Association / SHERPA, ?)



COUNTRY	NOT REGULATED	REGULATED	WATER USE AUTHORIZATION CONSTRAINT	RESPONSIBLE AUTHORITY	FORMULA
AUSTRIA		X	X	An official expert	There is no standard method: RF is fixed before granting a licence, with reference to the case under examination. Often, the reference is the range between annual mean minimum flow and annual minimum flow
FRANCE		X			General rule: RF >1/10 of inter-annual mean flow For flow rates higher than 80 m3/s: RF > 1/20 of inter annual mean flow.
GERMANY		X		Länder	Different regulation among Länder. A very common approach is to fix the RF between 1/3 and 1/6 of mean minimum flow.
GREECE		X			RF > 1/3 of average summer mean flow.
ITALY		outgoing	X	Regions	Different regulation among regions. A very common approach is to use parametric formulae, where the reserved flow is imposed as a fraction of the mean river flow. This fraction takes count of hydrological, morphological and environmental aspects.
LITHUANIA		X		Ministry of Environment	Differentiation among two different hydrological regions. 1): RF = low flow warm reason of 30 days duration and 5 years return period. 2): RF = low flow warm reason of 30 days duration and 20 years return period.
NORWAY		X			RF > Q350 (flow rate that is equalled or exceeded on average 350 days in/year).
PORTUGAL		X			RF >= 1/10 of inter-annual mean flow.
SCOTLAND		X			RF >= 45/100 of inter-annual mean flow.
SWEDEN		X			There is no standard method: RF is fixed to the specific case under examination.
SWITZERLAND		X		State	RF is a growing function of Q347 (flow rate that is equalled or exceeded on average 347 days in/year).
SPAIN		outgoing		River basin authority	Before 2001, RF was established at 10% of inter-annual mean flow; after 2001 different formulae have been developed for each basin. According to the new Water Act each river authority should develop a system to evaluate RF for each river. A majority tend to follow the IFIM method, but up to now only the Basque region has elaborated a computer programme to do it.
UK		X	X	Environment Agency	There is no standard method: RF is fixed before granting a licence, with reference to the case under examination. The starting point of negotiation is Q95 (flow rate that is equalled or exceeded on average for more than 95% of the year).

3.2.7.5 Mitigation of effects of dams on downstream water quality

Impacts of dams on the downstream water quality are outlined in Section 3.2.3.2.

Possible mitigation measures include:

- Spill of extra water (to increase downstream dissolved oxygen levels)
- Artificial aeration of turbine discharge (to increase oxygenation)

- Regulation of release temperature by means of withdrawal of water at different depths (e.g. with mobile intakes or intakes installed at different levels).

3.2.7.6 Mitigation of morphological changes and habitat disruption

Possible measures to restore or mitigate morphological changes and habitat disruption include (CIS, 2006):

- Improvement and diversification of bank and bed structures, riparian and aquatic habitats.
- Removal, realignment or modification of hard engineered structures or reinstatement of the alteration.
- Realignment of banks to facilitate the restoration of riparian habitat.
- Creation of submerged or partly-submerged berms or placement of other structures in front of embankments to absorb wave energy and hence reduce erosion.
- Recovery of the natural riparian corridor with its natural river movement and habitats − use of alternative ‘green’ bank protection techniques including willow spiling or other products/ systems which promote the establishment of riparian vegetation.
- Reinstate flow to meander or remove or realign reclamations.
- Restoration of connectivity across/past modified/ reclaimed/ affected areas, and re-connection of oxbows, wetlands etc.
- Conservation of remaining natural reaches and flood inundation areas.
- Establishment of hiding and resting places for fish. This allows fish to seek refuge either during low flow conditions (e.g. by providing pools). or high flows (e.g. floodplains with resting places).

3.3 Assessment of energy losses for already existing installations due to environmental adaptation measures

3.3.1 Objective

The improvement of the ecological status at locations of hydro power plants in the past years strongly aimed at achieving river continuity.

Upstream continuity was achieved by rebuilding weirs or by building fish-passes. Existing facilities were improved in the last years in terms of accessibility and passability. For diversion hydropower stations also the continuity of the original river bed must be guaranteed by a minimum residual flow which also enhances the ecological status within the original river bed.

To accomplish a low level of damaging rates during downstream fish migration the installing of mechanical barriers (fish-rakes) and bypass channels have been promoted. In some cases the fish-friendly turbine management was realized.

The sum of the discharges required in these ecological installations can be termed ecological discharge Qecol. Its components are:

- Operational discharge of fish-passes
- Operational discharge of bypass channels (permanent or temporary dotation during the main migration period)
- Minimum residual flow in the original river bed

In many cases Q_{ecol} is lost for electricity generation of the existing hydropower plant. The energy output is reduced and consequently the profitability or economical status of the hydropower facility affected. But the operational discharges of fish passes and the minimum residual flow can be utilized in residual flow turbines.

Additional ecological measures can cause losses of energy generation:

- Turbine management: reduction of the operational time of the hydropower plant, for instance by putting the turbines out of operation for ten hours at twenty days of the year,
- Reduction of the utilizable height of fall caused by increased losses at mechanical fish protection barriers with small distance of bars.

3.3.2 Results

A range of case studies for various types of HP stations in different regions is provided in the following sections. Since no standards on the quality of ecological measures are available it was tried to define ranges like “very good practice, good practice…”.

General figures on the impact of ecological measures on the HP electricity generation could not be estimated because data on the HP stations, their location and the different hydrological regimes could not be evaluated within this study .

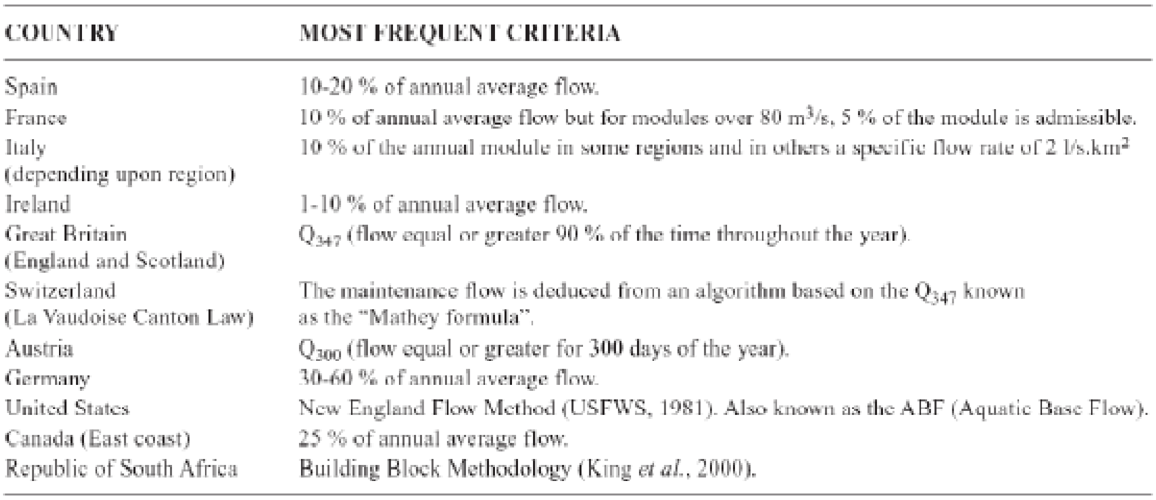
3.3.2.1 Minimum flow (Q_{min}) specifications in European countries

A minimum flow in the diversion reach of a HP station shall reduce the impact of the reduced flow to the quality of habitat and to the longitudinal conductivity.

European countries follow different ways in determining Q_{min}. Some relate to the mean annual flow (MQ), others to the mean low flow (MNQ) and some to the hydrology in the divergent reach. The hydrology method requires a considerable amount of data from the reach like cross sections to determine the depth of the resulting river bed. Therefore it is a rather complex method.

In Table 3.4 some criteria for the determination of the (necessary) minimum flow are compiled.

Table 3.4: Criteria used in different countries to estimate minimum flow (Palau, 2006)



COUNTRY	MOST FREQUENT CRITERIA
Spain	10-20 % of annual average flow.
France	10 % of annual average flow but for modules over 80 m^3/s, 5 % of the module is admissible.
Italy (depending upon region)	10 % of the annual module in some regions and in others a specific flow rate of 2 $l/s.km^2$
Ireland	1-10 % of annual average flow.
Great Britain (England and Scotland)	Q_{347} (flow equal or greater 90 % of the time throughout the year).
Switzerland (La Vaudoise Canton Law)	The maintenance flow is deduced from an algorithm based on the Q_{347} known as the "Mathey formula".
Austria	Q_{300} (flow equal or greater for 300 days of the year).
Germany	30-60 % of annual average flow.
United States	New England Flow Method (USFWS, 1981). Also known as the ABF (Aquatic Base Flow).
Canada (East coast)	25 % of annual average flow.
Republic of South Africa	Building Block Methodology (King *et al.*, 2000).

3.3.2.2 Estimation of energy losses due to minimum flow (Q_{min}) requirements for SHP

Computer programs can access the loss of energy production on the basis of local parameters. The results depend on the hydrological regime of the project location. As input data e.g. annual hydrographs serve as a basis for the calculation of the annual energy generation.

In the following examples the productivity losses were calculated for three standardized hydro power plants with different ratios between design flow and minimum residual flow.

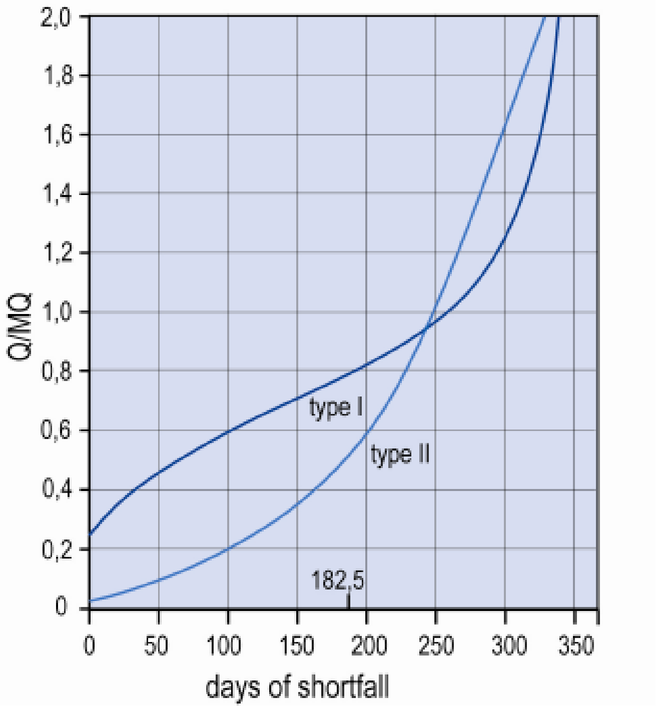
The effects of the minimum residual flow on the annual energy production largely depend on the discharge conditions and thus on the hydrological regime in the watershed (such as rainfall, topography, geology, sealing, overgrowth).

Running waters can be categorized, employing a simplified method, by the ratio between MNQ and MQ:

- Discharge type I: MNQ = ca. 0,25 MQ; regular condition due to high storage capacity of the soil and low level of sealed areas in the watershed
- Discharge type II: MNQ = ca. 0,12 MQ; irregular discharge condition.

The illustration Figure 3.17 shows the typical curve of the annual hydrograph.

Figure 3.17: Normalized annual hydrograph for rivers of discharge typ I and II (discharges normalized to medium flow MQ) (Source: Entwicklung eines beispielhaften bundeseinheitlichen Genehmigungsverfahrens für den wasserrechtlichen Vollzug mit Anewendungsbeispieöen im Hinblick auf die Novellierung des EEG, UBA-Gutachten 20031/37, U. Dumont, October 2005)



The annual productivity was calculated for different minimum residual flows at small HP stations (Figure 3.18, Figure 3.19).

In Figure 3.18 100% annual productivity represents a facility along a river of type I without minimum flow; hence, the highest theoretical potential. The annual production for different minimum flow situations were defined with reference to this theoretical potential. It is revealed that a facility along a running water of type II (irregular discharge) without minimum residual flow generates only 73.5 % of the theoretical value of type I (Figure 3.19). Consequently the relative loss of energy generation is smaller for running waters of type II than for running waters of type I.

Figure 3.18 and Figure 3.19 show that the reduction of energy generation of hydro power plants which is caused by a minimum flow (or by the operational flow of a fish-pass) depends largely on the discharge condition of the individual running water:

- Generally spoken, hydropower plants along running waters with a regular discharge condition have a higher annual energy production than facilities along running waters with an identical design flow but an irregular discharge condition.
- The annual productivity of hydropower plants along irregular running waters is stronger affected by the minimum residual flow.
- The annual production of a hydropower plant along an running water with an regular discharge condition and minimum flow discharge is often higher than of a hydropower plant of the same seize along a running water with an irregular design condition but without minimum residual flow.

Figure 3.18: Effect of Q_{min} on the generation of HPP in rivers of type I, Q_A = design flow of HPP, MQ = mean river discharge (Source: Entwicklung eines beispielhaften bundeseinheitlichen Genehmigungsverfahrens für den wasserrechtlichen Vollzug mit Anwendungsbeispielen im Hinblick auf die Novellierung des EEG, UBA-Gutachten 20031/37, U. Dumont, October 2005)

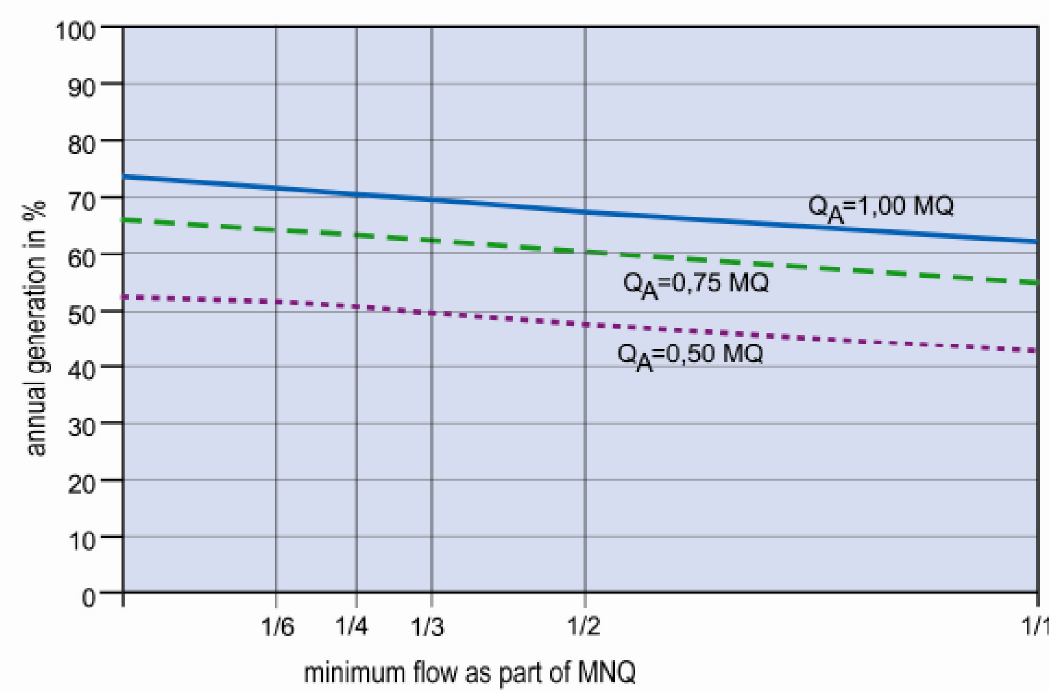
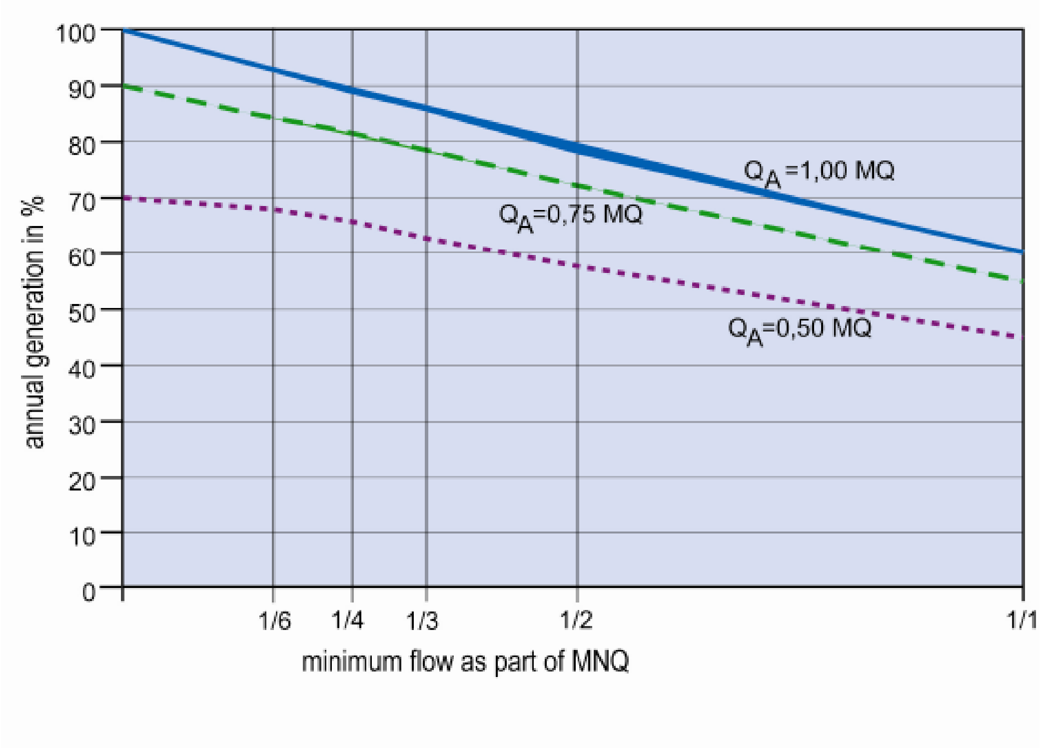


Figure 3.19: Effect of Q_{min} on the generation of HPP in rivers of type II, Q_A = design flow of HPP, MQ = mean river discharge (Source: Entwicklung eines beispielhaften bundeseinheitlichen Genehmigungsverfahrens für den wasserrechtlichen Vollzug mit Anwendungsbeispielen im Hinblick auf die Novellierung des EEG, UBA-Gutachten 20031/37, U. Dumont, October 2005)



3.3.2.3 Case studies Austria

Energy losses of HP stations have been calculated under scenarios that represent a general adaptation of certain measures to reach a good ecological status. The investigation concentrated on scenarios on minimum flow, recovery of longitudinal connectivity and reduction of upsurge operation.

