Assessment, at river basin level, of possible hydropower productivity with reference to objectives and targets set by WFD and RES-e directives.
The promotion of electricity from renewable energy sources is a high Community priority because it contributes to the following objectives:

- environmental protection;
- sustainable development;
- security of energy supply by reducing dependence on energy imports;
- improvement of industrial competitiveness;
- positive impact on regional development and employment.

The European Directive on the promotion of Electricity from Renewable Energy Sources (RES-e) sets a target of 12% of gross inland energy consumption from renewables and a share of 22% for green electricity for the European Union as a whole by 2010.

Furthermore, the decision of the 2007 Spring Council, where Europe’s Heads of States agreed to a binding target of 20% renewable energy by 2020, laid the ground for renewable energy sources to become a major pillar of the EU’s future energy supply. The 20% target is an ambitious but realistic objective!

So the European policy framework for renewable energies gives Member States a reason to look at hydropower, since it shows the best track record of all renewable energy technologies, being a clean and very efficient renewable energy source. During the twentieth century, hydropower gave a key contribution to the development of the electricity sector in Europe and most of the best sites have been exploited for big plants. Nevertheless, an important role in achieving European renewable energy goals can still be played by small hydropower resources, which are distributed on the continent and can offer all the benefits of dispersed renewable generation.
AIM OF THE REPORT
This document looks at European Directives respectively on the promotion of renewable energies (Dir. 2001/77/EC) and on the protection of waters (Dir. 2000/60/EC), taking into account their effects on national and regional legislation, with particular reference to the hydropower sector.

Hydropower deals indeed with both the issues of energy and water and if the two Directives are implemented without taking into account a comprehensive and integrated approach, this can lead to an inconsistent and distorted result.

In May 2001 the EU Water Directors agreed to define a common strategy to achieve a successful implementation of Directive 2000/60/EC (Common Implementation Strategy - CIS) and in November 2005 established an EU Strategic Steering Group (SSG) to address the issue of better integration of policies and to ensure coherence between the implementation of the WFD and other sectoral and structural policies.

At the beginning of 2006 a specific working group on “WFD and hydromorphology” was set up to identify and share good practice approaches in order to manage the adverse impacts of water uses on the hydromorphological characteristics of surface water bodies and to elaborate recommendations on the integration of energy (hydropower), transport and flood management policies with water policy.

The aim of this report is to propose a methodology to assess the possible hydropower productivity, at river basin level, with reference to objectives and targets set by WFD and RES-e directives. At a second stage the two analyses can be compared, in order to highlight where the targets of the 2 directives could be in conflict.

A case study of an Italian river basin (Magra) has been analysed in order to test the applicability of this methodology.

This report is mainly addressed to policy makers at national and regional level, who are in charge of the planning of water and energy resources, and aims to provide them with an overview on the European policy framework for water protection and renewable energies promotion and a tool to better coordinate and integrate these objectives in the local territorial planning actions.
1 THE TWO DIRECTIVES

1.1 THE RES-e DIRECTIVE: PRESENTATION, CONTENTS AND TARGETS, RESULTS

The promotion of electricity from renewable energy sources (RES) is a high European Union (EU) priority for several reasons, including security and diversification of energy supply, environmental protection and social and economic cohesion, and also constitutes an essential part of the package of measures needed to comply with the commitments made by the EU under the Kyoto Protocol on the reduction of greenhouse gas emissions. The RES-e directive aims at a significant increase in the contribution of renewable energy sources to electricity production, including hydropower together with all other renewable energy sources, and at creating a basis for a more comprehensive framework for the development of electricity from renewable energy sources.

The directive follows up the 1997 White Paper on renewable energy sources and sets an overall (EU 25) target of 21% share of renewable electricity in total electricity consumption in the EU by 2010. Member States have set up their own national indicative targets on the basis of the overall EU target, but they are free to implement the most appropriate measures to achieve their target.

In fact, as stated in the preamble of the Directive, “Since the general objectives of the proposed action cannot be sufficiently achieved by the Member States and can therefore, by reason of the scale of the action, be better achieved at Community level, the Community may adopt measures, in accordance with the principle of subsidiarity as set out in Article 5 of the Treaty. Their detailed implementation should, however, be left to the Member States, thus allowing each Member State to choose the regime which corresponds best to its particular situation. In accordance with the principle of proportionality, as set out in that Article, this Directive does not go beyond what is necessary in order to achieve those objectives”.

So the RES-e Directive identifies some general principles and outlines some strategies to lead Member States (MS) towards the achievement of their own national targets:

- **National indicative targets (Article 3):** not later than the 27th of October 2002, and then every five years, MS shall adopt and publish a report setting national indicative targets for future consumption of electricity produced from RES in terms of a percentage of the electricity consumption for the next 10 years. The report shall also outline the measures taken or planned, at national level, to achieve these national indicative targets.

- **Support schemes (Article 4):** MS can issue a support system for renewable energy plants. The need for public support in favour of renewable energy sources is recognized in the Community guidelines
for State aid for environmental protection, which, amongst other options, take account of the need to internalize external costs of electricity generation. MS may adopt different mechanisms of support for renewable energy sources at the national level, including green certificates, investment aid, tax exemptions or reductions, tax refunds and direct price support schemes.

- **Guarantee of Origin (Article 5):** MS have to set up a certification system for the electricity produced from renewable energy sources, in order to facilitate exchanges of RES-e and to increase transparency, while facilitating consumer choice. The guarantees of origin indicate both the renewable energy source from which the electricity is produced, the date and place of production and, in the case of hydroelectric installations, also state the capacity.