It was distinguished between SHPP, run-of the river stations with P>10 MW and storage plants. (Source: „Energiewirtschaftliche und ökonomische Bewertung potenzieller Auswirkungen der Umsetzung der EU-Wasserrahmenrichtlinie auf die Wasserkraft“, University of Graz, IEE, July 2005)

Results SHP

About 2070 HPP were evaluated which generate an energy of 4000 GWh representing about 8% of the Austrian electricity generation. Nearly 85% of the stations operate with diversion sections where minimum flow requirements are essential.

It is estimated that 90% of the SHPP cannot be passed in upstream direction, and that for most of the plants no regulation exists concerning minimum flow. Taking into account minimum flow of 1/3 to 1 MJNQT (=Q95) within the scenarios would lead to a reduction in HP electricity generation of 10 to 32%.

Energy reduction due to the discharge in fish passage ways has not been evaluated.

Results LHP

For a minimum flow of 1/3 to 1 MJNQT a reduction of 5 to 20% in generation was calculated for run-of-the river stations and 3 to 10% for storage plants while a variation of 0.3 to 45% for individual facilities was found. The main impact of minimum flow requirements and of an upsurge operation with a limitation to 1:3, 1:5 or 1:10 for storage plants would be a considerable reduction of power reserves, of peak load operation and of controlling power range.

3.3.2.4 Scenarios for the HPP Rosegg

The decision support system (DSS) was used to investigate the impact of various ecological measures on the generation of the diversion hydro power station Rosegg at the river Drau. With a capacity of 80 MW the LHP station reaches a mean production of 338 GWh/a. The investigated three scenarios changed from the present ecological status with value 3 (moderate) with scenario 2 to status = 2 and scenario 3 to status = 1.5 (status = 1 means “light ecological impact”). (source: RiverSmart – A Decision Support System for Ecological Assessment of Impacts and Measures on Rivers, in: International Journey of Hydropower and Dams, Hydro 2005, Villach, Austria 17-20 October 2005). The changes in energy production is shown in Table 3.5.

Table 3.5: HPP Rosegg: case studies on ecological improvements

	Ecological improvement	Forecasted ecological status	Change in energy production
Scenario 1	actual state 1998 Qmin = 5m³/s	3.0	0% (Ea = 338 GWh/a)
Scenario 2	Advanced sediment and flood management, installation of fish pass	2.0	–25% to –30%
Scenario 3	As scenario 2 plus increase of Qmin to 150 m³/s, installation of additional turbine	1.5	–20% to –25%

3.3.2.5 Case studies Portugal

In this study the electricity generation of 10 new HP plants that should be built in the river basins of Douro, Vougo-Mondego and Tejo has been examined. The minimum flow was estimated according to the Tennant Method (Source) taking into account intra-annual variability of discharge.

As a result the energy production of 62 to 340 GWh/a of the HP stations considered would be reduced by about 20% with a "fair" minimum flow and 35% for a "good" one. (Source: Arcadis report, confidential)

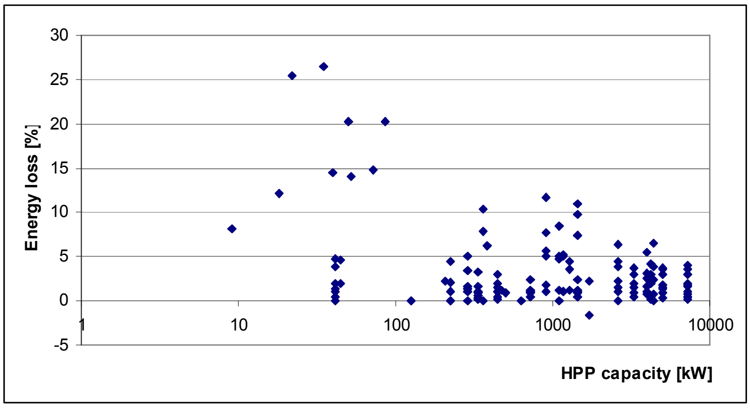
3.3.2.6 SHP case studies in German low mountain range rivers

At 41 different HP locations in 11 German low mountain range rivers ecological improvements have been investigated. In total 154 cases have been evaluated for different ecological discharges in fish passage ways (fish pass and bypass systems) and different minimum flow rates.

Figure 3.20 shows energy losses for up to 5 different mitigation measures for each HPP at a certain capacity value. In the case studies investigated normally the energy loss rose with the standard of the ecological improvement.

The energy losses for HP stations with very small capacities (< 100 kW) amounted up to 25%. A decrease of the maximum values of energy loss can be found with increasing capacity. (Source: Floecksmühle consultancy: internal reports, study for the BfN (to be published) and report on Bühler project)

Figure 3.20: Case studies on ecological improvements in low mountain range rivers in Germany (Source: several studies of IBFM)



3.3.2.7 Case studies from „Alpine Convention“

The examples in Table 3.6 relate to ecological improvements that were realized together with the refurbishment of existing HPP. They show that for old facilities there are good chances for both increasing the HP potential with improving the ecological status at the same time. (Source: Common guidelines for the use of small hydropower in the Alpine region, Annex 1, Good practice examples, July 2010)

Table 3.6: Case studies on ecological improvements „Alpine Convention“

Country	River / region	Impact	Ecological measure	Effect on Ea
Austria	Upper Austria, revitalisation campaign (2004-2009), HPP with P< 1 MW	Not stated, but probably lack of continuity and insufficient minimum flow	258 SHP where modernized or rebuilt with accompanying ecological measures (not precisely stated)	Average increase in electricity generation of 40%, in total +76 GWh/a
Austria	Große Mühl (HPP Magerlmühle)	Until 2004 lack of minimum flow, disruption of river continuity	Refurbishment of HPP (95 kW to 210 kW) and installation of fish pass	+0.65 GWh/a
Austria	Alm (HPP Cumberland)	Until 2005 lack of minimum flow, disruption of river continuity	Refurbishment of HPP (28 kW to 197 kW), minimum flow of 800 to 1400 l/s and installation of fish pass	+0.8 GWh/a
Austria	Steyr (HPP Steinbach)	disruption of river continuity	Refurbishment of HPP (100 kW to 1000 kW) and installation of fish pass	+4.5 GWh/a
Austria	Steyr (HPP Agonitz)	disruption of river continuity	Refurbishment of HPP (990 kW to about 2500 kW) and installation of fish pass	+9.4 GWh/a
Germany	Vils (HPP Vils)	lack of minimum flow, disruption of river continuity	Installation of fish passage way and residual water turbine (reversed water auger, 1.3 m³/s)	+0.2 GWh/a
Italy Sondrio	Tartano (Talamona) and Adda	inadequate minimum flow in river Adda, disruption of river continuity	Refurbishment of HPP (10.5 MW to 18.5 MW), construction of new and residual flow HPP (2.9 and 0.6 MW) and installation of a fish pass	+20 GWh/a

3.3.2.8 Case studies of VGB Group (http://www.vgb.org/en/members.html)

The VGB group is an European technical association for power and heat generation. The company “VGB Power Tech” has currently 466 member companies who are operators, manufacturers and institutions involved in the field of power industry. Members from 33 countries represent an installed capacity of 520,000 MW.

Case studies according to the EU-WFD are summarized in Table 3.7. The status of the ecological improvement has not been analysed.

The examples show, that the installation of fish passes at large HPP e.g. at the river Donau and the river Main only cause a minor reduction of 1 % or less. At the river Nahe SHP the loss amounts to more than 10%.

The energy loss caused by minimum flow requirements is about 50% for the SHP on the river Gurk and 5% to 20% for larger HPP.

Table 3.7: Case studies of VGB Power Tech

		Ea [GWh/a] Before ecological improvement	Considered ecological improvement	Change in energy production
Germany	Nahe/ HPP Niederhausen	5.6	Installation of fish pass, Qmin = 1.5 m³/s	-12% to –18%
Austria	Donau / HPP Melk	1221	Installation of fish pass	-0.1%
Austria	HP group Zemm-Ziller, 3 HPP with annual storage	1160	Minimum flow and reduction of surge	-7% (only for Qmin)
Austria	HP group Obere Ill-Lünersee, 9 HPP with annual storage	533	Minimum flow and reduction of surge (moderate scenario if HMWB status)	-18.5% (only for Qmin)
Austria	Bolgenach, Subersach/ HPP Langenegg	227	Minimum flow and reduction of surge	-6% (only for Qmin)
Austria	Gurk/ HPP Passering, Launsdorf	8.5	Installation of fish pass and minimum flow	-2.5 to –50% (only for Qmin)
Austria	Fragant group, annual storage	478	Minimum flow and reduction of surge	-17% (only for Qmin)
Germany	Donau/ HPP Bergheim	144	Installation of fish pass	-0.86 (only for fish pass)
Germany	Main/ HPP Randersacker	14	Installation of fish pass	-1.1% (only for fish pass)

3.3.2.9 Case studies from „WFD and Hydromorphological Pressures – Technical Report“

The case studies in Table 3.8 show, that like in other examples residual flows could be worked out in small turbines to compensate for energy losses. The installation of fish passes causes energy losses of one to a few percent. Again, refurbishment in combination with ecological improvement can lead to win-win situations, suspecting that economy works for the cited examples. (Source: WFD and Hydromorphological Pressures – Technical Report, Case Studies, November 2006)

Table 3.8: Case studies on ecological improvements „WFD and Hydromorphological Pressures – Technical Report“

Country	River	Impact	Ecological measure	Effect on Ea
Norway	Numedalslaagen	Almost no flowing water during long periods, disrupted conductivity	Qmin = 3 m³/s summer, 5 m³/s winter	- 28 GWh/a due to Qmin, but could be used in small turbine
Sweden	Klarälven	9 HPP with 1300 GWh/a, interruption of migration	Trap & truck	0
Finland	Kuusinkinkijoki	Disruption of river continuity	installation of fish pass, working 3 month a year	-40 MWh/a or -0.7% to -1% at an estimated total production of: 4200 to 5600 GWh/a
Finland	Oulujoki	Disruption of river continuity by 6 HPP with up to 120 MW and change from a stream with rapids to a chain of small lakes	results of study: construction of 6 bypass channels with 2 to 5 m³/s	-18 to –45 GWh/a or -2% to -8% at an estimated total production of: 600 to 800 GWh/a
Germany	Rhine/ Rheinfelden	No fish passage	Installation of fish pass at replacement construction as run-of river HPP	Increase from 185 to 600 GWh/a
Germany	Rhine/ Albruck Dogern weir HPP	Insufficient minimum flow in diversion section, no connectivity	Construction of fish pass, increase of residual flow from 3-8 m³/s up to 100 m³/s	Increase
Austria	Steyr/ Steinbach	Disruption of river continuity	Demolition and reconstruction of HPP, installation of fish pass	Increase from 0.8 to 5.5 GWh/a
Austria	Steyr/ Agonitz	Disruption of river continuity	Demolition and reconstruction of HPP, installation of fish pass	Increase from 6.4 to 15.8 GWh/a

3.3.3 Summary

Case studies can give a first impression on the energy loss of HP stations due to ecological improvements. The main losses are due to:

- minimum flow requirements,
- discharge in fish pass and bypass installations,
- reduction of head at fish protection screens,
- reduced turbine operation during fish migration, and
- requirements on mitigation of surge operation (especially for peak load and storage plants).

Although case studies are site and case specific they give a hint on the percentage of energy loss under certain conditions.

Fish passes and bypass systems at large HPP were found to cause losses of a few percent whereas in small rivers the losses can easily amount to more than 10%.

The actual number of European HP stations that apply mitigation measures is not registered and thus not known. Ongoing studies for Germany show in a first estimate, that 10 to 20% of SHP are equipped with fish passes and/or release a minimum flow. An investigation of the German Department of Transport / Federal Institute of Hydrology (BfG) responsible for the passability of the national navigable waterways and thus for most of LHP in Germany showed that nearly all existing fishways for upstream migration in navigable waterways need reconstruction. Malfunction is expected also at SHP for most of the passage facilities constructed in recent years. In many cases they are too small for the potential fish fauna, are not well located and not properly functioning.

Assuming that the number of mitigation measures that reasonably function amount to 10 to 20% for SHP and LHP the generation loss relative to the total future HP generation is estimated to be 8 to 9 TWh or 2,3 to 2,6% for the EU-27 countries. These losses are partly due to WFD, but also due to national legislation that is not related to WFD like e.g. Nature Legislation (see 3.4).

Table 3.9: Hydropower potential in the EU27 (Sources: EUROSTAT and ++ NREAP)

Hydro Power Potential		*Generation [TWh/a]*	
		2008	*Future estimate*
EU-27	SHP	42.7	50.7 (++)
	LHP	284.1	304.0 (++)
	Total	326.8	354.7 (++)

++ Data taken from the NREAP

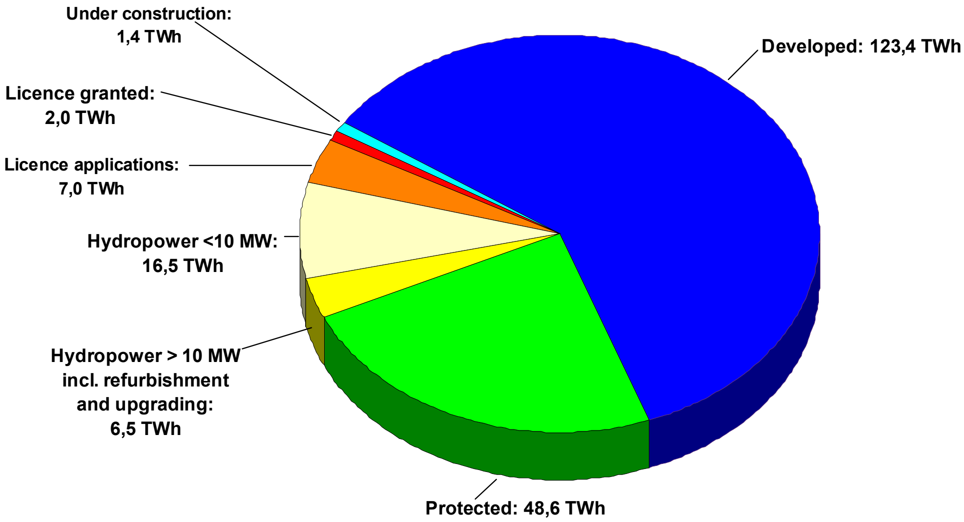
The case studies also show that there are many small and large HPP that can be refurbished and upgraded and that the combination of upgrading with ecological mitigation measures will probably even increase the HP generation.

3.4 Assessment of constraints for the possibility to develop the remaining hydropower potential

3.4.1 Longstanding conventions constraining the development of hydropower potential

A review of the available information has shown that several EU Member States have identified and acknowledged environmental constraints for the development of the remaining hydropower potential (example Norway, Figure 3.21). However, the stated constraints do not primarily relate to the WFD implementation, but to other European and country/state-specific codes of practice, regulations or legislation. These can also include longstanding conventions that were inaugurated before the WFD implementation.

Figure 3.21: Overview of Norway's hydropower potential (205 TWh) and proportion of environmental constraints for the development of hydropower potential (Source: NVE, energistatus, January 2011 http://www.nve.no/Global/Publikasjoner/Publikasjoner%202011/Diverse%202011/NVE_Energistatus2011.pdf)



On the European level the Natura 2000 areas/ Special Areas of Conservation as defined and designated by the EU Habitats Directive (92/43/EEC) are commonly considered as ”no-go areas/ water bodies”, or at least highly sensitive areas, for hydropower development. For example, the designation as Special Area of Conservation formed one of the two environmental sensitivity criteria in the “Opportunity and environmental sensitivity mapping for hydropower in England and Wales” (2010a) (although the approach is currently not implemented but rather used as a guidance).

On the country/ state-levels longstanding regulations and legislations are put forward as environmental constraints for the development of the remaining hydropower potential. In many cases the specific legal framework sets out environmental restrictions for building dams of developing hydropower in certain rivers or river reaches. Such country/ state-specific regulations include:

- Plans for protection of 341 watercourses against hydropower development in Norway (initiated in the early 1970's) (Halleraker, 2011)

- River Basin Management Plans – France. Restrictions on what is defined as mobilizable hydropower potential

For further examples see chapter 4.

3.4.2 Impact of WFD implementation on the possibility for development of the remaining hydropower potential

The protection and sustainable management of the aquatic ecosystems is the central aim of the WFD. According to the ‘new’ provisions, the quality of surface waters is assessed on the basis of the biological community, the hydromorphological characteristics, and the chemical and physico-chemical characteristics. The overall goal, the good (ecological) status or potential, is defined as allowing only a slight variance from the biological community that would be expected in conditions of minimal anthropogenic impact.

In principle, the enforcement of the WFD has introduced an entirely new assessment methodology/ framework with new water quality criteria throughout European countries.

As outlined in Section 3.2, physical modifications such as hydropower developments are known to impact on aquatic ecosystems. These pressures generally result in interconnected up- and downstream effects. The effects can be distinguished in hydromorphological, physico-chemical and biological impacts (or first, second and third order impacts in Sections 3.2.2 and 3.2.3). Such impacts can be assessed and monitored with a variety of the WFD defined quality elements, which again are decisive for water status classification.

Consequently, the enforcement and implementation of the WFD has impacted and will further impact on the possibility for development of the remaining hydropower potential. The transposition of the WFD requirements to national legislation can be regarded as the first step. Water acts/laws had to be adapted by 2003 at the latest (WFD Article 23). Since then further regulations, protocols, criteria catalogues etc. have been updated or introduced that - taking into account the WFD goals and requirements - a) define the rules for hydropower development and operation in European waters, e.g. ‘no-go’ areas, and b) delineate specific environmental mitigation measures for existing and future hydropower/dam schemes, e.g.

- LEMA law (new water and aquatic environment law) in France that specifies three types of rivers on which the establishment of new hydropower installations, which could impact on the ecological continuity, is prohibited.
- Law on Water and Governmental Decision of September 10, 2004 on a “List of 169 rivers and river reaches that are valuable in an environmental and cultural context” in Lithuania.
- Federal Water Act in Germany (WHG, 2010) that outlines general river basin management principles (§§ 27 - 31) and specific regulations and environmental mitigation measures with regards to dams and impoundments, e.g. minimum flow (§ 33), river continuity/ fish passage (§ 34) and fish protection/ downstream fish passage (§ 35) (Kibele, 2010).
- Criteria catalogue to evaluate further hydropower development in Tyrol, Austria that includes several environmental criteria, e.g. river ecology, protected areas, sediment budget, proportion of affected river reach vs. power output etc. (Tirol, 2009).

- Guidance and (good) mitigation practice documents in several EU Member Countries, e.g. Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrhein-Westfalen (2005), UK Environment Agency (2009), Scottish Environment Protection Agency (2010)
- Environment and Water Services Act and Water Environment (Controlled Activities) (Scotland) Regulations 2005 in Scotland that regulate activities such as abstraction of water from surface water bodies and the construction, alteration or operation of impounding works in surface water bodies.
- Water Act 2003 in England and Wales.

Commonly, surface water bodies with hydropower schemes have been (preliminary) designated as heavily modified water bodies (HMWB) according to Article 4(3)(iii), usually following the HMWB & AWB identification and designation process as detailed in CIS (2004). For example, the lower Ruhr River in Western Germany has been identified as HMWB due to numerous large-scale impoundments, weirs and hydropower plants. Maximum Ecological Potential (MEP) represents the reference condition on which status classification is based for HMWB,. The MEP represents the maximum ecological quality that could be achieved for a HMWB once all mitigation measures, that do not have significant adverse effects on its specified use or on the wider environment, have been applied. HMWB are required to achieve "good ecological potential" (GEP). GEP accommodates ”slight” changes in the values of the relevant biological quality elements at MEP. Hence, mitigation measures (Section 3.2.7) need to be applied at existing and new hydropower schemes to achieve GEP. Only if it is technically infeasible or disproportionately expensive to achieve GEP by 2015, Member States may extend the deadline for achieving GEP in accordance with Article 4(4) or establish a less stringent objective for the water body under Article 4(5) (CIS, 2003 and CIS, 2009). Environmental mitigation measures usually impact on hydropower generation (both, from economic and operational point of view), e.g. result in loss of energy production. In general, new hydropower schemes (greenfield developments) will be difficult to develop, amongst other things because of the resulting status change of surface water bodies which does not comply with Article 1 (prevention of further deterioration and protection and enhancement of status of aquatic ecosystems). However, development of new hydropower plants is possible at existing barriers, or other anthropogenic structures and natural features, such as waterfalls. For example, in 2006 a hydropower plant with an annual output of 1.5 M kWh was installed at the Ennepe Dam in Germany. Respective approaches are being followed at different scales (e.g. UK Environment Agency, 2010) and relevant regulations have already been put in place (e.g. Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrhein-Westfalen, 2009).

Repowering of existing stations as well as modernization and upgrading, e.g. installation of new turbines with higher efficiency or installation of surplus turbine(s), results in less conflicts with the WFD and is therefore commonly promoted in EU member countries today. However, other measures that increase generation, such as head raise (e.g. increase in storage level) can have detrimental ecological impacts and need to be assessed case by case.

Finally, some innovative win-win solutions have recently been realized by combining hydropower development and ecological mitigation measures, e.g. the attraction flow hydropower plant at Iffezheim dam fish pass (Heimerl et al., 2002).

4 Approaches in EU Member States on policy integration

4.1 Overall objective and scope

In the course of the Common Implementation Strategy for the EU Water Framework Directive (CIS), specific guidance documents have been jointly developed, aiming at achieving better policy integration between the water and energy sector. In addition, a workshop was held in Berlin in 2007 with relevant outcomes.

The following understanding is crucial:

- An analysis of costs and benefits of the project is necessary to enable a judgment on whether the benefits to the environment and to society preventing deterioration of status or restoring a water body to good status are outweighed by the benefits of the new modifications.
- Pre-planning mechanisms allocating “no-go” areas (or less favorable areas) for new hydro-power projects should be developed. This designation should be based on a dialogue between the different competent authorities, stakeholders and NGOs.

The existing guidance calls for a strategic approach in selecting the best places for hydropower development balancing the benefits of the projects (basically renewable energy generation) with the impacts on the aquatic environment. Only such strategic approach will ensure that the best environmental option is achieved and that a balance is struck between benefits and impacts.

For this project, ongoing activities in Member States are screened and an assessment is done on how far Member States decided to follow a strategic approach, in accordance with the agreed principles, as stated in the CIS guidance documents.

The **analysis has a focus on:**

1. Whether strategic planning is taking place eg at river basin level or MS level
2. If pre-planning mechanisms are applied for the allocation of suitable and non-suitable areas (or “go” and “no-go” areas”)
3. If this designation is based on a dialogue between different competent authorities, stakeholders and NGOs.
4. If other elements of strategic planning are applied eg prior agreement of a catalogue of criteria which informs the judgment on the right balance between the benefits of the hydropower facility and the benefits of protecting the aquatic environment

The study is aimed to do a review of **strategic approaches** (either applied nationally, regionally or at a basin scale). As this is related to planning of new hydropower stations, the requirements set for existing hydropower stations has not been looked at as part of this task, although these hydropower plants can be subject to main changes in licensing system.

In relation to the **Habitats and Birds Directive** as well as the **EIA Directive**, this applies to individual projects, but can be applied as a strategic approach. If done so, it is included as part of the review, but effects of both Directives on the licensing of individual projects has not been looked at in detail.

Countries to include in this review are those countries included in the ToR as requested by the Commission (France, Norway, Lithuania, Germany, Austria, England & Wales, Scotland). Further on, Switzerland was also included because of its high share and potential in renewable energy and available information on strategic approaches. Reference is also made to certain countries that have relevant hydropower potential such as Spain, Italy and Portugal.

The information was compiled at least for Member States where plans are available in German and English next to the summaries of information for countries that was already available as part of the ToR (i.e. Lithuania, France, Norway). Additional, French documents (SDAGE) were also consulted. As discussed at the inception meeting with the Commission, only those documents should be considered that are published and could be clearly referred to.

Approaches considering both large hydropower and SHP are looked at. However, threshold values for SHP seem to differ between different countries and studies. For this review the following threshold values were applied (Table 4.1).

Table 4.1: Threshold values for definition of SHP as referred to in studies used for the review

Country	***Threshold value for definition SHP [MW]***
Austria[3]	<10MW
Germany[4]	<1MW
France[5]	Multiple definition: <4.5 or <10 or <12
Italy[6]	Double definition: <1 or <3MW
Switzerland[7]	<10MW
England and Wales[8]	<5MW

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[3] Alpine Convention Platform. Situation Report (2010). Water Management in the Alps' DRAFT Situation Report on Hydropower Generation in the Alpine Region focusing on Small Hydropower

[4] Alpine Convention Platform. Situation Report (2010). Water Management in the Alps' DRAFT Situation Report on Hydropower Generation in the Alpine Region focusing on Small Hydropower

[5] SHERPA, 2008b. Strategic Study for the Development of Small Hydro Power (SHP) in the European Union. SHERPA – Small Hydro Energy Efficient Promotion Campaign Action.

[6] Alpine Convention Platform. Situation Report (2010). Water Management in the Alps' DRAFT Situation Report on Hydropower Generation in the Alpine Region focusing on Small Hydropower

[7] Alpine Convention Platform. Situation Report (2010). Water Management in the Alps' DRAFT Situation Report on Hydropower Generation in the Alpine Region focusing on Small Hydropower

[8] Environment Agency (2010b). Streamlining permitting of hydropower projects in England and Wales. Consultation document. 19 March 2010.

4.2 Background and general considerations

Strategic planning in selecting the best places for hydropower development balancing the benefits of the projects with the impacts on the aquatic environment is a key need identified in several WFD Common Implementation Strategy workshops (Prague, 2005; Berlin, 2007). Conclusions of these workshops are included in certain way into the CIS policy paper[9] has been produced: ***“WFD and Hydro-morphological pressures POLICY PAPER: Focus on hydropower, navigation and flood defence activities Recommendations for better policy integration”*** Objectives set according to the WFD – could lead to the application of a strategic approach by some Member States (but definition of HMWB and AWB and subsequent objective setting of GEP is possible so no real ‘strategic approach’ but often as a case by case decision), but in reality, this is mainly done at a case-by-case basis (see further on Alpine Convention Report). Currently, the WFD stepwise approach, implemented by the Member States, should be as follows for past and new developments: prevention, restoration, mitigation The WFD approach for dealing with hydromorphology pressures on the water environment is as follows (see WFD Art. 4(3)-4(7)). For new developments, there is a need firstly to prevent deterioration of 'status' in a water body. Where this is not possible, mitigation measures should be applied). Where a physical modification has already taken place, actions should first be considered to restore the water body with the aim to achieve 'good ecological status' (restoration). Where restoration is not possible, mitigation measures should be investigated with the aim to meet 'good ecological potential' (GEP) (CIS guidance: Identification and Designation of Heavily Modified and Artificial Water Bodies)

One of the key conclusions from this policy paper are the development of clear guidance on authorisation procedures for hydropower in relation to the WFD is recommended. In order to minimize the need for new sites, the development of hydropower capacities could be supported first by the modernisation. and the upgrading of existing infrastructures. Pre-planning mechanisms, in which regions and municipalities allocate suitable and "no-go" areas for the development of hydropower is also recommended. This communication recommends that Member States should establish pre-planning mechanisms in which regions and municipalities are required to assign locations for different renewable energies, As recommended in the Communication on support of electricity from renewable energy sources (COM(2005) 627), pre-planning mechanisms allocating suitable areas for new hydro-power projects should be developed on appropriate water stretches. Practical examples could be allocating suitable areas for hydropower development with the identification of sites where new plants would be both acceptable in terms of water protection and economically beneficial. In that frame, some of the remaining unregulated rivers in areas of high values could be designated as “no-go” areas for hydropower schemes. This designation should be based on a dialogue between the different competent authorities, stakeholders and NGOs. This is also confirmed in the *Meeting of Water and Marine Directors of the European Union, Candidate and EFTA Countries, Segovia, 27-28 May 2010* (Hydropower Development under the Water Framework Directive - Statement of the Water Directors[10]).

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[9] WFD and Hydro-morphological pressures. POLICY PAPER. Focus on hydropower, navigation and flood defence activities Recommendations for better policy integration. COMMON IMPLEMENTATION STRATEGY FOR THE WATER FRAMEWORK DIRECTIVE. 2007

[10] Statement of the Water Directors on Hydropower and the EU Water Framework Directive, Segovia 2010

In the pre-planned areas, the permitting process could be reduced and implemented faster, provided WFD article 4.7 is respected When applicable, the “SEA directive” (2001/42/EC) can help co-ordination and integration between the different policies in assessing the environmental consequences of plans and programmes and in producing an environmental report including consideration of reasonable alternatives.

Also in the *CIS Berlin workshop (2007) (WFD & Hydropower, 4-5 June 2007, Conclusions paper)* the workshop participants recognised the advantages of pre-planning mechanisms to facilitate the (proper location) identification of suitable areas for new hydropower projects. These pre-planning mechanisms should take into account WFD and other environmental criteria as well as socio-economic aspects, including other water uses. The use of such preplanning systems could assist the authorisation process to be reduced and implemented faster, provided that the criteria of WFD Art. 4.7 are met. At the workshop, it is proposed that at least 3 categories of areas could be distinguished for pre-planning: suitable, less favourable and non-favourable areas. These categories should be identified with the involvement of all stakeholders based on transparent criteria, they should be monitored and revised within a period of time.

This is also one of the recommendations from the **Alpine convention**, which is a platform for water management in the Alpine region (*Alpine Convention, Situation Report, 2010*). The needs for strategic planning are getting more urgent due to the large number of applications due to Renewable Energy Directive and incentives. Due to progress in renewable energy generation and environmental legislation, the pressure on the competent authority has certainly increased in recent years. It seems vital to provide support to the authorising bodies by backing up decision procedures with strategic planning instruments, since different aspects of the (overriding) public interests basically have to be defined on a higher level since it seems unfeasible to generally decide on a case-by-case basis. Strategic planning is also considered to be inevitable for sound implementation of WFD – Art 4.7 which exceptionally allows the deterioration of water status under strict conditions. According to Art 4(7)(d), alternatives for projects of better environmental options should be assessed at an early stage when better alternatives are available (eg alternative locations for hydropower stations). In case several developments in the same river basins, what is generally considered to be the case with regard to hydropower projects, best environmental options need to be addressed at a strategic level since a decision on that issue seems to be impossible on a project basis without any strategic guidance.

Further on, **SNIFFER (**Scotland and the Northern Ireland Forum for Environmental Research(**has conducted a study[11] in 2006 on appraising new hydropower projects in the light of the WFD.** The objectives of the research were to make recommendations on processes and criteria for appraising new hydropower projects in Scotland that comply with the WFD. The recommendations were based on a review of processes and criteria in use by other countries and international organisations involved in hydropower development. In the Sniffer 2006 report, a proposal is included on how certain assessment criteria can be applied in an application and assessment process for new hydropower developments, in line with the relevant parts of Article 4.7 of the WFD. The project has been commissioned by SNIFFER on behalf of its

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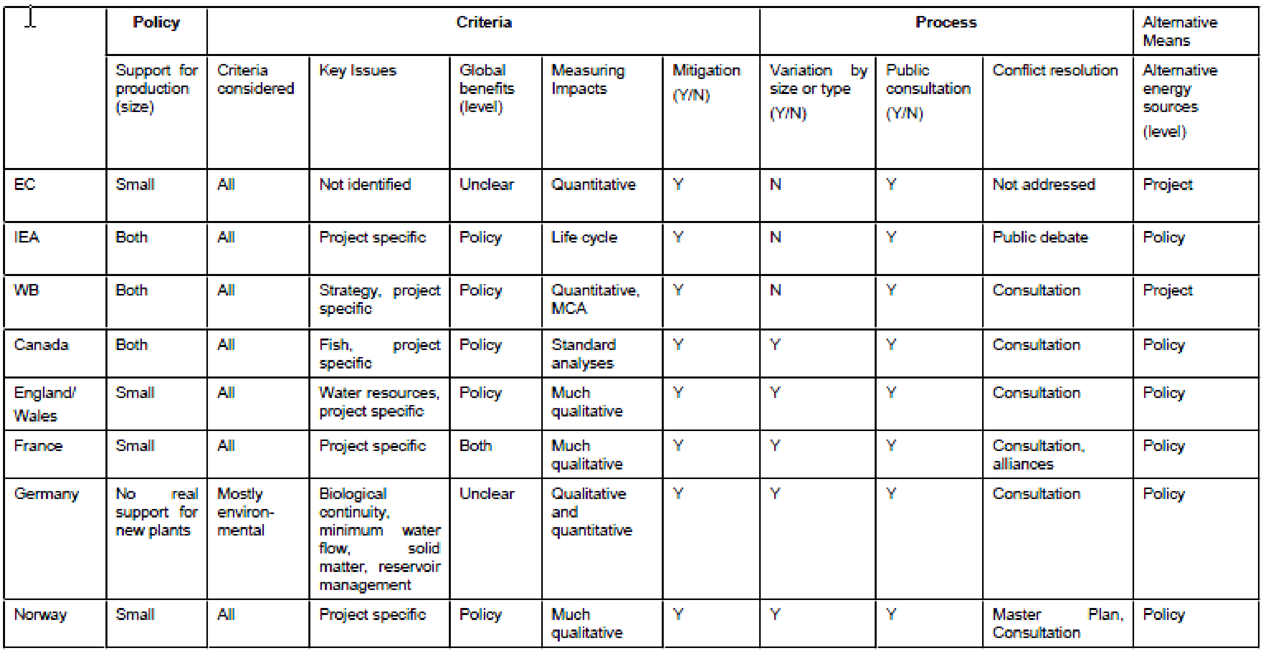
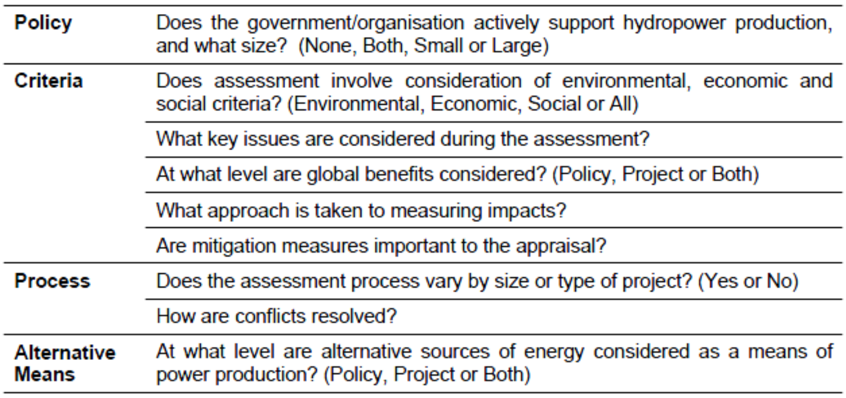
[11] Sniffer (2006). Application of WFD Exemption Tests to New Hydropower Schemes Likely to Result in Deterioration of Status. Project WFD75.

members, in particular the Scottish Environment Protection Agency (SEPA) and the Scottish Executive (SE). The aim of this research was to provide recommendations on appraising proposals for new hydropower projects in accordance with the requirements of the WFD. More specifically, the research responds to Article 4.7 of the WFD, which permits authorization of projects likely to cause deterioration in water status if certain conditions are met. A comparative summary of key findings is given in Figure 4.1 is also of relevance to this study. The study revealed that in effect no strategic approaches were identified as all applied approaches on regulating new hydropower projects seem to happen on a project-specific basis.

Figure 4.1: Comparative summary of key findings of Sniffer (2006) study.. Application of WFD exemption tests to new hydropower schemes likely to result in deterioration of status. Project WFD 75. Legend included below.