- **Administrative procedures (Article 6):** MS are required to review their existing legislative and regulatory frameworks concerning authorisation procedures in order to reduce regulatory and non-regulatory barriers, to rationalise and speed up administrative procedures, to ensure that the rules are transparent and non-discriminatory and to take into account the particular characteristics of the different technologies using renewable energy sources.

- **Access to the grid (Article 7):** MS are required to adopt necessary measures:
  - to ensure the transmission and distribution of RES-e;
  - to provide priority access to the grid system of RES-e;
  - to require transmission system operators (TSO) and distribution system operators (DSO) to set up and publish their standard rules relating to the bearing of costs of technical adaptations, such as grid connections and grid reinforcements, which are necessary in order to integrate new producers feeding electricity produced from RES into the interconnected grid. These rules shall be based on objective, transparent and nondiscriminatory criteria taking particular account of all the costs and benefits associated with the connection of these producers to the grid. Where appropriate, MS may require TSO and DSO to bear, in full or in part, these costs;
  - to ensure that the charging of transmission and distribution fees does not discriminate against electricity from RES, including in particular electricity from renewable energy sources produced in peripheral regions, such as island regions and regions of low population density.

### THE ACHIEVED RESULTS

The Directive 2001/77/EC provides that Member States should publish, for the first time by 27/10/2003 and then every two years, a **report** which includes an analysis of success in meeting the national indicative targets and which indicates to what extent the measures taken are consistent with the national climate change commitment (Article 3). The chart below shows national indicative target set for each Member State and the present progress degree of achievement of these targets (2007).

As you can see, all Member States are still far from their national objective and the Community is still far from the overall objective of 21%. This means that **more efforts have to be made** in relation with the renewable energy promotion.
1.2 THE WFD: PRESENTATION, CONTENTS AND TARGETS, RESULTS

On December 22nd, 2000 the European Water Framework Directive (EU/60/2000, WFD) came into force, thus establishing a framework for Community action in the field of water policy. It establishes an innovative approach for water management based on river basins, the natural geographical and hydrological units, and sets specific deadlines for Member States to protect aquatic ecosystems. The directive addresses inland surface waters, transitional waters, coastal waters, groundwater, water ecosystems and terrestrial ecosystems dependent on water. The Directive also establishes innovative principles for water management, such as public participation in planning and economic approaches, focusing on the increasing demand from citizens and environmental organisations for sustainable water management.

The main purposes of the Directive are (see Article 1):

- to prevent further deterioration, to protect and enhance the status of aquatic ecosystems and associated wetlands;
- to promote sustainable water use;
- to reduce water pollution from priority substances;
- to prevent the deterioration in the status and to progressively reduce pollution of groundwaters;
- to contribute to mitigating the effects of floods and droughts.

The overall target of the WFD is to achieve a good ecological status (GES) of all water bodies, or a good ecological potential (GEP) in case of heavily modified water bodies (HMWB), by 2015.

To achieve this target, the WFD provides a path in different steps:

- first of all, MS have to identify river basin districts and identify the appropriate competent authority;
- after that, they have to carry out a characterization of the river basin, containing an analysis of the environmental impact of human activity and an economic analysis of water use, and implement a register of protected areas.
- then they have to implement programmes for the monitoring of water status in order to establish a coherent and comprehensive overview of water status within each river basin district;
- finally they have to implement programmes of measures to achieve the objectives.

All the elements gathered through these steps must be set out in the River Basin Management Plans (RBMP). This plan is a detailed account of how the objectives set for the river basin are to be reached within the timescale required.
One key component of the RBMPs is the economic analysis, as it allows to select among a range of different possible measures the ones with an higher cost-effectiveness.

The Water Framework Directive sets out clear deadlines for each of the requirements. The key milestones are listed below.

<table>
<thead>
<tr>
<th>Year</th>
<th>Issue</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>Directive entered into force</td>
<td>Art. 25</td>
</tr>
<tr>
<td>2003</td>
<td>Transposition in national legislation</td>
<td>Art. 23</td>
</tr>
<tr>
<td></td>
<td>Identification of River Basin Districts and Authorities</td>
<td>Art. 3</td>
</tr>
<tr>
<td>2004</td>
<td>Characterisation of river basin: pressures, impacts and economic analysis</td>
<td>Art. 5</td>
</tr>
<tr>
<td>2006</td>
<td>Establishment of monitoring network</td>
<td>Art. 8</td>
</tr>
<tr>
<td></td>
<td>Start public consultation (at the latest)</td>
<td>Art. 14</td>
</tr>
<tr>
<td>2008</td>
<td>Present draft river basin management plan</td>
<td>Art. 13</td>
</tr>
<tr>
<td>2009</td>
<td>Finalise river basin management plan including programme of measures</td>
<td>Art. 13 &amp; 11</td>
</tr>
<tr>
<td>2010</td>
<td>Introduce pricing policies</td>
<td>Art. 9</td>
</tr>
<tr>
<td>2012</td>
<td>Make operational programmes of measures</td>
<td>Art. 11</td>
</tr>
<tr>
<td>2015</td>
<td>Meet environmental objectives</td>
<td>Art. 4</td>
</tr>
<tr>
<td></td>
<td>First management cycle ends</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Second river basin management plan &amp; first flood risk management plan.</td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td>Second management cycle ends</td>
<td>Art. 4 &amp; 13</td>
</tr>
<tr>
<td>2027</td>
<td>Third management cycle ends, final deadline for meeting objectives</td>
<td>Art. 4 &amp; 13</td>
</tr>
</tbody>
</table>

THE ACHIEVED RESULTS

In 2007 the EU Commission published a Communication to the European Parliament and the Council entitled “Towards Sustainable Water Management in the European Union - First stage in the implementation of the Water Framework Directive 2000/60/EC” (COM 2007 128-SEC Final 2007, 363), that provides a first overview on progress with implementation of the Directive in each Member State. It comes out that few EU-15 Member States transposed the Water Framework Directive into their national legislation by the required deadline, while most Member States set up river basin districts and designated competent authorities on time. But the key question Member States had to answer, with reference to article 5 analysis, was: “What is the risk of failing to meet WFD environmental objectives based on current data?”. The result of the risk assessment shows in many countries high percentages of water bodies identified as "at risk of failing to meet the WFD objectives by 2015". In addition, a high proportion of surface water bodies have been provisionally identified as Heavily Modified Water Bodies (HMWB) and to a less extent as Artificial Water Bodies (AWB).