	Policy	**Criteria**					**Process**			Alternative Means
	Support for production (size)	Criteria considered	Key Issues	Global benefits (level)	Measuring Impacts	Mitigation (Y/N)	Variation by size or type (Y/N)	Public consultation (Y/N)	Conflict resolution	Alternative energy sources (level)
EC	Small	All	Not identified	Unclear	Quantitative	Y	N	Y	Not addressed	Project
IEA	Both	All	Project specific	Policy	Life cycle	Y	N	Y	Public debate	Policy
WB	Both	All	Strategy, project specific	Policy	Quantitative, MCA	Y	N	Y	Consultation	Project
Canada	Both	All	Fish, project specific	Policy	Standard analyses	Y	Y	Y	Consultation	Policy
England/ Wales	Small	All	Water resources, project specific	Policy	Much qualitative	Y	Y	Y	Consultation	Policy
France	Small	All	Project specific	Both	Much qualitative	Y	Y	Y	Consultation, alliances	Policy
Germany	No real support for new plants	Mostly environ-mental	Biological continuity, minimum water flow, solid matter, reservoir management	Unclear	Qualitative and quantitative	Y	Y	Y	Consultation	Policy
Norway	Small	All	Project specific	Policy	Much qualitative	Y	Y	Y	Master Plan, Consultation	Policy



Policy	Does the government/organisation actively support hydropower production, and what size? (None, Both, Small or Large)
Criteria	Does assessment involve consideration of environmental, economic and social criteria? (Environmental, Economic, Social or All)
	What key issues are considered during the assessment?
	At what level are global benefits considered? (Policy, Project or Both)
	What approach is taken to measuring impacts?
	Are mitigation measures important to the appraisal?
Process	Does the assessment process vary by size or type of project? (Yes or No)
	How are conflicts resolved?
Alternative Means	At what level are alternative sources of energy considered as a means of power production? (Policy, Project or Both)

Next to the discussion on effect of the Water Framework Directive on new planned hydropower (see also Section 3.4.2), each EU Member State will also have to deal with restrictions because of its location is of importance for species and habitats protected under the **Habitats Directive (92/43/EEC[12]) and the Birds Directive (78/409/EEC[13])**

Following these Directives, an appropriate assessment should be carried out i.e. in accordance with article 6.3 of the Habitats Directive, for any plan or project that is likely to significantly affect a Natura 2000 site, an appropriate assessment of its effects on the integrity of the site should be carried out. A plan or project can only be authorised after having ascertained that it will not have an adverse effect on the integrity of the site. When certain conditions are met (there are no other alternatives and there are imperative reasons of overriding public interest for carrying out the plan or project), the provisions of article 6.4 can be applied and the plan or project may be authorised if all necessary compensatory measures to guarantee the coherence of the Natura 2000 network are taken.

Article 6, paragraph (3) of the Habitats Directive (92/43/EEC):

Any plan or project not directly connected with or necessary to the management of the site but **likely** to have a **significant effect** thereon, either individually or in combination with other plans or projects, shall be subject to appropriate assessment of its implications for the site in view of the **site's conservation objectives**. In the light of the conclusions of the assessment of the implications for the site and subject to the provisions of paragraph 4, the competent national authorities shall agree to the plan or project only after having ascertained that it **will not adversely affect the integrity of the site** concerned and, if appropriate, after having obtained the opinion of the general public.

Further on, the Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment1, as amended, known as the **"EIA" (environmental impact assessment) Directive,** requires that an environmental assessment to be carried out by the competent national authority for certain projects which are likely to have significant effects on the environment by virtue, inter alia, of their nature, size or location, before development consent is given. The projects may be proposed by a public or private person. An assessment is obligatory for projects listed in Annex I of the Directive, which are considered as having significant effects on the environment. Other projects, listed in Annex II of the Directive, are not automatically assessed: Member States can decide to subject them to an environmental impact assessment on a case-by-case basis or according to thresholds or criteria (for example size), location (sensitive ecological areas in particular) and potential impact (surface affected, duration). Installations for hydroelectric energy production is part of Annex II; The process of determining whether an environmental impact assessment is required for a project listed in Annex II is called screening.

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[12] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora

[13] Council Directive of 2 April 1979 on the conservation of wild birds(79/409/EEC)

4.3 Planned and current strategic approaches

4.3.1 France

Is strategic planning taking place? At river basin level or MS level?

Yes, there seems to be **planning at the national level taking place** (PPI 2009).

In the PPI (2009) for installing new plants, these projects must integrate the objectives for the quality of water bodies. They must take into account the:

- Statutory minimum flow in rivers (as defined in LEMA, 2006)
- Requirements specified under the RBMPs (SDAGE)
- Eels plan

Restrictions and constraints are defined nationally but implemented at the river basin scale: 4 potentials are identified: (estimated by ADEME, Agence de l'Environnement et de la Maîtrise de l'Energie and Water Agencies for drafting SDAGE) and these are included in the SDAGE to determine the restrictions on strategic planning for new hydropower development:

- A potential which cannot be mobilized because the river is reserved according to article 2 of Law 1919 (i.e. rivers where no concession for hydroelectricity can be granted
- A potential which can only mobilized with difficulty for plants located in Natura2000 sites with migratory amphibian species, classified sites, national natural nature reserves, rivers with migratory species
- A potential which can only be mobilized under strict conditions for plants located in other Natura2000 sites
- A potential which can be easily mobilized (constraints defined locally)

The implementation of strategic plans seem to be organised per RBMP (SDAGEs - schémas d'aménagement et de gestion des eaux). « *L'étude a été réalisée sur la base d'un cahier des charges national comportant quelques adaptations à des spécéficités propres à chaque basin, tenant aux conditions naturelles ou à des éléments de contexte relatifs aux enjeux environnementaux. A la demande de la Direction de l'eau, elle a été conduite avec une co-maîtrise d'ouvrage Agence de l'eau – Agence de l'environnement e de la maîtrise de l'énergie (ADEME) et un comité de pilotage comprenant des représentants des producteurs d'énergie, des services de l'Etat du bassin en charge de l'environnement » (SDAGE Corsica).* The restrictions given are rather general but are supposed to be applied in a general way on the river basin scale. Local constraints can still be applied but then specific studies are needed at the level of the project to determine possible impacts. All RBMPs have an Annex including the national approach and some information on how this is implemented at the river basin scale.

An example from what is included in French RBMP is given in Figure 4.2. The table details the hierarchical approach of existing environmental regulation that regulates the hydropower development. Under the condition a site is regulated by different regulations: the most stringent condition applies, to make a sure a site gets sufficient level of protection.

Figure 4.2 : Table (translated) included in Annexes to the French RBMPs (SDAGEs) details approach taken for regulating hydropower on the river basin scale.

	Potential categories			
	Non-mobilizable	**Potential mobilizable, under very strict conditions**	**Potential mobilizable under strict conditions**	**Mobilizable**
Running waters (article 2, law 1919	X			
National nature reserves	X			
National parks	X			
Natura2000 sites with priority species and habitats in aquatic environment		X		
Running waters with listed species of migratory amphibians		X		
Other Natura 2000 sites			x	
Other classified watercourses with listed species			X	
Ordinance on habitats			X	
Regional nature serves			X	
Humid zone borders			X	
Classified sites			X	
Prescriptions of the RBMP			X	
Regional natural partks			X	
Outside of existing regulations				x

If pre-planning mechanisms are applied for the allocation of suitable and non-suitable areas

Yes, this could be considered as a pre-planning mechanism, although for some categories, implementation could differ depending on the river basin. Reference to this pre-planning approach applied in France was also found in the EEA report (2008) where the French hydropower potential (2005) study is mentioned: after estimating the technically and economically feasible potential, environmental constraints are accounted for and further reduce the achievable potential.

According to results from a study for EC DG Energy and Transport (AEON, 2010), the French Hydro Power Association highlighted the new classification of French water courses under the water law of 2006 as a limiting barrier for the further development of hydro power in France. The French water law of 2006 introduced a new classification of French water courses, especially to enforce the respect of ecological continuity, by classifying the water courses into two parts. List 1 contains all building being an obstacle for the ecological continuity, including hydro power installations. The association is arguing that this future classification will put decisive constraints on a further development of hydro power in France. Furthermore, association is stressing the non transparent classification scheme in place, characterized by the non justification of classification of the administration, as well as the unilateral application of the Water Framework Directive (WFD), without taking the economical usage of water courses into account (Hydro, 2010). No further information is available to conclude if a participatory approach has been taken.

If this designation is based on a dialogue between different competent authorities, stakeholders and NGOS

There is no information found that the developed approach was developed based on a dialogue with stakeholders. However, as the approach is included in the SDAGEs, it is part of a public consultation procedure for which stakeholders can give comments. Stakeholder responses for SDAGEs have not been analysed to determine if there was any discussion on this topic.

If other elements of strategic planning are applied eg prior agreement of a catalogue of criteria which informs the judgment on the right balance between the benefits of the hydropower facility and the benefits of protecting the aquatic environment

Next to the pre-planning approaches, as detailed in PPI (2009) and in relation to ecological continuity (Water Law, 2006), other elements of strategic planning are:

- Minimum flow regulation (LEMA, 2006)
- Eels plan (fish migration) (Le règlement européen du 18 septembre 2007 institue des mesures de reconstitution du stock d'anguilles européennes et demande à chaque Etat membre d'élaborer un plan

de gestion national d'ici le 31 décembre prochain. Les mesures possibles pour reconstituer les stocks de géniteurs : Arrêter temporairement les turbines des centrales hydroélectriques)

- Environmental Impact Assessment

References included in review on strategic approaches for France:

AEON (2010). Assessment of non-cost barriers to renewable energy growth in EU Member States – AEON (for EC DG Energy and Transport).

PPI (2009). Annual investment program for electricity production in France (2009-2020) (Programmation plurianuelle des investissements de production d'électricité Période 2009-2020). http://www.developpment-durable.gouv.fr/IMG/pdf/ppi_elec_2009.pdf

Document d'acompagnement N°7 du SDAGE Bassin Seine et cours d'eau côtiers Normands. Potentiel hydroélectrique du bassin Seine Normandie. Central Data Repository. European Environment Agency.

Les documents d'accompagnement du SDAGE Bassin Artois-Picardie Districts Escaut, Somme et Côtiers Manche Mer du Nord et Meuse (Partie Sambre). Central Data Repository. European Environment Agency.

Documents d'accompagnement du SDAGE. Bassin de Corse. Central Data Repository. European Environment Agency.

Etude du potentiel hydroélectrique de la Guyane. SDAGE. Central Data Repository. European Environment Agency.

Note d'évaluation du potentiel hydroélectrique du district hydrographique Meuse et Sambre. SDAGE. Central Data Repository. European Environment Agency.

Note d'évaluation du potentiel hydroélectrique du district hydrographique Rhin. SDAGE. Central Data Repository. European Environment Agency.

Documents d'accompagnement. Bassin Rhône-Méditerranée.SDAGE. Central Data Repository. European Environment Agency.

LEMA (2006). LEMA (Loi n°2006-1772 du 30 décembre 2006 sur l'eau et les milieux aquatiques.http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000649171.

EEA report (2008). A methodology to quantify the environmentally compatible potentials of selected renewable energy technologies.

Hydro (2010): France Hydro-Électricité; Anne Penalba and Jean-Marc Levy. Interview on 24.02.2010 and 05.05.2010 (included in AEON, 2010).

4.3.2 Norway

Is strategic planning taking place? At river basin level or MS level?

The following strategic planning tools are of importance for integrating hydropower development with implementing WFD in Norway:

Master Plan – defining go/no go areas for larger hydropower projects (the English description of the Master Plan and the following link http://www.dirnat.no/naturmangfold/vann/samlet_plan_for_vassdrag/)

The regional small scale hydropower master planning – giving indications of high versus low conflict areas on a county district basis. However, this planning tool do not give any absolute go/no go area definition, but is more **a priorisation tool/ guidance** to hydropower developers (link til OEDs småkraft veileder)

Permanent Protected catchments – defines no-go areas for larger hydropower. Only the smallest hydropower could under certain circumstances be allowed. Reference:

National Salmon rives – mitigations for caretaking of wild salmon should be given priority. Hydropower development should be restricted if this may have significant influence on salmon. Ref: enclosed document and

Revision of hydropower licence terms for excisting hydropower plants. 340 licenses may be initiated for revision by 2022. Until 2011, this processes have not fully been integrated with the RBMP planning processes. National HMWB guidance on environmental objectives in regulated rivers/lakes have not been finalized. No deadline for duration of revision processes excist, and only one licence have until February 2011 been finalized (water course outside any of the first RBMPs). (personal communication, Jo Halleraker)

Hydropower licensing procedures. National HMWB guidance on environmental objectives in regulated rivers/lakes have not been finalized. No changes have been made with regards to WFD art 4..7 in the national licensing procedures.

Further information on each of the planning tools is given below:

Protection Plans for Watercourses

The conflict between hydropower development schemes and environmental considerations brought about a need for protection plans for rivers and lakes as well as for master plans concerning hydropower development. Protection plans for inland waters were initiated in the early 1970s. Parliament adopted four protection plans between 1973 and 1993, and a supplement in February 2005. This is called the Protection plan for watercourses. These plans represent binding instructions to the authorities not to licence regulation or development of the rivers included in the plan for the purpose of hydropower generation. By these plans, 341 watercourses have been protected against hydropower development. River system protection was codified in the 2000 Water Resources Act, which defines what is meant by protected watercourses and lays down provisions for their protection also from types of development other than hydropower projects.

The purpose of the protection plans is to safeguard complete watersheds to maintain the environmental diversity stretching from the mountains to the fjords. The current plans only protect against hydropower, but a restraint policy should also be exerted towards other kinds of development activities. However, other activities may be permitted in accordance with the licensing system pursuant to the Water Resources Act. This may sometimes result in conflicting situations, where a protected watercourse/watershed actually can be exploited for other uses than hydropower, uses that can have even greater environmental impacts.

There is also an opening for development of mini- and micro hydropower (<1 MW) in protected watercourses, but only if the development is not contradictory to any of the protection criteria. In practice, the policy is very restrictive and permissions are only given in special cases.

Figure 4.3: Permanent protected rivers in Norway. 388 rivers/parts of rivers are protected from hydropower development (green areas). Estimated potential in protected areas: 45,7 TWh Reference Permanent Protected Plans (2010)

Master Plan for Hydropower Development

A white paper to the Parliament in 1980, Norway's future energy- use and production, asked for development of a national master plan for hydropower. The Government was in demand for an extended planning and licensing system that took into account not only the particular hydropower scheme, but also hydropower development at a broader scale, including consideration of socioeconomic and environmental issues. The plan includes many strategic elements comparable to a SEA.

Altogether 310 hydropower schemes larger than 5 GWh/year were considered with respect to project economy and it also comprised possible impacts on the regional economy and conflicts with other user- and protection interests (13 topics were considered). Based on an overall assessment, the projects were then divided into three categories:

- Category I comprises the hydropower projects that are ready for immediate licensing and consecutively "go projects",
- Category II comprises the hydropower projects that need Parliament approval, and
- Category III cover "no go" projects due to disproportionately high development costs and/or high degree of conflict with other user interests, including environmental interests.

The plan has later been supplemented and category II and III have been merged.

Today the Norwegian Directorate for Natura Management is still using the old Master plan (which included updates up to 2009) but the idea is to merge the Master Plan into the WFD work.

Regional Plans for Small Hydropower (information received from the Ministry of Environment, Norway)

In Norway, the interest for small hydropower (<10 MW) is growing rapidly, and more than 200 applications are currently in some stage of the licensing process. The licensing follows the regulations in the Water Resources Act, but is simplified compared to larger projects. A general description of possible environmental impacts and conflicts is required, and a separate and more detailed report on biodiversity with focus on red listed species is compulsory.

In order to ensure better planning and handling of cumulative impacts arising from several separate projects within a limited area or watershed, the Government has called for development of master plans at the regional level. The plans will also increase predictability and provide guidance for developers, presumably resulting in better applications and discouragement of poorly planned projects. The county administrations will coordinate the planning process pursuant to the Planning and Building Act and the final plans will be approved by the county councils. Mechanisms for proper coordination with other plans, such as the river basin management plans under the WFD, will be included.

As a basis for the regional planning, the Ministry of Oil and Energy, together with the Ministry of Environment, will provide for national guidelines as a tool for the regional authorities for development of plans and to promote harmonisation of the planning procedures. Draft guidelines have been prepared by a committee consisting of representatives from various agencies, including the Water Resources and Energy

Directorate, the Directorate for Nature Management and the Directorate for Cultural Heritage, and also with input from the regional authorities.

The first step in the planning process will be to demarcate “planning areas” in each county based on the resource maps for small hydropower (development potential) that are available from the Directorate for Water Resources and Energy. It is recommended to carry out planning first in areas where the density of feasible projects is high (clusters) and where conflicts are not likely to occur. Second step implies mapping of various interests (topics) that are sensitive to small hydropower, such as landscape, biodiversity, recreation and tourism, cultural heritage, salmon and fishery, unaffected “wilderness” areas without major infrastructure development (at least 1 kilometer away from such development), and Sami interests (reindeer husbandry) that are mainly associated with northern Norway. The topical areas within each of the planning areas will be defined and classified according to their intrinsic “value”: High, medium and low value. Use of available EIA methodology is generally recommended, although it may have to be adapted to serve the specific purpose. By combing the resource maps for small hydropower and the topical maps, e.g. by use of overlay, possible areas of conflict will appear. Methodologies for classification of possible cumulative effects and related conflicts are less developed, and the classification will therefore have to rely more on expert judgement.

The final step includes development of management policies, strategies and regulative measures based on the information for each of the planning areas. The counties can make references to the plan during the formal inquiry, which is part of the licensing process. Hence, approved plans and inquiries will be directional for the licensing process at the national level. It has been suggested to announce joint start-up of planning in all the relevant counties and to have one year trial period for evaluation and exchange of experiences.

The national guidelines also contain a standard framework and template for the case-by-case assessment of small-hydropower applications as part of the licensing process at the state level. The guidelines for assessment are derived from the national policies and goals for each sector/topic, and thus they are also meant to be normative for the planning at the regional level. Some examples are presented below:

- **Landscape/environment**: Small hydropower projects should be carefully designed and fitted to the landscape. Normally, the headrace/pipeline will have to be buried or otherwise covered, and transmission lines will have to be underground cables. Construction work should be carried out as carefully as possible and with minimum disturbance to the environment. A detailed plan is required before the work can commence. Requirements for minimum flow, thresholds and other abatement measures should be applied when necessary. Activities that may reduce the aesthetic value of important landscape components, e.g. waterfalls, canyons, pools etc., or lead to fragmentation of continuous landscapes should be avoided. Small hydropower projects that require location of intake-dam and power station within areas that are not previously affected by technical interventions will normally not be accepted, as well as interventions in vulnerable mountain/alpine areas above the timber line.
- **Biodiversity:** Conservation of biodiversity is a national priority area. All applications for small hydropower are required to provide a separate report describing in detail the biodiversity in the affected area with focus on Red List plant and animal species, and concluding with an impact analysis. Small hydropower that may have negative impacts on directly threatened species should be avoided.

- **Recreation:** Outdoor recreation is very popular and is part of the Norwegian tradition. Many of the activities are directly related to water. Development of small hydropower in areas of high value for recreational use should be restricted. Special attention should be given to impacts that reduces the nature experience or that may affect particularly vulnerable user-groups such as children. Furthermore, impacts on recreational areas close to (urban) settlements and areas for certain activities that cannot be substituted, e.g. the only bathing area close to a local settlement, should be avoided.
- **Cultural heritage:** Activities that have direct negative impacts on cultural heritage should be avoided and security/buffer-zones around protected sites/objects (as defined by the cultural heritage act) should be respected. Particular attention should be paid to take care of cultural heritage sites/objects related to earlier use of the river, such as old mills, floating dams, hunting and fishing constructions etc. The power station and other buildings should be designed in accordance with the local architectural style.
- **Salmon and fishery:** Development of small hydropower in national salmon rivers (their status has been defined by a Parliament resolution) should be restricted. Projects that may alter the natural water flow, water quality or temperature or that may obstruct fish migration should be avoided. The power station/tailrace should preferably be located upstream of fish migration/spawning areas. Requirements for manoeuvring of the power station, minimum flow, thresholds and other abatement measures should be applied when necessary.
- Sami interests (reindeer husbandry): Special requirements are applicable for Sami areas. Development activities will normally not be allowed within defined areas of special value for reindeer husbandry. Small hydropower development affecting reindeer pasture land will be subjected to comprehensive assessment before decisions are made.

The economy of small hydropower projects is also considered. At the moment, projects with investments up to 3 NOK per kWh (approx. 0,38 EUR) are regarded to be economically feasible. Projects with higher costs are not promoted, but this may of course change over time.

In many cases, small hydropower projects that at first seem unacceptable because of environmental impacts or conflicts with other uses, can be adjusted in accordance with the national guidelines and thus be realised. Careful planning and consultation with other user-groups in the river is required.

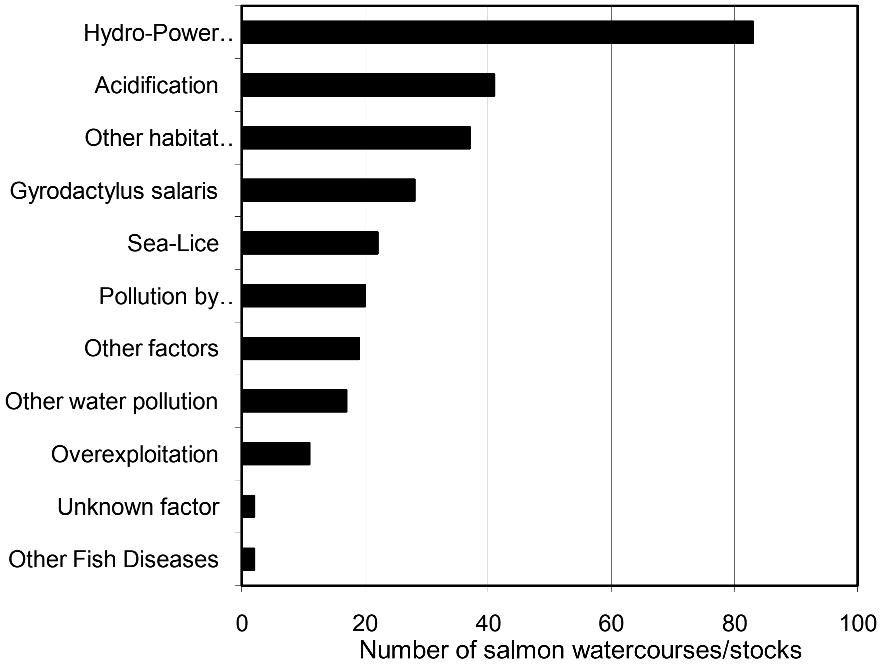
National Salmon rivers

A unique management scheme for important salmon rivers has been developed. Hydropower development is only accepted I salmon stock are not affected. In addition, mitigations for improvement of the stocks should be given priority

The category system for salmon rivers is used as a basis for deploying necessary management measures both on a local, regional and national level. Management guidelines are developed for each category e.g. with regard to fishery regulations. An overview over the frequency of adverse human impacts decisive for category assignment is given in Figure 4.4.

In Norway there are two schemes than are important for protect salmon habitat. In 2003 the Norwegian Parliament established a system of national salmon rivers and national salmon fjords where the wild Atlantic salmon is granted special protection. Today the scheme comprises 52 national salmon rivers and 29 national salmon fjords. Further118 salmon rivers or parts of such are protected against further hydropower development by the National Protection Plan for River Systems.

Figure 4.4: Overview over frequency of adverse human impacts decisive for category assignment.



If pre-planning mechanisms are applied for the allocation of suitable and non-suitable areas

Yes, all different types of plans (master plans, conservation plans, regional plans and the designated salmon rivers) are all types of applied pre-planning mechanisms.

If this designation is based on a dialogue between different competent authorities, stakeholders and NGOS

No information has been found in relation to the aspect of stakeholder consultation for these planning approaches.

If other elements of strategic planning are applied eg prior agreement of a catalogue of criteria which informs the judgment on the right balance between the benefits of the hydropower facility and the benefits of protecting the aquatic environment

The Ministry of Petroleum and Energy and the Norwegian Water Resources and Energy Directorate (NVE) is responsible for and deals with licensing applications for the quantitative use of water resources, especially hydropower, but also other encroachments that affect physical conditions in watercourses. NVE is involved in all the aspects of hydropower licensing. NVE co-operates with the Directorate for Nature Management preparing the Protection Plans and the Master Plan for hydropower development. This sets up an important framework for the licensing and includes an overall evaluation of electricity demand and supply.

There are several acts regulating hydropower development in Norway. The most important is The Water Resources Act. According to this act, license is granted regarding all kind of measures in the river systems, e.g. power plants. Further, licenses to establish reservoirs and to transfer water between river systems are granted in accordance to The Water Courses Regulation act.

All applications for hydropower projects bigger than 40 GWh or reservoirs bigger than 10 mill.m3 is handled in accordance with the procedures in the Planning and Building Act (PBA), including an early notification and environmental impact assessments (EIA). For small projects that are not handled in accordance with the procedures in the Planning and Building Act, there is no need for a notification. Except that part, the procedures are in general the same as for larger projects.

The case handling procedures ensure participation from related authorities, affected communities and the public. All documents are publicly available and all parties are invited to express their opinion. It is a challenge for the responsible and involved authorities to make the procedures work efficiently and to focus the environmental impact assessments on the important issues.

The Norwegian hydropower licensing system in short:

- NVE considers hydropower license applications
    >10 MW final decision in cabinet
- Thorough process
- Hearings/consultation
- Local public meetings
- Site visits
- Includes all elements
- Sum of benefits larger than costs/damage

The legislation establishes conditions for the licenses. Based on experience and co-operation with the relevant authorities, NVE have developed a set of standard terms of license, which, among others, covers rules for revision every 30 years of the terms of license. Further, there are terms for nature conservation. This gives authority to require mitigating measures regarding, landscape, biotope adjustments to maintain biological diversity, weirs in the affected river stretch, fish stocking and pollution. It also gives opportunity for monitoring of long-term environmental effects.

The rules of operation establish limitations regarding the use of the reservoirs, such as highest and lowest regulated level, and may include seasonal restrictions on regulation levels and minimum water release to the rivers.

Revision of hydropower licence terms

- 340 licenses may be initiated for revision by 2022
- All major hydropower schemes
- Also the hydro scheme including all environmental issues
- Comprises environmental conditions and user interests
- Today, only 1 revsion completed. About 20 started the process.
- River Basin Authority may initiated the process

Decision in Norwegian parliament as of June 2010 regarding regulated rivers and RBMPs:

Executive Decree as the cabinet adopted RBMP (June 2010):

- Environmental objectives in regulated river based on existing licence conditions.
- These environmental objectives are reported to ESA as binding targets.
- RBMP may also include suggestion for future environmental state (regardless existing terms).
- Means:
- Look for the opportunities for improvement within the existing framework
- Update the environmental goal if license conditions are changed

References included in review on strategic approaches for Norway:

Permanent Protected Plans (verneplan for vassdrag) (2010). http://www.nve.no/no/Vann-og-vassdrag/Verneplan -for-vassdrag/

Ministry of Environment. The Master Plan for water resources.

Regional Master Plans” for Small Scale Hydropower in Norway.

CIS Policy Guidance – WFD & hydromorphological pressures – focus on hydropower. 3 November 2006.

Licencing procedures: http://www.nve.no/en/Licensing/Handling-prosedures/

Licencing history: http://www.nve.no/en/Licensing/History/

Implementation of WFD n Norway: http://www.vannportalen.no/enkel.aspx?m=40354

Recent updates WFD and hydropower in Norway (presentation by Anja Ibrekk at) : http://www.vannportalen.no/ferdigakt.aspx?m=42793&amid=3425537&fm_site=31134,31134 Nordic workshop on WFD implementation Sigtuna, Sweden, 20-22 September 2010.

4.3.3 Lithuania

Is strategic planning taking place? At river basin level or MS level?

According to the Information available from Annex 6 (Terms of Reference, EC DG ENV Tender ENV/D.1/ETU/2010/0042rl) a pre-planning approach exists as plans for development of new hydropower projects to a large degree are limited by an existing legal framework that sets out environmental restrictions for building dams in certain rivers and segments. Law on Water (2003), article 14 prohibits the establishment of dams in rivers „...that are valuable in an environmental and cultural context“. The list consisting of 169 rivers and river segments was approved by the Decision of the Government (2004). Criteria for including the segment of the river in the list (provided individually for each river/ river segment in the list) are:

- Species registered in the Lithuanian Red Book;
- Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora;
- The Convention on the Conservation of European Wildlife and Natural Habitats (the Bern Convention);
- Wild salmon protection in the Baltic Sea drainage basin (under the HELCOM convention);
- Former International Baltic Sea Fishery Commission (IBSFC);
- National program of salmon restoration.

The Water Framework Directive 2000/60/EC (WFD) is not specifically listed as a criterion for the restriction of hydropower development.

If pre-planning mechanisms are applied for the allocation of suitable and non-suitable areas

Yes, it can be considered as a pre-planning mechanism. A map of rivers with environmental restrictions for building of dams is given in with restricted riverLithuanian Hydropower Association

If this designation is based on a dialogue between different competent authorities, stakeholders and NGOS

No information is available in terms of stakeholder participation in pre-planning and strategic approaches.

In terms **of further strategic approaches**, the following information is available: within the framework of the implementation of the EU Water Framework Directive, the Lithuanian Environmental Protection Agency has contracted a work to prepare recommendations on reducing environmental impacts of hydropower plants (information obtained from Lithuanian Hydropower Association, 2010). The report analyses environmental issues related to the production of hydropower and provides recommendations related to more environmentally friendly operations of small hydropower plants. It also discusses issues related to the removal of dams. The study also provides schematic maps showing relative power of the rivers and rivers segments favorable for hydropower production.

Figure 4.5 Map of rivers with environmental restrictions for building of dams (Lithuanian Hydropower Assocation- Presentation of Dr Petras Punys of March 2010)

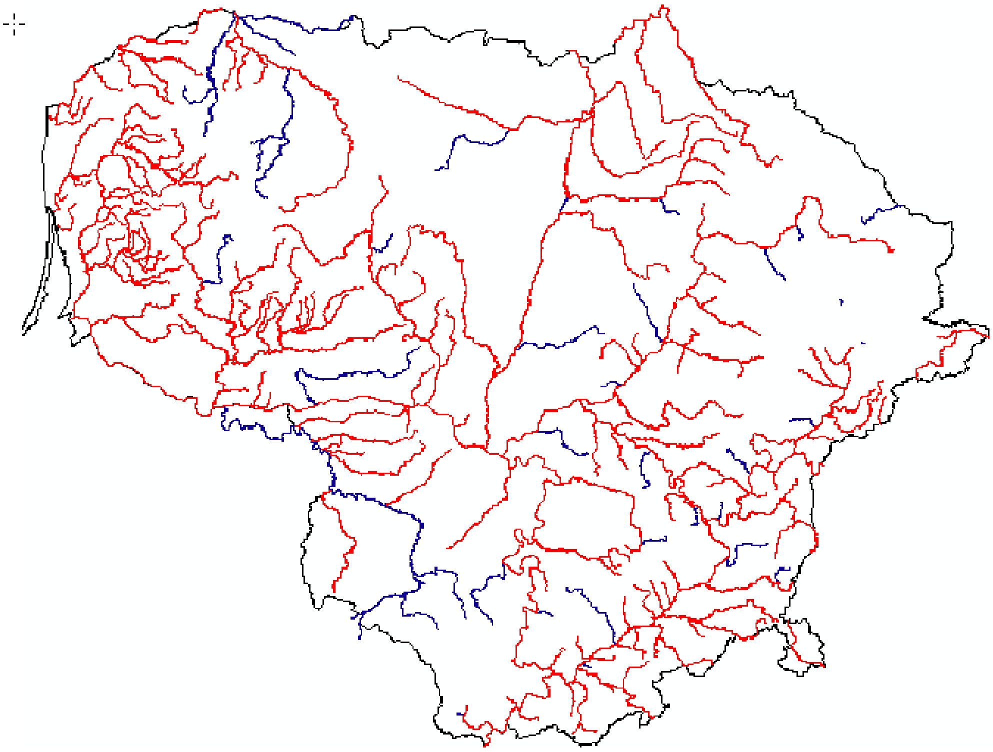


Figure 1. Map of rivers with environmental restrictions for building the dams [4].

Note: Rivers where building of dams is prohibited are marked in red. Building of dams in other rivers is not prohibited by law; however the hydropower development projects have to follow Environmental Impact Assessment and Spatial Planning procedures. Rivers that are not favourable for hydropower production due to technical and economical reasons are omitted for clarity.

References included in review on strategic approaches for Lithuania:

Annex 6 (Terms of Reference, EC DG ENV Tender ENV/D.1/ETU/2010/0042rl). Summaries of hydropower potentials, strategic planning approaches and information on ecological concerns when developing hydropower for France, Norway and Lithuania. Annex to the ToR for Tender.

Law on Water (Zin. 1997, No. 104-2615, Zin., 2003, No. 36-1544).

Decision of the Government of the Republic of Lithuania of September 10, 2004 on the Approval of the List of Rivers and River Segments Valuable in Environmental and Cultural Context (Zin. 2004, No. 137-4995).

Lithuanian Hydropower Association (Presentation of Dr Petras Punys of March 2010 at the European Sustainable Energy Week): http://www.esha.be/fileadmin/esha_files/documents/EUSEW_2010/Punys.pptx

4.3.4 Germany

Is strategic planning taking place? At river basin level or MS level?

Elements of strategic planning on national level are the Federal Water Act (Wasserhaushaltsgesetz, WHG 2009, Gesetz zur Ordnung des Wasserhaushalts, vom 31. Juli 2009 (BGB1.I Nr. 51 vom 6.8.2009, S. 2585), gültig ab 1.3.2010) and the Renewable Energy Law for feed-in tarifs (Erneuerbare Energien Gesetz, EEG 2009, last revision published in 25. Oktober 2008 - Bundesgesetzblatt Jahrgang 2008, Teil I Nr. 49, S. 2074. Revision in preparation for 2012).

The WHG (§§33 to 35) requires ecological measures at HP stations according to the WFD. As a strategic element concerning HP it demands as well (§35) the examination of unused weirs and dams as locations for hydro power production.

The Ministery of Federal Environment Ministry (Bundesumweltministerium) had prepared a study on the hydropower potential in Germany (Anderer, P.; Dumont, U.; Heimerl, S.; Ruprecht, A.; Wolf-Schumann, U.: Das Wasserkraftpotential in Deutschland. In: WasserWirtschaft 100 (2010), Heft 9.). The results were intended to form a basis for the development of a stategic planning. Since it was not possible to evaluate the potential location wise, only an estimate of the additional potential could be performed under ecological conditions. The results were accepted by an advisory committee.

The federal states (FS) incorporated the WHG into their legislation (FS Water Acts (Landeswassergesetze) and FS Fishery Acts (Landesfischereigesetze)). In a study for the Federal Environment Agency (FEA, Study:: “Efficient measures and criteria for the ecological improvement at hydro power stations”, FKZ: 3708 97 200, to be published in 2011) Ingenieurbüro Floecksmühle is just comparing the ecological requirements within these revisions.

All federal states (FS) of Germany elaborated management plans for the 10 relevant river basins under public participation. Collaboration between FS was necesary when rivers crossed their borders. The results are published in the internet together with the action plans (www.wasserblick.net).

As part of strategic planning some FS had investigated not only the technical HP potential potential but also the ecological potential under WFD standards on a location basis:

- Northrhine-Westfalia

  (Anderer, P., U. Dumont, R. Kolf (2007): „Das Wasserkraftpotential in Nordrhein-Westfalen“, Wasser und Abfall 7-8, 2007, S. 16-20)

- Rhineland –Palatinate

  (Anderer, P., U. Dumont, C. Linnenweber, B. Schneider (2009): „Das Wasserkraftpotential in Rheinland-Pfalz“, KW – Korrespondenz Wasserwirtschaft, 04/09, S. 223-227)

- Bavaria (BY)

  (E.ON & BEW (2009): „Potentialstudie – Ausbaupotentiale Wasserkraft in Bayern“, Bericht aus der Sicht der beiden großen Betreiber von Wasserkraftanlagen in Bayern, 21 S.)

- Baden-Württemberg (BW)

  (Heimerl et al.: “Ausbaupotential der Wasserkraft bis 1000 kW im Einzugsgebiet des Neckar unter Berücksichtigung ökologischer Bewirtschaftungsziele ohne Bundeswasserstrasse Neckar”, December 2010)

- Hesse (Prof. Theobald University of Kassel) and

- Thuringia

  investigation of HP potential at weirs in the rivers Saale, Ilm and Unstrut under ecological aspects.

Beside these individual FS investigations there had studies been performed on a river-basin level. For example the FGG Weser, a river basin association (Flußgebietsgemeinschaft (FGG) Weser, Hildesheim) of the adjacent states Lower-Saxony, the Free Hanseatic City of Bremen, Northrhine-Westfalia, Hesse an Thurangia had performed a study on a strategic action plan concerning mitigation measures at hydropower stations in the river Weser (internal report: “Umsetzungsstrategie Weser”, 2008).

For the Weser basin the FEA had worked out an action plan (FEA Dessau, study: „Preparation and testing of an action plan for an ecologically compatible use of hydro power in the Weser basin “, to be published in 2011).

The states with international boarders are involved in the international commissions for the protection of river basins like the Rhine, Moselle, Danube, Elbe and Odra.