This analysis shows that some significant step forward have been made, but a there is still a long and challenging road ahead for Member States.

Figure 1: Percentage of surface water bodies at risk of failing WFD objectives per Member State - 'x' = 'at risk', '=' = 'insufficient data', 'o' = 'not at risk' (based on Member States' reports)
1.3 CONTRADICTIONS BETWEEN RES-e AND WFD DIRECTIVES

Both the Water Framework Directive (WFD) and the RES-electricity Directive have some impacts on the further development of Small Hydropower and, at a first glance, there might be a risk of conflict between the implementation of these different policies.

These impacts are closely related to the main targets of the mentioned Directives:

- **the RES-e Directive** aims at a significant increase of renewable energy production, including hydropower together with all the other renewable energy sources. The European as well as the national targets are precisely defined and to be reached at a certain deadline.

- **the WFD** aims at a good ecological status (GES) of all water bodies and at a good ecological potential (GEP) in case of heavily modified water bodies (HMWB). To reach these targets there are two general and simple obligations:
  - any decrease of ecological quality is strictly forbidden;
  - any efforts have to be done to increase ecological quality.

The WFD is an environmental directive, focusing on water quality, and puts a strong emphasis on the hydro-morphological conditions, as they support the type-specific aquatic communities that constitute good ecological status.

The past developments of hydropower generation, navigation infrastructures and activities, and flood defence facilities have often required major hydro-morphological changes.

However, whilst impacting on aquatic ecosystems, such activities can also deliver important *environmental benefits* (e.g. reducing the impacts of climate change) or *socio-economic benefits* (human safety, employments).

In principle, the use of water to gain energy is not ruled out by the WFD. However, depending on the strictness of its interpretation, the SHP sector can be potentially affected by the WFD.
By nature, the construction of SHP plants has some impacts on the water body. Nevertheless, the final decrease in ecological quality of the river depends on the different measures to mitigate environmental impacts that have been applied during the construction and operation of the plant.

The crucial question is how to reach a balance and equilibrated solution between the characteristics of the plant and the ecological quality in the most economically and technologically feasible way. Moreover, an increase of ecological quality combined with new hydropower exploitation is possible (in theory) only if ecological deficiencies (flood control, river regulation etc.) exist in the previous situation.

Implementing the necessary measures to increase the ecological quality of a river will lead to:

<table>
<thead>
<tr>
<th>MEASURES IMPLEMENTED</th>
<th>EFFECTS ON SHP PLANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>increase of reserved flow</td>
<td>decrease in energy production</td>
</tr>
<tr>
<td></td>
<td>(up to 15% or more)</td>
</tr>
<tr>
<td>new construction or improvement of existing fish bypass systems</td>
<td>additional investment cost</td>
</tr>
<tr>
<td>reduction of the distance of the trash rack bars</td>
<td>additional operation cost</td>
</tr>
<tr>
<td>installation of fish-friendly turbines</td>
<td>additional investment cost</td>
</tr>
</tbody>
</table>

The strict implementation of the WFD will therefore cause a remarkable reduction of SHP production combined with higher investment (new plants) and operation (existing plants) costs and the reduced profitability of SHP will lead to the shutdown of small sites and to the slow down in the development of new plants. In the last decades the SHP sector has become very familiar with ecological concerns and with the preservation of river ecosystems.

Nevertheless, due to the disproportionate economic burden that in many cases the fulfillment of such requirements implies for the SHP, a compromise on how to compensate the financial losses should be envisaged at European level.

Another critical point is the meaning of some key terms within the WFD, such as Good Ecological Status (GES) or Heavily Modified Water Body (HMWB). Depending on their interpretation and application in the river basin management plans, SHP will have to face completely different scenarios. This is why a clear and precise definition of these terms is necessary to make the WFD transposition more clear and predictable.

Finally, it is of significant importance that the contradictions between these two European directives are made obvious to all the policy makers at national and regional level, so that they can adopt the right approach to overcome the possible conflicts.
2.1 HYDROELECTRIC POTENTIAL FROM A RES-e PERSPECTIVE

The aim of this section is to describe a methodology for the assessment of the hydropower potential of a river basin from a RES-e perspective, that allows to calculate the maximum and the realistic hydropower potential available in a river basin.

This evaluation can be approached in different ways and we tried to elaborate a methodology that is scientifically based, but at the same time quite general and split into different steps, so that it can be adapted to different situations.

The methodology we are going to present is then divided in two main parts:

A) physiographic and hydrologic data processing and calculation of the maximum natural potential;

B) calculation of the realistic potential.

In order to apply this methodology to a real water basin, it is necessary to implement a numerical technique coupled with a GIS (Geographical Information System).

A) The maximum natural potential is due mainly to two different elements: the water availability and the physiographic characteristics of the basin itself. This potential is just a theoretical and rough estimation of the overall “vocation” of a basin with regards to HP production.