The programs on the re-settlement of eel and salmon in the Rhine basin strongly depend on the management of the last dike (Abschlussdeich) at the Rhine estuary. The present Dutch government withdrew the commitment for an eel and salmon friendly gate management which counteracts the international efforts in the Rhine basin.

Pilot projects were and are being built to investigate the impact of HP facilities (eg. 10mm screens in Roermond, river Roer, NL and in Unkelmühle, DE, river Sieg).

If pre-planning mechanisms are applied for the allocation of suitable and non-suitable areas

Together with the HP potential evaluations, most of the FS worked out guides for judging the ecological impact of HP stations and for improving the facilities concerning (fish) ecology.

- Northrhine-Westfalia (NW)

  (Anderer, P., U. Dumont, R. Kolf (2007): „Das Querbauwerke-Informationssystem QUIS-NRW“, Wasser und Abfall 7-8, 2007, S. 10–14.

  DUMONT, U., P. ANDERER, U. SCHWEVERS (2005): „Handbuch Querbauwerke“, Hrsg. Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrhein-Westfalen, Düsseldorf, 213 Seiten.) http://www.floecksmuehle.com/index.php?page=cat&catid=93)
- Rhineland –Palatinate (RP)

  (LANDESAMT FÜR UMWELT; WASSERWIRTSCHAFT UND GEWERBEAUFSICHT RHEINLAND-PFALZ): „Durchgängigkeit und Wasserkraftnutzung in Rheinland-Pfalz“, Bearbeitung Ingenieurbüro Floecksmühle, LUWG-Bericht 2/2008, Mainz, ca. 220 S.)
- Hesse (HE)

  (Hydro power and WFD in Hesse – an expert system for optimizing locations with HP generation, F. Roland, University of Kassel)
- Thuringia (TH)

  (Fachliche Anforderungen zur Herstellung der Durchgängigkeit in Thüringer Gewässern, Thurangian Federal Agency for Environment and Geology and Ingenieurbüro Floecksmühle, March 2009)

The FS reported within the action plans ecologic development rivers or priority rivers or river sections with a high demand on longitudinal connectivity and on the protection of species. The priority rivers comprise especially rivers with diadromous habitat and the rivers connecting them to the sea.

Example river Kinzig (Baden-Württemberg): the Kinzig directly discharges into the Rhine. Because of a short ways to salmon habitats within the Kinzig river basin it was chosen as development river. With highest priority the longitudinal connectivity is being reconstructed there.

- Northrhine-Westfalia

  (DUMONT, U., P. ANDERER, U. SCHWEVERS (2005): „Handbuch Querbauwerke“, Hrsg. Ministerium für Umwelt und Naturschutz, Landwirtschaft und Verbraucherschutz des Landes Nordrhein-Westfalen, Düsseldorf, 213 Seiten)
- Rhineland –Palatinate

  (Anderer, P., U. Dumont, C. Linnenweber, B. Schneider (2010): Entwicklungskonzept ökologische Durchgängigkeit. In: WasserWirtschaft 100 (2010), Heft 9 and

Anderer, P., U. Dumont, C. Linnenweber, B. Schneider (2008): „Durchgängigkeit der rheinland-pfälzischen Gewässer, Instrumente für die Entwicklung von Maßnahmenplanen“, KW – Korrespondenz Wasserwirtschaft, 10/08, S. 568-574)

- Brandenburg

  (Concept for the longitudinal connectivity in the rivers of Brandenburg – designation of priority rivers, Landeskonzept zur ökologischen Durchgängigkeit der Fließgewässer Brandenburgs - Ausweisung von Vorranggewässern, Institute of Inland Fisheries in Potsdam-Sacrow, 2010, www.ifb-potsdam.de)

- Schleswig-Holstein

  (Report on the implementation of the WFD – detemination of priority rivers, by an interdisiplinary expert workgroup, december 2009 ; Erläuterungen zur Umsetzung der Wasserrahmenrichtlinie in Schleswig-Holstein - Ermittlung von Vorranggewässern)

Neither did the FS report on go-areas or -rivers where HP should be used nor did they place a ban on the use of HP in ecological priority and development rivers. The political discussion is in progress.

If this designation is based on a dialogue between different competent authorities, stakeholders and NGOS

This implementation of the WFD was attended by the LAWA (Länderarbeitsgemeinschaft Wasser), which is the German Working Group on water issues. The group is composed of members of the ministries of the Federal States responsible for water management and water legislation and of the Federal Government which is represented by the Federal Environment Ministry. The aims are to discuss in detail questions arising in the areas of water management and water legislation, to formulate solutions and to put forward recommendations for their implementation. The results form a basis for the implementation of a standardised water management system within the Federal States. The LAWA e.g. prepared a guidance document for the implementation of the WFD (http://www.lawa.de/ also English version).

The German Association for Water, Wastewater and Waste (DWA) is a specialist technical and scientific organisation. Experts from all sectors of water-resource management document the "generally acknowledged rules of technology" and develop from these the DWA set of rules and standards. The results of this work are technical rules and standards (http://dwa.de). They following reports are related to connectivity and HP stations:

- DWA-M 509 - draft - Fischaufstiegsanlagen und fischpassierbare Bauwerke - Gestaltung, Bemessung, Qualitätssicherung - Entwurf (Februar 2010)
- DWA-Themen WW 8.0 - April 2006 - Durchgängigkeit von Gewässern für die aquatische Fauna - Free Passage for Aquatic Fauna in Rivers and other Water Bodies
- DWA-Themen WW 8.2 - April 2006 - Funktionskontrolle von Fischaufstiegsanlagen

- DWA-Themen WW-8.1 - Juli 2005 Fischschutz- und Fischabstiegsanlagen - Bemessung, Gestaltung, Funktionskontrolle, 2. korrigierte Auflage
- ATV-DVWK (2004): Fischschutz- und Fischabstiegsanlagen - Bemessung, Gestaltung, Funktionskontrolle. - Hrsg.: ATV-DVWK - Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V., Hennef, ISBN 3-934063-91-5, 256 S..

There seems to be an increasing dialogue between the electricity industry and those FS that want to increase the HP potential. While the increase in HP is mostly promoted by the ministeries of economy, the ecological aspects are expressed by the ministeries of environment. Conferences and workshops are organised where the stakeholders get together and discuss the HP potential and ecological issues, e.g.

- Workshop Wasserkraftnutzung am 26.10.2010 Thüringen (www.tlug-jena.de/de/tlug/umweltthemen/wasserwirtschaft/wasserbau/wasserkraftnutzung)

It is more a political dialogue where each stakeholder tries to push decisions for his own benefits.

If other elements of strategic planning are applied eg prior agreement of a catalogue of criteria which informs the judgment on the right balance between the benefits of the hydropower facility and the benefits of protecting the aquatic environment

The Federal Agency for Nature Conservation (Bundesamt für Naturschutz BfN) addresses the issue. As a first result a draft of a guide for evaluating the impact of HP stations has been prepared and is supposed to be further evaluated and discussed in the cause of the feed-in law EEG (Dumont et al., 2010: The reconstruction and building of new HP stations regarding the conflict between the protection of biodiversity and the climate change, 2009 „Aus- und Neubau der kleinen Wasserkraft im Spannungsfeld von Biodiversitätsschutz und Klimawandel“; Vorhaben im Auftrag des Bundesamtes für Naturschutz, Leipzig).

A judgment on the right balance is not available. In some federal guides it is agreed that 20 to 30% of a river length could be influenced by weirs and HP considering minimum flow sections and reservoirs.

References included in review on strategic approaches for Lithuania:

All references have been included in the text as there are many supporting documents.

4.3.5 Austria

NATIONAL APPROACH

Is strategic planning taking place? At river basin level or MS level?

If pre-planning mechanisms are applied for the allocation of suitable and non-suitable areas

No information – only for Tirol state (see further)

If other elements of strategic planning are applied eg prior agreement of a catalogue of criteria which informs the judgment on the right balance between the benefits of the hydropower facility and the benefits of protecting the aquatic environment

For small hydropower installations: Promotion schemes and incentives giving support to operators or licensees in fulfilling environmental objectives eg in the course of the "Umweltföderungsgezetz" (Environmental Promotion Act) 140M euro are provided by the Federal state in form of investment grants until 2015 for environmental measures like mitigation measures in case of hydropeaking. Currently there is a double strategy: refurbishment of existing facilities combined with the implementation of environmental measures in Upper Austria (Alpine Convention, Annex 1, National Data Templates, 2010).

From AEON (2010) for small hydropower: the legal framework has not yet been completely established, leading to uncertainties. In addition in some domains, the Austrian interpretation of the WFD is considered restrictive in comparison to the regulations in other European countries by the Hydropower Assocation. For example in terms of the size of the water bodies: in Austria very short water bodies are fixed which means that interferences have a more significant impact than they would have if longer water bodies were defined. This leads to problems with the need to improve and the prohibition to deteriorate the ecological status of the water (As part of AEON (2010): KÖ (2010): Kleinwasserkraft Österreich; Martina Prechtl. Telephone interview on 17.03.2010)

TIROL APPROACH (Kritierenkatalog, 2009)

Is strategic planning taking place? At river basin level or MS level?

The following only applies to the state of Tirol and is based on Kritierenkatalog (2009) "Wasserkraft in Tirol - Kriterien für die weitere Nutzung der Wasserkraft in Tirol". A summary of the approach is also given in (Alpine Convention, Annex 1, Good Practice examples).

The draft document was produced by a project-specific expert committee consisting of independent members of public bodies (Energy, river ecology, water management, regional planning authorities and Universities) and private entities (consultants). Hydropower has a share of almost 100% of total power generation in Tyrol.

The main goals of the document are:

- outline the importance and remaining potential of hydropower in Tyrol, and
- suggest a catalogue of criteria as a basis for assessment and exploitation of acceptable and sustainable future use of the remaining hydropower potential in Tyrol.

The document represents the result of step 2 of a systematic evaluation approach. The next steps include: public consultation, adaptation of criteria and political resolution.

The final results shall form the basis for:

- concept and design of integrated and “sensible” hydropower projects,
- assessment/ evaluation of hydropower utilization in specific River Basins or even river reaches, and
- development of management plans according WFD. Do you know if there is any certainty/knowledge that the results have been integrated in the RBMPs for Austria?

The results don’t exist yet and the criteria catalogue isn’t definitive (merely a draft). The wording in the document alludes to the assumption that the results will be integrated in the RBMPs once they are available and have been politically agreed.

There is no strategic planning in terms of where hydropower can be located. The criteria catalogue will form the basis for future developments. It seems as if the criteria will lead to some sort of a designation process or weighting.

If pre-planning mechanisms are applied for the allocation of suitable and non-suitable areas

No, but suggested criteria from Kritierenkatalog (2010) could lead to designation of favorable – non favorable areas.

The main criteria (with different sub-criteria in brackets):

a) energy industry (technical-economic data, production efficiency, profit, contribution to system stability, security of supply, avoidance of CO2 emissions, grid aspects, synergies)

b) water management (exploitation of potential, design discharge, head, proportion of affected river reach vs. power output, influence on floods, risk potential, influence on sediment budget, immissions, influence on groundwater)

c) regional planning (sustainable regional planning, maintenance of ecosystem, recreation areas, maintenance of cultural landscape, maintenance and development of economy (tourism, macro-economic effects, forestry))

d) river ecology (protected areas, low-value/affected/ contaminated reaches, criteria of public interest, plant efficiency)

a)e) nature protection (maintenance of native flora & fauna, maintenance of natural, recreational value, habitat, national and international protected areas, e.g. Natura 2000

If this approach is based on a dialogue between different competent authorities, stakeholders and NGOS

It seems that **public participation on the draft catalogue has taken place** and that over **400 comments/ statements have been reviewed** and discussed with public officials. http://www.tirol.gv.at/regierung/steixner-anton/kriterienkatalog/ The proposal was presented to the public in December 2009 and opened for comments until February 2010 (Alpine Convention, Annex 1, Good Practice examples). **Currently the final catalogue is being developed.**

References included in review on strategic approaches for Austria:

AEON (2010). Assessment of non-cost barriers to renewable energy growth in EU Member States – AEON (for EC DG Energy and Transport)

Alpine Convention, Annex 1, National Data Templates (2010). ALPINE CONVENTION PLATFORM WATER MANAGEMENT IN THE ALPS. Situation Report. Hydropower Generation in the Alpine Region focusing on Small Hydropower. ANNEX 1. DATA TEMPLATES FROM ALPINE COUNTRIES.

Alpine Convention, Annex 1,Good Practice Examples (2010). ALPINE CONVENTION PLATFORM WATER MANAGEMENT IN THE ALPS. Common Guidelines for the use of Small Hydropower in the Alpine region

ANNEX 1. GOOD PRACTICE EXAMPLES FOR THE USE OF SMALL HYDROPOWER

Kritierenkatalog (2009). Wasserkraft in Tirol. Kriterien für die weitere Nutzung der Wasserkraft in Tirol. Dezember 2009, Rev. 1 ENTWURF. http://www.tirol.gv.at/regierung/steixner-anton/kriterienkatalog/

4.3.6 England & Wales

The following text relates to small-scale hydropower only.

Is strategic planning taking place? At river basin level or MS level?

There is no strategic planning, although the 'opportunities mapping project' (Environment Agency 2010a) could give a basis for this. Based on the information given in the Final Report to the Government in terms of streamlining permitting of hydropower projects in England and Wales – following a public consultation (Environment Agency 2010b), it is merely developed for using it in the permitting process to make sure all local teams involved in the permitting process have correct information on what should be the basis of permitting with regard to environmental impacts of the hydropower installations.

However, the consultation document itself (Environment Agency, 2010b) reflects the idea of a need for a strategic approach to be taken for the of hydropower schemes in England and Wales. Some suggestions are given: *"The strategic approach could involve developing catchment level strategies that would be based on information relating to, among other things, the barriers within a catchment and any functions they may fulfil, the passability of barriers to fish, and the potential hydropower opportunities. The aim would be to enhance fisheries within catchments and increase fish passage whilst maximising the available hydropower opportunity. This could benefit both industry and conservation stakeholders by increasing the clarity as to where hydropower is appropriate and where it is not, and by helping identify win-wins."*

The Environment Agency refers to its report of Phase 1 of our opportunities mapping project (Environment Agency 2010a) which identifies 25,935 barriers within rivers that may provide a hydropower opportunity. The sites are mostly weirs, but also include other man-made and natural features, such as waterfalls. The estimated average power generation capacity on a barrier was 45 kW, with a small number of sites having a potential of more than 1 MW. The total theoretical potential capacity is nearly 1200 MW. In reality, the actual potential will be a proportion of this due to practical and environmental constraints. This initial work also considered two environmental sensitivities: (i) the presence of different fish species and (ii) whether the site has been designated as a Special Area of Conservation (SAC) under the Habitats Directive. Almost half (46%) of the sites are classified as highly sensitive, mostly because of the presence of migratory fish species such as salmon and eel. About a quarter (26%) are medium and A second phase of work is planned that will improve the quality and accuracy of the data, and apply a more detailed analysis at the catchment scale for a number of trial catchments. We will use this information to inform catchment level approaches that seek to maximise fish passage and sustainable hydropower generation potential. This will include prioritising barriers for removal, identifying good hydropower opportunities, and identifying win-win sites that would deliver fish benefits and renewable energy if a fish pass were incorporated into a hydropower scheme at that site. If these pilots are successful, the Environment Agency would like to apply the methodology principles to other appropriate catchments. This is, however, subject to finding the necessary funding and resources.

In the Final Report to the Government (2010) it is indicated that the Environment Agency will continuing to examine potential catchment-scale opportunities and impacts of hydropower. It is indicated that this will link with the Water Framework Directive programme of measures for protecting and enhancing the water environment, including Natural England's River Restoration Plans.

If pre-planning mechanisms are applied for the allocation of suitable and non-suitable areas

From the consultation document (Environment Agency, 2010b), it is indicated that the results of the project on mapping opportunities and sensitivities in England and Wales (phase 2 ongoing) will be used to inform catchment level approaches that seek to maximise fish passage and sustainable hydropower generation potential. This will include prioritising barriers for removal, identifying good hydropower opportunities, and identifying win-win sites that would deliver fish benefits and renewable energy if a fish pass were incorporated into a hydropower scheme at that site. If these pilots are successful, the Environment Agency would like to apply the methodology principles to other appropriate catchments. This is, however, subject to finding the necessary funding and resources.

One could see that in first instance, there will be no overall national policy or restricted areas, but it will be part of a catchment-based approach of minimizing hydropower impacts and identifying win-win sites for hydropower & environment. In the Final Report to the Government (Environment Agency, 2010c), it is also indicated that catchment-scale opportunities and impacts of hydropower with a link to WFD PoMs and River Restoration Plans, but no indication given that this will be used as a “planning” approach.

If this designation is based on a dialogue between different competent authorities, stakeholders and NGOS

Yes, the consultation document (Environment Agency, 2010b) includes questions on the need for a strategic approach of hydropower at catchment level.

Questions included are: Do you agree that we should develop catchment level strategies for hydropower? If so, what do you think catchment strategies should aim to deliver and what environmental and other impacts should they consider? Should they seek to identify sites that are suitable and not suitable for hydropower

The Environment Agency had published the consultation document (Environment Agency, 2010b) on 19 March 2010 and notified over 1300 organisations and interested parties. There were 69 responses from industry, environmental organisations and land owners. The Environment Agency held separate discussions with other regulators and partners in Natural England (NE), Countryside Council for Wales (CCW), WAG, Scottish Environmental Protection Agency (SEPA) and the Northern Ireland Environment Agency (NIEA).

However, in the answer to the consultation document which is the response to the Government (Environment Agency, 2010c), there is no further information given on this aspect, so it is assumed that this is not taken into account (yet). A good practice guideline will be published early 2011 promote best practice and model hydropower schemes. A summary of consultation responses is available: http://publications.environment-agency.gov.uk/pdf/GEHO1210BTHI-E-E.pdf, including the answers of the Environment Agency.

Extract of consultation responses and reply of the Environment Agency (Environment Agency, 2010b) on the following questions:

Do you agree that we should develop catchment level strategies for hydropower?

Of 24 respondents who answered this question,17 responded ‘yes’, four ‘no’ and four ‘don’t know’.

Those responding ‘no’ expressed the view that each scheme should be “taken on its own merits”, and that “they should not be having catchment wide effects”. Another respondent said that “...the reality is that people will develop hydropower close to where it will be used, and where there is the means and the will to develop it. This may not coincide with the best sites”.

If so, what do you think catchment strategies should aim to deliver and what environmental and other impacts should they consider?