The water availability, in terms of annual stream discharge duration curve, is obtained through the historical rainfall data sets. The rainfall distribution over each elementary basin is the main parameter to determine the natural flow. Effective natural discharge is obtained using the water rainfall and the runoff coefficient. The multiplication between the rainfall, the basin surface and the runoff coefficient determines the mean river discharge available at the basin closure point.

The evaluation concerning the available geodetic heads is obtained through a geodetic profile of territory (DTM – Digital Terrain Model).

For the calculation of the maximum potential see BOX 1.

B) If we want to know the realistic potential, we have to take into account several restrictions and constraints, such as current water uses, technical problems, economic aspects and environmental requirements.

First of all, it is necessary to evaluate human effects on the water availability. This kind of impact is due to the flow withdrawals determined by different human activities that detract water volumes from the rivers:
• **IRRIGATION:** normally this kind of withdrawal has no restitution, all the volume taken away is used;

• **DRINKABLE WATER:** usually there is a restitution, even if the returned volume is less than the withdrawn volume;

• **INDUSTRY:** generally has a restitution, lower than the withdrawal;

• **POWER GENERATION:** all the water volume drawn for hydroelectric generation purposes is also given back in the river at a downstream section.

As a consequence of these human activities, the water availability is different from the natural flow and can be considered as an “anthropic flow”. Besides water exploitation, there is another constraint that decreases the water available for HP production, which is the application of reserved flow (RF). The role of reserved flow is to prevent excessive river exploitation; consequently every water withdrawal must take into account that the river flow cannot ever be lower than this particular threshold.

We decided to input RF at this level, and to consider it as a “human effect” more than an “environmental constraint”, because reserved flow is nowadays commonly accepted by HP producers as a necessary environmental protection measure and, even if its value can change a lot with reference to local conditions and ecological characteristics of the river, it has a direct and measurable effect on water availability for HP. For the calculation of the anthropic residual potential see BOX 1.

After that, technological, economic and environmental constraints have to be considered. There are no general mathematic formula to evaluate these elements, anyway in the next paragraphs we will try to highlight which are the most important aspects to be considered within their assessment.

**Technological constraints** take into account the technical feasibility of hydropower plants with the current available technology.

During the twentieth century, the exploitation of water power was boosted by continuous technical development. Turbine efficiencies of some 95 to 96 per cent were achieved. As regards generators, the efficiency figures reached 98 to 99 per cent. This implies that only marginal improvements may be expected with respect to efficiency.

In the last decades technical development has been concentrated on the use of new materials and on the exploitation of low heads.

As regards the material sector, tests are being made to introduce new composite materials which, apart from having sufficient strength and durability, can also compete with traditional materials with respect to costs.

Since high head sites are relatively rare, and most of the best ones in the world have already been exploited, the greatest scope for new SHP is at low head sites. Low heads are difficult to exploit economically, as the physical dimension of the turbine increases when the head is reduced. Therefore, heads below 2.5 to 3 m are rarely exploited on the basis of the conventional turbine technique. There are developments underway related to fast running propeller/semi Kaplan turbines with the aim to eliminate the need for gear boxes between turbine and generator and for small units in multiple arrangements, using techniques for variable speed and frequency conversion.

So in general we can say that, even if no revolutionary technical advances have been made during the last few years, refined and targeted technological improvements are reducing these constraints day by day.
Economic constraints take into account the cost of generating electricity and its sustainability on the electricity market. They are frequently related to environmental constraints, as far as their implementation causes additional investment and operational costs and a decrease in energy production. Generation costs (€/kWh) include capital costs, investment costs, Operation and Maintenance (O&M) costs. There are two general rules that are widely valid for the generation costs in an HP plant:
- costs decrease as the size (installed capacity) of the plant increases, since scale factors occur;
- costs for low head plants are higher than costs for high head plants, since low head plants generally operate at higher flow rate and so they need bigger turbines and more civil works, that are the two cost items with higher weight on the financial plan of an HP plant.

Since the electricity market and the incentive system for hydropower are quite different from one Member State to the other, it is not possible to define a general methodology to assess their impact on the HP potential. We can anyway suggest to evaluate these elements: possibility to ask the Electric System Operator for a withdrawal of the electricity at an administrated price, existence of special tariffs for very small plants (P<1MW), existence of special conditions for connecting to the grid (access and costs), existence of a feed-in tariff or green certificate system and their duration.

In fact, as far as the external costs related to the whole process of energy generation from all kinds of sources won’t be considered in the energy price calculation, renewable energies will depend on incentives for their competitiveness on the energy market and their economic sustainability.

Environmental constraints take into account a variety of different environmental requirements that an HP plant has to fulfil for its construction and operation. Some of these are connected with the impacts that an HP plant causes on the river ecosystem and are closely related to the WFD implementation (e.g. reserved flow, fish passes, fish friendly turbines). We will go deeper into this point in paragraph 2.2.

Other requirements are related to the impact that an hydropower plant can cause on the landscape (e.g. aesthetical improvements for powerhouses, interment of penstocks) and on the environment in general (e.g. noise reduction systems, hydraulic-forest arrangements).

An overview of the mitigation/restoration measures available to reduce these impacts and of the costs related to their implementation can be found in two other SHERPA publications:
- “Hydropower and environment: technical and operational procedures to better integrate SHP plants in the environment”;
- “Economic analysis of environmental mitigation activities and equipment for SHP”.

Up to now, we considered only factors that determine a decrease of the potential. On the opposite side, a contribution to the increase of the residual hydropower potential can be obtained through the upgrading and improving of the oldest existing plants (replacing the existing equipments with more efficient ones) and through recovering existing resources (waterworks and irrigation channels).

In some cases the increase in production obtained through upgrading and re-powering can only compensate the loss of productivity due to the implementation of environmental constraints (e.g. strict regulations as regards reserved minimum flow), but is anyway important to avoid an overall loss of productivity of existing plants.
Summing up, the analysis we propose goes through the calculation of the following parameters:

- "maximum natural potential": that is the SHP production that could theoretically be developed given the water resource availability;

- "anthropic residual potential": that is the SHP production that could theoretically be developed taking into account human effects on the water availability (irrigation, industrial and potable use, MIF "Minimum Instream Flow");

- "residual technical potential": that is the SHP production that could theoretically be developed given the current available technology;

- "residual economic potential": that is the SHP production that could theoretically be developed taking into account economic constraints;

- "realistic potential": that is the SHP production that could theoretically be developed taking into account existing environmental constraints.

As far as all these steps have been run through, one should be able to evaluate how much all these constraints affect the maximum natural potential calculated at point A) and to find out the figure (kW or kWh) that represents the realistic potential. The use of a GIS allows to evaluate not only the amount of the potential, but also the localisation within the river basin of the sites where this potential is in fact available.
This box explains in detail the methodology to calculate the maximum natural potential and the anthropic residual potential. We can obtain water availability taking into account the infl ow to, outflow from and storage within each elementary hydrologic units (sub-basin). The mean river discharge available at a basin closure point is obtained from the multiplication between the annual mean rainfall \((p)\), the basin surface \((A)\) and the rainfall-runoff coefficient \((c)\)

\[
Q = p \cdot c \cdot A
\]

We can define the natural hydrological discharge \((Q_{\text{eva}})\) as the discharge in the closure point of the current basin, taking into consideration the afferent discharge in the basin itself \((Q_{\text{up}})\) and the discharge coming from the upstream basins \((Q_{\text{up}})\);

\[
Q_{\text{eva}} = Q_{\text{up}} + Q_{\text{down}}
\]

We can instead define the anthropic discharge \((Q_{\text{anth}})\) as the discharge in the closure point of current basin taking into account the upstream flow, the human effect on the natural flow \((\text{withdrawal}^{\text{"+q"}}\text{ or restitution}^{\text{"-q"}})\) and the applications of Reserved Flow \((Q_{\text{RF}})\)

\[
Q_{\text{ anth}} = Q_{\text{up}} + Q_{\text{RF}} - \sum Q_{\text{q}} - Q_{\text{RF}}
\]

The extracted energy relative to a particular basin is proportional to the product between the value of the discharge withdrawal and the existing head between the withdrawal elevation and the basin closure section elevation and can be calculated from the formula:

\[
E_r = \eta \cdot g \cdot Q \cdot \Delta H \cdot 8760
\]

where:

- \(E_r\): energy extracted [kWh/year],
- \(x\): cross section,
- \(\eta\): energy efficiency of the system (0.8),
- \(g\): gravity acceleration (9.81 m/s^2),
- \(Q\): discharge withdrawal (m^3/s),
- \(\Delta H\): net head (m) taking account of hydraulic losses in the channel and in the penstock,
- 8760: number of hours considering the total exploitation of available discharge withdrawal during the year.

The Digital Elevation Model (DEM), coupled with GIS tools, allows to obtain the ground elevation pattern and consequently the geodetic head related to a particular “structural length” \((L)\), for any cross section “x” along the river bed.

We can calculate the maximum total annual hydropower production \((E_{\text{max}}, \text{kWh/year})\) related to a considered basin as the sum of energy potential associated with the current single water basin \((E_{\text{own}})\) and the energy potential associated with the upstream flow contributions \((E_{\text{up}})\), using the total theoretically available discharge:

\[
E_{\text{max}} = E_{\text{own}} + E_{\text{up}} = \eta \cdot g \cdot Q_{\text{own}} \cdot (H_{\text{own}} - H_{\text{closure}}) \cdot 8760 + \eta \cdot g \cdot Q_{\text{up}} \cdot (H_{\text{up}} - H_{\text{closure}}) \cdot 8760
\]

where \(H\) indicate the elevation (m asl) and \(H_{\text{own}}\) is the mean elevation of the current water basin, calculated as the integral weighted elevations of the ipsogetic curves.

In this formula, the water basin own energy has been calculated under simplified assumptions. In fact the potential hydropower in a generic point inside of the river basin, with reference to the closure basin section, is equal to:

\[
E_{\text{max}} = \eta \cdot g \cdot Q_{\text{own}} \cdot (H_{\text{own}} - H_{\text{closure}}) \cdot 8760
\]

where \(Q_{\text{own}}\) and \(H_{\text{own}}\) are respectively the own basin discharge \((Q_{\text{own}} = A \cdot p \cdot c_r)\) and the elevation of a generic elementary area \(i\).

The potentiality of the entire water basin is obtained through summation of the contributions of \(N\) elementary areas that compose the river basin itself \(E_{\text{max}} = \eta \cdot g \cdot \sum (Q_{\text{own}}(H_{\text{own}} - H_{\text{closure}})) \cdot 8760\), where the sub-index \(i\) indicates each elementary basin, and varies from 1 to \(N\).