Respondents suggested that the strategies should take account of cumulative impacts, the location and status of fish spawning beds, impacts on range of ecosystem and physical habitat parameters, and supporting full fish continuity strategies.

Natural England said that “catchment strategies should consider all relevant mechanisms of impact on river ecosystems and their biological communities.” They state that a key aim of any catchment strategies “should be the identification of existing in-channel structures that are considered permanent...and seek to specify whether off-line turbines are likely to be acceptable at these structures....”

Should they seek to identify sites that are suitable and not suitable for hydropower? Of 30 respondents who answered this part of the question, 17 said ‘yes’, 13 said ’no’, and 1 ‘don’t know.’

There were few responses to this part of the question. Two respondents requested more information, one calling for “detailed information on potential locations so that judgements can be made.” One respondent stated that the “criteria used in identifying the sites [in the opportunity mapping] was not agreed and therefore questionable”.

Environment Agency response: The catchment strategies will be developed as part of the Water Framework Directive River Basin Management Plans, working with stakeholders in those catchments suitable for hydropower.

We have shared the criteria used for opportunity mapping and it is available on our website http://www.environment-agency.gov.uk/hydropower.

If other elements of strategic planning are applied eg prior agreement of a catalogue of criteria which informs the judgment on the right balance between the benefits of the hydropower facility and the benefits of protecting the aquatic environment

The legal framework for hydropower development is complex with separate environmental legislation covering the different impacts. A summary of the legal framework is given in Annex 1 of the Consultation Document (Environment Agency, 2010b) The Government will simplify the permitting of water abstraction and impoundment by including it in the Environmental Permitting Regulations. New fish passage regulations and greater flexibility over the two month mandatory determination time for flood defence consents will also help to streamline the application process. A single decision process, within the existing framework, will deliver a more consistent and robust assessment of the environmental impact. Since October 2010 the Environment Agency adopted a new approach to our management of hydropower permitting. Fundamental to this is the allocation of an Environment Agency account manager for each scheme proposal. The simplified permitting process (Environment Agency, 2010b) is given below (Figure 4.6). A unified suite of application forms and advice which will be published in full in February 2011.

http://www.environment-agency.gov.uk/business/topics/water/32022.aspx

For any hydropower scheme, the Environment Agency needs to consider (Figure 4.6):

- Abstraction – EA needs to agree the amount of water that a scheme can take from a river to flow through a hydropower turbine.
- Impoundment - any new or raised weir will change the water levels and flows in the river. EA needs to agree these changes.
- Flood risk – EA needs to give its consent to any works in or near rivers that have the potential to increase flood risk.
- Fish passage - for many schemes EA will require a fish pass to allow fish to pass safely up and down the river.

References included in review on strategic approaches for England & Wales:

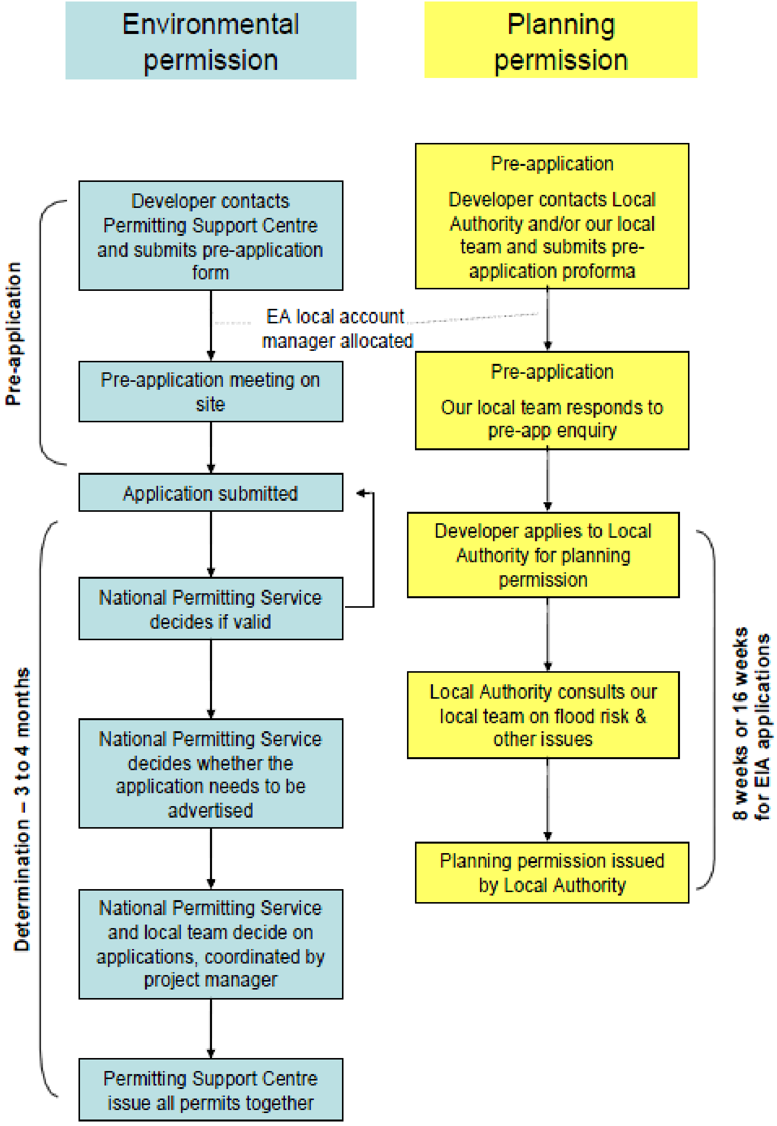
Environment Agency (2010a). Mapping Hydropower Opportunities and Sensitivities in England and Wales. Technical Report. Final Report, February 2010.

Environment Agency (2010b). Streamlining permitting of hydropower projects in England and Wales. Consultation document. 19 March 2010.

Environment Agency (2010c). Streamlining the permitting of hydropower projects in England and Wales. Report GEHO1210BTHH-E-E. Final report to Government, December 2010.

Environment Agency (2010d). Hydropower permitting review. Summary of consultation responses December 2010. Report GEHO1210BTHI-E-E. Final report to Government. December 2010.

Figure 4.6. Flowchart illustrating the Environment Agency's planned permitting approach – one single process of delivering permissions alongside planning (to be finalized February, 2011 – see consultation document Environment Agency (2010b).



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4.3.7 Scotland

Is strategic planning taking place? At river basin level or MS level?

From the Scottish Hydropower Resources study (2008): New guidance is being drafted to assist local authorities in evaluating the relative importance of designations, but the most recent grouping suggests that land designations are grouped into three tiers, suggestive of the level of environmental protection that is likely to apply

- Tier 1 (least restrictive): Gardens and Designed Landscapes (GDLs), LIsted buildings, conservation areas, scheduled ancient monuments
- Tier 2: National Scenic Areas, Sites of Special Scientific Interest (SSSIs), Local Nature Reserves (LNRs) and National Nature Reserves (NNRs), National Parks (NPs), National Heritage Areas
- Tier 3: Ramsar wetlands, Natura 2000 Areas - Special Protection Areas (SPAs), Special Areas of Conservation (SACs). As with impacts of increasing hydro development on the national grid, there will be cumulative impacts upon the environment from each successive hydro scheme within an area. It is difficult to predict how many hydro developments a particular habitat can tolerate, but it seems likely that planning decisions will take into account existing development within the area, and may see this as a reason to restrict development. Because some areas will have a greater density in terms of hydro potential, it might not be appropriate to assume a single maximum amount of hydro development per unit area across the whole of Scotland's designated areas. Instead, reducing hydro potential by a predetermined proportion may be a fairer way of countering cumulative impacts while taking a pragmatic approach in areas of high potential.

The Scottish Hydropower Resources study (2008) is similar to the French hydropower potential (2006) study in that effect that after estimating the technically and economically feasible potential, environmental constraints are accounted for and further reduce the achievable potential.

It is not clear how in the planning process these restrictions are implemented, but main reference here is LUPS-GU18.

If pre-planning mechanisms are applied for the allocation of suitable and non-suitable areas.

No, it is all embedded in the licensing process. In the Sniffer (2006) report, the following analysis is given on applying planning approaches in Scotland for allocating suitable and non-suitable areas for hydropower:

"Some form of negative mapping i.e. the identification of areas where hydropower development is unlikely to be approved, may be worth considering. On a simpler scale it could take the form of specifying conditions in guidance material where the benefits of environmental protection (eg protection of a protected watercourse) are likely to outweigh the benefits to sustainable development".

If this designation is based on a dialogue between different competent authorities, stakeholders and NGOS

Yes, see public consultation procedure (SEPA, 2010a) for the run-of-river scheme guidance, where a set of mitigation measures is proposed. Following a consultation period with the hydropower industry and other interested stakeholders, the Scottish Environment Protection Agency (SEPA) has published its Guidance for developers of run-of river hydropower schemes (SEPA, 2010b). According to a note included, the technical content has been signed off by SEPA but the document is still considered to be in draft format as it has not been fully reviewed and edited in the corporate style. However, SEPA is making the content available now in response to industry demand, and encourage anyone considering a run of river hydropower scheme to read and use this guidance. The final version will be published in early 2011.

If other elements of strategic planning are applied eg prior agreement of a catalogue of criteria which informs the judgment on the right balance between the benefits of the hydropower facility and the benefits of protecting the aquatic environment

Land Use Planning System. SEPA Guidance Note 18. According to LUPS-GU18, all hydropower developments will require authorization under the Water Environment (Controlled Activities) (Scotland) Regulations 2005 (CAR) for the abstractions, impounding works (weirs and dams) and any other engineering works associated with the scheme, next to the planning permission. Due to the likely adverse impact of hydro schems on the water environment, the applicant will be required to apply for a derogation determination through CAR for exemption from WFD objectives in almost every case.

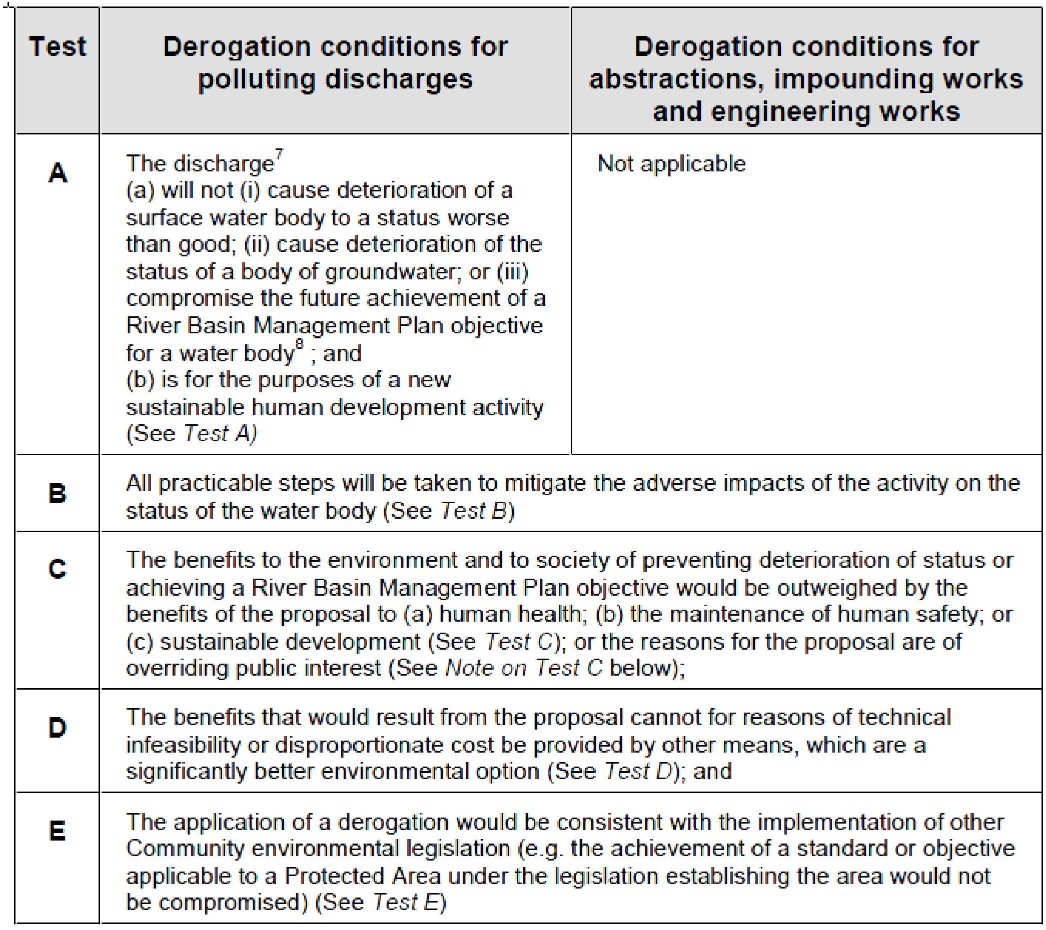
Regulatory Method (WAT-RM-34). Derogation Determination - Adverse Impacts on the Water Environment. October 2009. This document provides information for determining the applicability of a derogation for proposals that would:

- Breach an environmental standard
- Cause deterioration of status or
- Prevent the future achievement of an objective in a River Basin Management Plan.

The process on how this applicability of a derogation for proposals is applied is given in Figure 4.7.

Until the guidance on run-of-river schemes is finalized (SEPA, 2010), SEPA will apply this draft when carrying out its regulatory functions under the Water Environment (Controlled Activities) (Scotland) Regulations 2005. The Water Environment and Water Services (Scotland) Act 2003 is the enabling act for the European Water Framework Directive, which introduced a new integrated approach to the protection, improvement and sustainable use of the water environment. The Water Environment (Controlled Activities) (Scotland) Regulations 2005 (CAR) introduced controls on previously unregulated activities, including water abstractions and impoundments, which is of significant relevance to hydropower developments. http://www.sepa.org.uk/water/hydropower/regulation.aspx

Figure 4.7. Test for determining the applicability of a derogation for proposals (Regulatory Method (WAT-RM-34))



Test	Derogation conditions for polluting discharges	Derogation conditions for abstractions, impounding works and engineering works
A	The discharge[7] (a) will not (i) cause deterioration of a surface water body to a status worse than good; (ii) cause deterioration of the status of a body of groundwater; or (iii) compromise the future achievement of a River Basin Management Plan objective for a water body[8] ; and (b) is for the purposes of a new sustainable human development activity (See *Test A)*	Not applicable
B	All practicable steps will be taken to mitigate the adverse impacts of the activity on the status of the water body (See *Test B*)	
C	The benefits to the environment and to society of preventing deterioration of status or achieving a River Basin Management Plan objective would be outweighed by the benefits of the proposal to (a) human health; (b) the maintenance of human safety; or (c) sustainable development (See *Test C*); or the reasons for the proposal are of overriding public interest (See *Note on Test C* below);	
D	The benefits that would result from the proposal cannot for reasons of technical infeasibility or disproportionate cost be provided by other means, which are a significantly better environmental option (See *Test D*); and	
E	The application of a derogation would be consistent with the implementation of other Community environmental legislation (e.g. the achievement of a standard or objective applicable to a Protected Area under the legislation establishing the area would not be compromised) (See *Test E*)	

Scottish Ministers expect SEPA to manage the individual and cumulative impacts of sub-100 kilowatt schemes. SEPA is expected to do this by ensuring that, in general, no deterioration is permitted unless a scheme delivers particularly significant benefits.

SEPA will continue to assess whether any adverse impacts caused by schemes of 100 kilowatts or more are justifiable in terms of costs and benefits. It will make these assessments on a case-by case basis using the regulatory method (See WAT-RM-34: Derogation Determination - Adverse Impacts on the Water Environment:www.sepa.org.uk/water/water_regulation/guidance/all_regimes.aspx) it has developed for such purposes.

One part of the consultation is on the mitigation SEPA considers likely to be practicable to include in run-of-river hydropower scheme developments.

After the consultation process, a final draft document has been produced end of November 2010 (SEPA, 2010b). The final document is expected to be published early 2011. The final draft document included the tiered approach as given in Figure 4.8.

Figure 4.8. Tiered approach to the regulation of proposed hydropower scheme developments as given in SEPA (2010b).

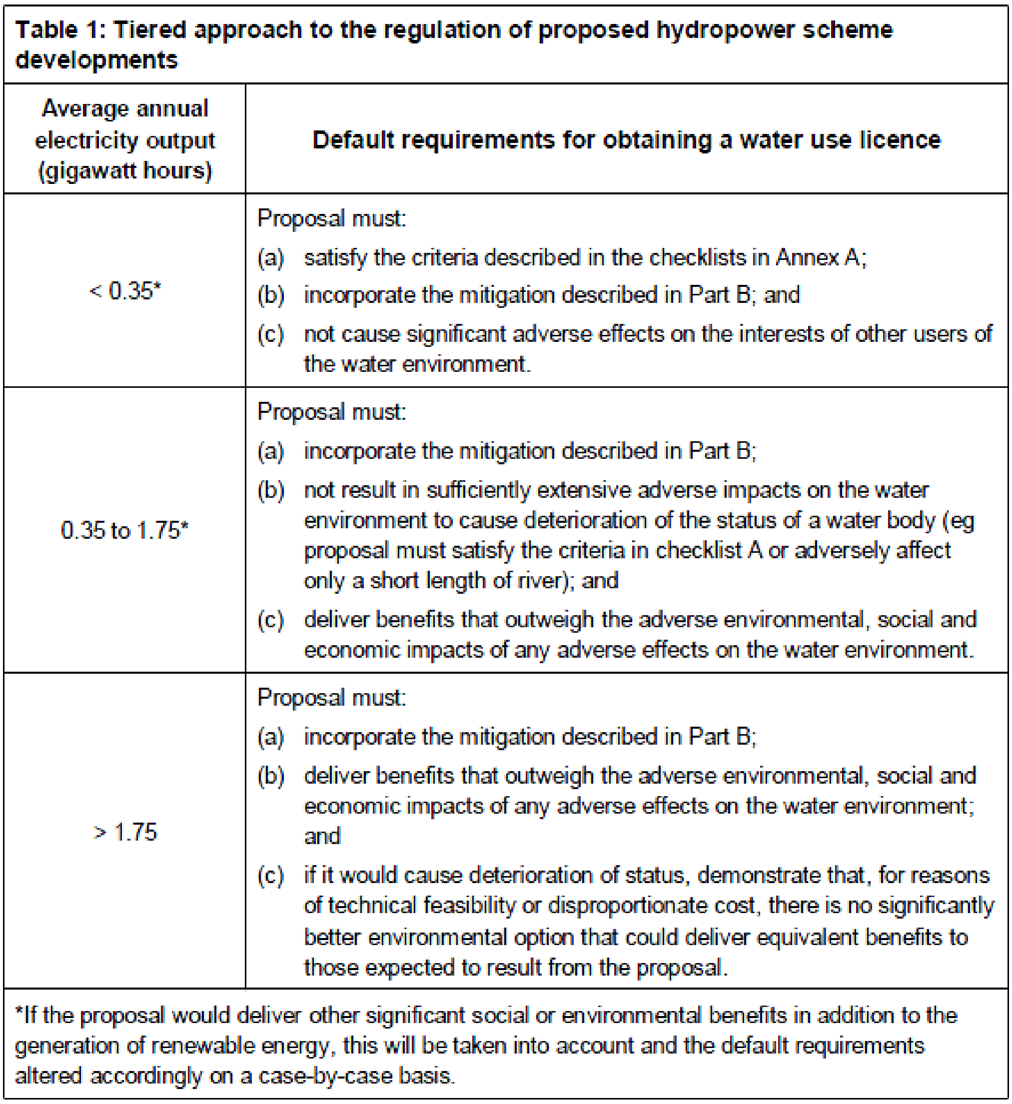


Table 1: Tiered approach to the regulation of proposed hydropower scheme developments

Average annual electricity output (gigawatt hours)	**Default requirements for obtaining a water use licence**
< 0.35*	Proposal must: (a) satisfy the criteria described in the checklists in Annex A; (b) incorporate the mitigation described in Part B; and (c) not cause significant adverse effects on the interests of other users of the water environment.
0.35 to 1.75*	Proposal must: (a) incorporate the mitigation described in Part B; (b) not result in sufficiently extensive adverse impacts on the water environment to cause deterioration of the status of a water body (eg proposal must satisfy the criteria in checklist A or adversely affect only a short length of river); and (c) deliver benefits that outweigh the adverse environmental, social and economic impacts of any adverse effects on the water environment.
> 1.75	Proposal must: (a) incorporate the mitigation described in Part B; (b) deliver benefits that outweigh the adverse environmental, social and economic impacts of any adverse effects on the water environment; and (c) if it would cause deterioration of status, demonstrate that, for reasons of technical feasibility or disproportionate cost, there is no significantly better environmental option that could deliver equivalent benefits to those expected to result from the proposal.