Considering the river basin as a physical entity, one may assume that it has one unique precipitation \((p)\) and rainfall-runoff coefficient \((c)\) value, uniformly distributed between the elementary areas. That means \(p_i = p = \text{constant} \text{ and } c_i = c = \text{constant}\). The above formula is expressed in terms of the medium watershed elevation \((H_{\text{own}})\)

\[
E_{\text{max}} = \eta \cdot g \cdot p \cdot c \cdot A \cdot (H_{\text{own}} - H_{\text{closure}}) = \eta \cdot g \cdot Q_{\text{own}} \cdot (H_{\text{own}} - H_{\text{closure}})
\]

To calculate the anthropic residual hydropower production \((E_{\text{anth}})\), we can simply substitute the natural hydrological discharge \((Q_{\text{own}})\) with the anthropic discharge \((Q_{\text{anth}})\) in the formula above.

The methodology presented can be a quite useful tool to produce maps, at a national or regional scale, which gives a first approach for the identification of interest areas with a residual hydropower potential. These maps may provide the support to administrations, decision makers and stakeholders, to make Energy Master Plans.
2.2 HYDROELECTRIC POTENTIAL FROM A WFD PERSPECTIVE

The aim of this section is to describe a methodology for the assessment of the hydropower potential of a river basin from a WFD perspective, that means the HP potential, in terms of existing plants and new plants, that is compatible with the objective of the WFD.

To address this challenging topic, we decided to go through the WFD step by step, following the path that the Directive has foreseen towards its objectives.

In line with the WFD deadlines, so far Member States should have identified river basin districts and designated competent authorities (art. 3) and should have carried out a characterisation of each river basin district, containing an analysis of its characteristics, a review of the impact of human activity on the status of surface waters and on groundwater and an economic analysis of water use (art. 5).

They should also have established programmes for the monitoring of water status, in order to establish a coherent and comprehensive overview of water status within each river basin district (art. 8).

All this information has to be included in the River Basin Management Plans (RBMP), that should be adopted by 2009, implemented until 2012 and reviewed every six years (art.13).

The RBMPs set the environmental objectives for each water body within the river basin (art. 4) and establish a programme of measures, taking account of the results of the analyses required under Article 5, in order to achieve the objectives established under Article 4. The RBMP also specify the timescale required to achieve these objectives.

In 2005, a WFD risk assessment was carried out all over Europe and emerged that hydromorphological pressures and impacts are one of the most important risks of failing to achieve the WFD objectives in many Member States.

This term summarizes all structural and physical modifications, including river regulation, channeling, damming, regulation of water flow and level, embankments and so on. Three main hydromorphological driving force were identified: hydropower, navigation and flood protection.

In fact, even if hydropower has no direct effect on the chemical quality of water, this technology is unavoidably related to hydromorphological alterations of water bodies.

Key hydromorphological alterations typically associated with hydropower include: impoundment and diversion of the water courses, impact on water balance due to storage effects, retention of bed load, hydropeaking, interruption of biological continuity (upstream and downstream fish migration). Many of these impacts can be mitigated by different measures, but some alterations are so significant that they don’t allow the water body to reach a good ecological status.

It is therefore evident that the Article 4 of the WFD is the heart of this legislation, since it provides the methodology to assess whether the presence of an existing or a new hydropower plant is compatible with the achievement of the environmental objectives.

For surface waters, article 4 provides 2 general principles:

- Member States shall prevent the deterioration of the status of all water bodies
- Member States shall protect and enhance the status of all water bodies

Annex V contains all the parameters that have to be analysed and evaluated to determine the ecological and chemical status of surface water bodies, but it is important to underline that the article 4 provides 2 different kinds of environmental objectives:

- **GOOD ECOLOGICAL STATUS (GES)** for all body of surface water
- **GOOD ECOLOGICAL POTENTIAL (GEP)** for Artificial Water Bodies (AWB) and Heavily Modified Water Bodies (HMWB)

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1 This report has been written in 2008.
Accordingly to the definition provided in art. 2 of the WFD and in the CIS Guidance Document n. 4:\(^2\):
- an **AWB** is a body of surface water created by human activity, in a location where no water body existed before;
- a **HMWB** is a body of surface water which, as a result of physical alterations by human activity, is substantially changed in character and cannot therefore meet the “good ecological status”. In general these hydromorphological changes alter both *morphological* and *hydrological* characteristics of the water body and cannot be removed/restored without impacting on the specific anthropic water use that determined these changes.

Instead of “good ecological status”, the environmental objective for HMWB and for AWB is good ecological potential (GEP), which has to be achieved by 2015.

This designation is not an opportunity to avoid achieving demanding ecological and chemical objectives, since GEP is an ecological objective which may often, in itself, be challenging to achieve.

Moreover, the designation of a water body as a HMWB/AWB and the reasons for it have to be specifically mentioned in the river basin management plans and reviewed every six years.

On the other hand, this designation was created to allow for the continuation of some specific uses which provide valuable social and economic benefits and contribute to protect wider environmental interests.

Article 4 provides some precise conditions that have to be verified in order to designate a water body as a “HMWB/AWB”:

(a) the changes to the hydromorphological characteristics of that body which would be necessary for achieving good ecological status would have significant adverse effects on:
   (i) the wider environment;
   (ii) navigation, including port facilities, or recreation;
   (iii) activities for the purposes of which water is stored, such as drinking-water supply, *power generation* or irrigation;
   (iv) water regulation, flood protection, land drainage, or
   (v) other equally important sustainable human development activities;

(b) the beneficial objectives served by the artificial or modified characteristics of the water body cannot, for reasons of technical feasibility or disproportionate costs, reasonably be achieved by other means, which are a significantly better environmental option.

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Within the CIS activities, a specific Guidance Document (n.4) was elaborated in order to assist experts and policy makers in the identification and designation of the HMWB/AWB. The scheme below is useful for a better understanding of the different steps behind this process.

1. **Water body identification** [Art. 2(10)] (iterative process)
   - Step 2: Is the water body artificial? [Art. 2(8)]
     - no

2. **“Screening”: Are there any changes in hydromorphology?**
   - yes

3. **Description of significant changes in hydromorphology** [Annex II No. 1(4)]
   - no

4. **It is likely that water body will fail good ecological status due to changes in hydromorphology?** [Annex II No. 1(5)]
   - yes

5. **Is the water body substantially changed in character due to physical alterations by human activity?** [Art. 2(9)]
   - yes

6. **Identify provisionally as HMWB** [Art. 5(1) and Annex II No. 1(1)(i)]
   - no

7. **“Designation test 4(3)(a)”: Identify restoration measures necessary to achieve GES. Do these measures have significant adverse effects on the wider environment or the “specified uses”?** [Art. 4(3)(a)]
   - yes

8. **“Designation test 4(3)(b)”: Can the beneficial objectives served by the AWB be achieved by other means, which are a significantly better environmental option, technically feasible and not disproportionately costly?** [Art. 4(3)(b)]
   - no

9. **Designate as HMWB** [Art. 4(3)]

10. **Designate as AWB** [Art. 4(3)]

11. **Establishment of Maximum Ecological Potential. Comparison with closest comparable surface water body** [Annex V No. 1(2)(5)], considering all mitigation measures which do not have a significant adverse effect on the specified uses or the wider environment.

12. **Establishment of GEP. Only slight changes in the biological elements found at MEP, otherwise measures have to be taken to ensure GEP is achieved.** [Art. 4(1)(a)(iii) and Annex V No. 1(2)(5)].
Now, after an overview of the main elements of the WFD that are essential for our assessment, we can start our evaluation process. As for the assessment from the RES-e perspective (par. 2.1), we will split it into steps.

1) From the activity of characterisation of each river basin district (art. 5), we should be able to identify the different water bodies within river basin we selected for our assessment. First of all, we have to establish for each water body if it is a HMWB/AWB or not, applying the scheme above.

2) After that, we can define the corresponding environmental objective for each water body (GEP for HMWB/AWB and GES for all the others) and we can verify if the present status of the water body corresponds to its objective or not.

3) At this stage we should have 4 different situations and for each of them different actions should be taken:
   
   A - the water body is a Natural Water Body and is in a GES → we have to preserve and protect this status and prevent deterioration;
   
   B - the water body is a Natural Water Body, but is not in a GES → we have to enhance the status and restore the water body, implementing the necessary measure to get the GES;
   
   C - the water body is a HMWB and is in a GEP → we have to preserve and protect this status and prevent deterioration;
   
   D - the water body is a HMWB, but is not in a GEP → we have to enhance the status, implementing the necessary measure to get to GEP.

Given these conditions, it seems that HP could not have any further room for developing within the implementation of the WFD.

But even if the WFD is an ambitious piece of environmental legislation, requiring reconsideration in the way certain users operate, we want to point out that the mechanism for setting environmental objectives in the River Basin Management Plans provides also flexibility.

In fact article 4 provides three different "exemptions" to the general principles that we have seen at the beginning of this section:
EXTENSION OF DEADLINES (art 4.4)

The deadlines established under paragraph 1 may be extended for the purposes of phased achievement of the objectives for bodies of water, provided that no further deterioration occurs in the status of the affected body of water when all of the following conditions are met:

(a) Member States determine that all necessary improvements in the status of bodies of water cannot reasonably be achieved within the timescales set out in that paragraph for at least one of the following reasons:
   (i) the scale of improvements required can only be achieved in phases exceeding the timescale, for reasons of technical feasibility;
   (ii) completing the improvements within the timescale would be disproportionately expensive;
   (iii) natural conditions do not allow timely improvement in the status of the body of water.
(b) Extension of the deadline, and the reasons for it, are specifically set out and explained in the river basin management plan required under Article 13.
(c) Extensions shall be limited to a maximum of two further updates of the river basin management plan except in cases where the natural conditions are such that the objectives cannot be achieved within this period.
(d) A summary of the measures required under Article 11 which are envisaged as necessary to bring the bodies of water progressively to the required status by the extended deadline, the reasons for any significant delay in making these measures operational, and the expected timetable for their implementation are set out in the river basin management plan. A review of the implementation of these measures and a summary of any additional measures shall be included in updates of the river basin management plan.

LESS STRINGENT ENVIRONMENTAL OBJECTIVES (art 4.5)

Member States may aim to achieve less stringent environmental objectives than those required under paragraph 1 for specific bodies of water when they are so affected by human activity, as determined in accordance with Article 5(1), or their natural condition is such that the achievement of these objectives would be infeasible or disproportionately expensive, and all the following conditions are met:

(a) the environmental and socioeconomic needs served by such human activity cannot be achieved by other means, which are a significantly better environmental option not entailing disproportionate costs;
(b) Member States ensure
   - for surface water, the highest ecological and chemical status possible is achieved, given impacts that could not reasonably have been avoided due to the nature of the human activity or pollution,
   - for groundwater, the least possible changes to good groundwater status, given impacts that could not reasonably have been avoided due to the nature of the human activity or pollution;
(c) no further deterioration occurs in the status of the affected body of water;
(d) the establishment of less stringent environmental objectives, and the reasons for it, are specifically mentioned in the river basin management plan required under Article 13 and those objectives are reviewed every six years.