*If the proposal would deliver other significant social or environmental benefits in addition to the generation of renewable energy, this will be taken into account and the default requirements altered accordingly on a case-by-case basis.

This balancing determination will be in line with the policy statement issued by the Scottish Government in January 2010. The Scottish Government has on January 21, 2010 published a policy statement outlining its support for hydro projects The policy statements key parts relevant to this study are given below:

Policy statement – Scottish Government – January 2010 on hydropower development:

BALANCING THE BENEFITS OF RENEWABLES GENERATION AND PROTECTION OF THE WATER ENVIRONMENT

…..

Larger schemes with a generation capacity of 100 kW or more are considered to make an important contribution to renewables targets, and Ministers accept that in supporting such schemes some deterioration of the water environment may be necessary. However any deterioration must be justifiable in terms of costs and benefits, and therefore considerations such as wider social or economic benefits, or impacts on other users of the water environment, will continue to be important factors in the decision-making process.

Small schemes with a generating capacity of less than 100 kW may provide local economic benefits and, where they can be shown to have no adverse impact on the water environment, such schemes will be welcomed. At this scale of development, particular attention will need to be given to managing both individual and cumulative impacts. Generally no deterioration will be permitted, unless the proposed scheme delivers particularly significant benefits. SEPA will be developing guidance to facilitate the appropriate siting and authorisation of sub 100 kW schemes which will be available in Spring.

…..

Full text available here:

http://www.scotland.gov.uk/Topics/Business-Industry/Energy/Energy-sources/19185/17851-1/HydroPolicy

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Scottish Hydropower Resource Sttudy Final Report August 26th 2008. Study commissioned by the Scottish Government through the Hydro Sub Group of the Forum for Renewable Energy Development in Scotland (FHSG) during the first half of 2008. The study was was completed by a consortium of partners from the Scottish Institute of Sustainable Technology (SISTech), Nick Forrest Associates and Black & Veatch Ltd.

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4.3.8 Switzerland

Is strategic planning taking place? At river basin level or MS level?

No strategic planning approach, the main ideas in the Strategie Wasserkraftnutzung Schweitz (2008) seem to be expanding hydropower in Switzerland. This document was produced by the Federal Energy Dept and covers the whole Switzerland. The goals of the strategy are:

- Sustainable development of hydropower (new structures & modernization and upgrading of plants)
- Optimal positioning of Swiss hydropower in the context of the European competion

If pre-planning mechanisms are applied for the allocation of suitable and non-suitable areas

From the Questionnaires in the Alpine Convention Report (Alpine Convention Report, Annex 1, National Data Templates (2010), diverse institutions are working on the development of new decision-making aids such as a classification system of river stretches, inventory of hydropower potential or recommendations for assessment criteria. The federal energy and environmental administrations are developing a guidance document for cantonal strategies on small hydropower

This guidance document was not found (intended to be published in autumn 2010). The guidance document under preparation by the federal administrations will correspond to a statement of will at national level aiming to guide the competent authorities in the development of cantonal/regional strategies of how to deal with small hydropower. At cantonal level, the situation is different from Canton to Canton: in some Cantons (eg Fribourg, Berne) the developed strategies are binding for the administrations. In other cases the strategies may have only the status of “statements of will”

If this designation is based on a dialogue between different competent authorities, stakeholders and NGOS

No indication in Strategie Wasserkraftnutzung Schweitz (2008).

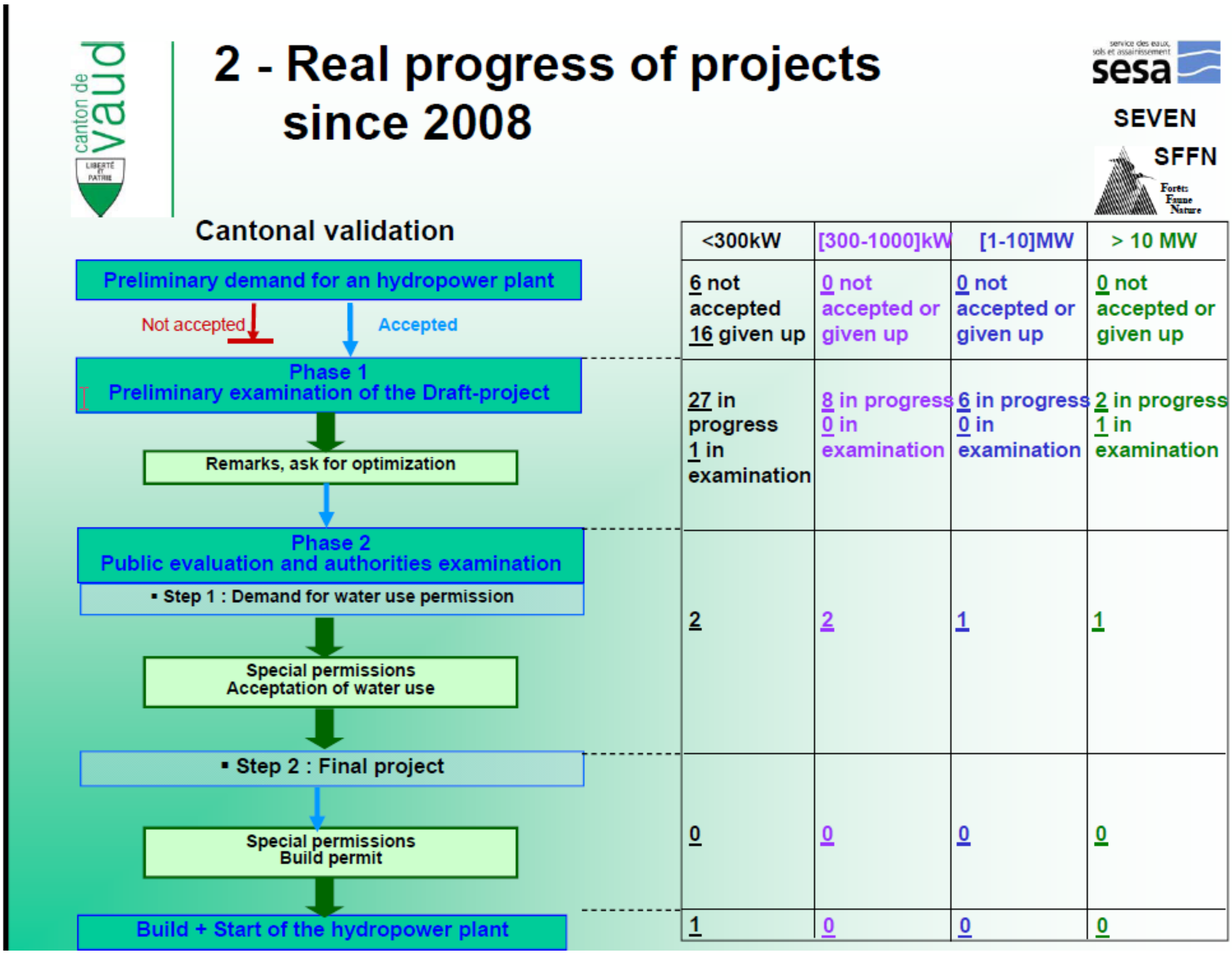
If other elements of strategic planning are applied eg prior agreement of a catalogue of criteria which informs the judgment on the right balance between the benefits of the hydropower facility and the benefits of protecting the aquatic environment

Economic incentives such as Naturemade labeling scheme are implemented: certification of electricity with labels that get a higher price on the electricity market under the condition that granting the label is based on ecological criteria

The Federal Water Protection Act (GSchG) as swiss equivalent to the EU-WFD, has implications on hydropower: GSchG also lays down planning obligations and fixed deadlines for achieving specific goals. The procedure for granting concessions is laid down in the Federal Hydropower act. Finally, national or provincial levels have in addition their specific nature legislation protection laws in place which in case require to be taken into account as well

On the HydroEnergia Conference (2010), an example is given on the Vaud Canton (Figure 4.9). Looking at the figures of hydropower projects either not accepted or given up at a first stage of the cantonal validation seems to be rather high. For this process, at a case-by-case basis, the analysed requirements are looked at in terms of hydrology, hydraulic and civil engineering, environment, electromechanical equipments, energy production and historical value and the objectives of the authorities is to make optimal use of the hydraulic resources while ensuring public security, minimizing the environmental (water fauna and flora, ecology) impacts, keeping a well landscape integration, with the guarantee of economic profitability.

Figure 4.9: Vaud Canton validation of SHP projects



canton de vaud

2 - Real progress of projects since 2008

sesa

SEVEN

SFFN

Cantonal validation

Preliminary demand for an hydropower plant

Not accepted

Accepted

Phase 1
Preliminary examination of the Draft-project

Remarks, ask for optimization

Phase 2
Public evaluation and authorities examination

- Step 1 : Demand for water use permission

Special permissions
Acceptation of water use

- Step 2 : Final project

Special permissions
Build permit

Build + Start of the hydropower plant

<300kW	[300-1000]kW	[1-10]MW	> 10 MW
6 not accepted 16 given up	0 not accepted or given up	0 not accepted or given up	0 not accepted or given up
27 in progress 1 in examination	8 in progress 0 in examination	6 in progress 0 in examination	2 in progress 1 in examination
2	2	1	1
0	0	0	0
1	0	0	0

References included in review on strategic approaches for Switzerland:

Alpine Convention, Annex 1, National Data Templates (2010). ALPINE CONVENTION PLATFORM WATER MANAGEMENT IN THE ALPS. Situation Report. Hydropower Generation in the Alpine Region focusing on Small Hydropower. ANNEX 1. DATA TEMPLATES FROM ALPINE COUNTRIES.

Hydroenergia (2010). 16-17 June 2010, Lausanne, Switzerland. Small hydropower in Vaud Canton: between potential and development of a project - Stéphanie André & Philippe Hohl, Service des eaux, sols et assainissement; Norbert Tissot, Service de l'environnement et de l'énergie; Paul Külling, Service des forêts, de la faune et de la nature, Canton de Vaud, Switzerland

Strategie Wasserkraftnutzung Schweiz (2008). BFE März 2008. Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK. Bundesamt für Energie BFE. Abteilung Energiewirtschaft.

4.3.9 Other countries considered with relevant hydropower production and potential but not part of the scope of this study

For **Italy**, some information is available. From the Alpine Convention, Annex 1, Good Practice examples, the following information is available in relation to Territorial Plan for the Provincial Coordination; water balance plan of the Province of Sondrio:

The adopted method is based on a multi-criteria evaluation aimed to exclude or limit new concessions in those parts of the basin where there is a significant risk to deteriorate the actual water quality status or not to reach the good ecological status on the terms foreseen by the 2000/60/EC directive. The aggregation approach used for the implementation of the multi-criteria procedure was the overlapping of five different maps, where any of these maps represented the risk of not reaching the good ecological status due to a single critical aspect. In those part of the basin where at least one of the critical aspect was characterized by an high risk rate the water concessions were excluded, while in the areas characterized by a medium or a low risk rate the water concessions were allowed but only if not deteriorating the ecological status of the stretch.

The method provides a simple evaluation scheme that consists of a "risk map" where the different river stretches colour represent the risk of not reaching the good ecological status by 2015.

The five indexes used to identify the different river stretches criticalities are listed below:

a) An index representing the impact of the cumulated withdrawals with respect to the mean annual natural discharge;

b) An index representing the impact of the cumulated withdrawals with respect to the mean annual low flow considering the human activities impact;

c) An index representing the interruption risk in the river regime due to the presence of discharges from reservoirs;

d) An index representing the LIM pollution risk in the “mean annual low flows considering the human activities impact” scenario;

e) The FFI (Fluvial Functioning Index), for the connectivity and the ecological functionality.

Results from this method have been integrated into the Territorial Plan for the Provincial Coordination and have also updated the Water Quality Protection Plans at regional lavel and the Transitional plan for the Hydrogeological Settlement (PAI) on the parts regarding the concession

Further information can be found on: http://www.provincia.so.it/territorio/piano%20territoriale/default.asp

From the SMARTHYDRO Project, the following information is obtained: Italy – Environmental Consolidation Act N° 152 of 2006 that implements the Water Framework Directive and deals with qualitative and quantitative protection of water, as well as the protection of aquatic ecosystems: the “Protection Plan” is adopted as a planning tool, and confirms the ublic nature of waters. Moreover, the environmental code amends the Royal Decree 1175/33 (regulating public water use) and is bound both to the need to guarantee the quantitative balance, and the need to achieve quality standards, according to what has been planned for the catchment basin. Therefore, the grant of concessions shall take planning into account, that is why water withdrawals are granted provided that:

- They do not endanger the maintenance or the achievement of the quality objectives established for the concerned waterway;
- The reserved flow and water balance are guaranteed
- The reuse of purified sewage water or rainwater is not possible.

Basin planning, of which the Basin Authority is in charge, is corroborated by the regional detailed planning through the Water Protection Plan (WPP) under regional competence. The WPP is a programmatic document that should contain the regional programmatic directions on pressure limitation, water saving, aquatic ecosystems safeguard.

Portugal has a significant hydropower potential, but impact of climate change will certainly have an effect on this.In terms of applied planning approach a lack of information exist. From the RES Technology Roadmap, information is available that Portugal anticipate upgrading capacity investments for existing hydropower plants, in order to reach the 5,575 MW target of installed hydropower capacity by 2010 (575 MW more than expected in previous energy policies). For 2020 the target is higher than 6960 MW following the recently granted projects included in the National Plan for Dams with High Hydroelectric Potential PNBEPH (National Plan for Dams with High Hydroelectrical Potential).

For **Sweden,** as was previously mentioned in terms of hydropower potential figures, 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).

No further information (in English) was found than this summarized in the dissertation of Melin (2010).

For **Spain,** no relevant information has been found (in English) and it was also not part of the scope of this study.

References included for Italy, Spain, Portugal and Sweden :

Alpine Convention, Annex 1,Good Practice Examples (2010). ALPINE CONVENTION PLATFORM WATER MANAGEMENT IN THE ALPS. Common Guidelines for the use of Small Hydropower in the Alpine region

SMARTHydro Project: Small Hydro Power Plants in Europe: Handbook on Administrative Procedures.

Alpine Convention, Annex 1,Good Practice Examples (2010). ALPINE CONVENTION PLATFORM WATER MANAGEMENT IN THE ALPS. Common Guidelines for the use of Small Hydropower in the Alpine region ANNEX 1. GOOD PRACTICE EXAMPLES FOR THE USE OF SMALL HYDROPOWER

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4.4 Conclusions

For some of the countries, strategic approaches have been suggested and have been under public consultation, but the **final plan has not been published yet** (eg Scotland, Austria (Tirol), Norway (regional plans)). For these countries or regions, there is still uncertainty on what will be exactly implemented. For some countries, **suggestions towards strategic planning are made but will be looked at in future** (England & Wales, Switzerland). Only for Norway (Master Plan, Protection Plans), Lithuania and France (SDAGE) evidence has been found of already **implemented strategic approaches** that define **suitable and non-suitable areas** for hydropower development at a national scale. Evidence has also been found of some strategic approaches applied at a **regional basis** (eg Austria, Italy, Switzerland) but it is often difficult to define how they are applied in practical as for some of these cases only limited information was available and further discussion with authorities would be needed to reveal details. Only France had included a strategic approach **as part of its RBMPs** in which case the decision process on what is defined as **mobilizible potential** in a certain river basin is given. Further restrictions due to the WFD are given in Section 4.2 and 3.4.2.

In general, most of the information available is on **environmental restrictions included in the country's or region's licensing system. Licensing will happen on a case-by-case basis, but as for example for England & Wales as well as Scotland,** a more strategic approach for this is suggested to ensure planning authorities and environmental regulators receive good guidance as well as to allow an overall basin-view on hydropower planning. Further on, individual projects will also be looked at as part of the Art 4.7 exemption applies and mitigations needed.

Due to the scope of this review (limited list of countries to be considered as well as documents to be consulted due to language restrictions), the results need to be interpreted with caution. To allow a **complete review of planned and implemented strategic approaches**, relevant authorities and stakeholders would need to be contacted to reveal the diversity of planned strategic approaches on hydropower.

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References used for task 3 are included directly under each of the chapters for MS review of strategic approaches.

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B-1000 Brussels

(1) Consultancy, study and design of buildings, infrastructure, environment and environmental planning. Outsourcing of project staff on site.
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