FAILURE TO ACHIEVE THE OBJECTIVE OR PREVENT DETERIORATION (art 4.7)

Member States will not be in breach of this Directive when:

- failure to achieve good groundwater status, good ecological status or, where relevant, good ecological potential or to prevent deterioration in the status of a body of surface water or groundwater is the result of new modifications to the physical characteristics of a surface water body or alterations to the level of bodies of groundwater, or
- failure to prevent deterioration from high status to good status of a body of surface water is the result of new sustainable human development activities and all the following conditions are met:
  (a) all practicable steps are taken to mitigate the adverse impact on the status of the body of water;
  (b) the reasons for those modifications or alterations are specifically set out and explained in the river basin management plan required under Article 13 and the objectives are reviewed every six years;
  (c) the reasons for those modifications or alterations are of overriding public interest and/or the benefits to the environment and to society of achieving the objectives set out in paragraph 1 are outweighed by the benefits of the new modifications or alterations to human health, to the maintenance of human safety or to sustainable development, and
  (d) the beneficial objectives served by those modifications or alterations of the water body cannot for reasons of technical feasibility or disproportionate cost be achieved by other means, which are a significantly better environmental option.
Once we have defined the necessary actions to maintain or achieve the specific objective for each water body, we can verify if it is possible to apply one of the “exemptions”.

We can consider 2 different approaches for existing plants and new plants.

**existing plants**: 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’ (GES). Where restoration is not possible (HMWB), mitigation measures should be implemented with the aim to meet ‘good ecological potential’ (GEP). In both cases, it is possible to consider an extension in deadlines (art. 4.4) or to set a less stringent environmental objective (art. 4.5) whether the necessary measures are technically unfeasible or disproportionately expensive to implement within the WFD deadlines or, in general, for the particular water body characteristics and uses.

**new plants**: actions should first be considered to prevent deterioration of the present status of the water body. Where this is not possible, mitigation measures should be applied. If the setting-up of a new hydropower plant doesn’t allow to achieve the objective (GES or GEP) or to prevent deterioration, this plant is compatible with the WFD only if it complies with the art. 4.7 test. There is relatively little experience across Member States with the use of this test. Exchange of experience is needed to develop a transparent approach.

At this point we should have all the necessary elements to evaluate if the maintaining of existing HP plants and the setting-up of new HP plants within a certain water body are compatible with the WFD requirements and in which cases “exemptions” to the WFD objectives could be accepted.

Obviously, we should apply this methodology to each water body within our river basin, considering that some impacts or measures can produce effects to a larger scale that the one of the single water body.

**2.3 COMPARISON OF THE 2 ANALYSES**

If we put on a map the results of the assessment made from a RES-e perspective and the one from a WFD perspective, we should be able to compare the 2 outcomes. For example we can select one of the sites where the RES-e assessment indicated the availability of a good residual HP potential and verify if the characteristics of the water body (HMWB or not) and the ecological status are compatible with the setting-up of a new HP plant. Otherwise we can evaluate if an existing HP plant should be decommissioned (for example with the removal of a dam) to allow the water body to achieve the good ecological status or if the implementation of some mitigation measures (increase of reserved flow, realisation of fish passes) allows to maintain it.
In any case, we want to point out some crucial issues that can influence and affect the results of this comprehensive assessment, mainly with reference to the implementation of the WFD. These elements can be critical because they are not well defined within the legislation, because they are sometimes underestimated or because the scientific knowledge about them needs more improvements. So our general advice is to consider them with particular attention.

**DESIGNATION OF A HMWB**

There is a continuous and heated debate among HP producers and environmentalists to assess if a SHP plant heavily modifies a water body, i.e. if it significantly changes the hydromorphological characteristic of that body. In fact hydromorphological alterations consist of hydrological and morphological alterations and both these impacts should be present to designate a water body as a HMWB.

In principle, any hydrological alteration must result in a morphological alteration, because hydrology (discharge regime) is the driving force of morphology. But in our opinion, most parts of SHP plants don’t affect significantly the hydrology of a water body as far as they don’t have storage basins that allow the transfer of water volumes in space and time. On the other hand, the morphology of the river is changed because of the water abstraction and the reduction in velocity, wetted perimeter and bed load transport. So it is not clear if these morphological alterations are enough to state that the water body is heavily modified.

In the first months after the issuing of the WFD, HP producers were quite worried about the overall impact of the Directive on the development of the sector; after some years of experience, and also thanks to the activity of the working group on WFD and hydromorphology set up within the CIS of WFD, HP producers believe that there is not a general rule and that it is important to consider the whole water body and not only every single HP site.

Indeed, hydropower is not the only anthropic activity that has an impact on river hydromorphology and there could be the case of 2 existing HP plants that don’t affect “significantly” the hydromorphological characteristics of the river; but, if another HP plant or another diversion (e.g. for irrigation purposes) is set up between the existing two plants, then the overall impact can go over a certain threshold and becomes “significant”.

We also have to consider that the designation of a river as an HMWB could produce positive effects for the existing HP plants (objective is GEP instead of GES), but at the same time negative effects for the future development of the sector, because it will become very difficult to set up new plants on natural river bodies. On the other hand, if the river body is not designated as an HMWB, the implementation of the environmental measures necessary to achieve and preserve the GES will be more burdensome for existing HP plants than for new HP plants, because the last ones can be designed with the new available techniques.

Anyway, it is important to underline that the identification and designation of HMWB is not a “one off” process and that the WFD provides for the flexibility to modify designations to take account of changes over time in environmental, social and economic circumstances.

**INDIVIDUATION OF A SIGNIFICANTLY BETTER ENVIRONMENTAL OPTION**

Obviously there are many other means to produce energy, but the amount of energy produced by existing and expected HP plants can’t be easily replaced by other sources in a better economic and environmental way at the same time. In fact, the same amount of energy could be produced from photovoltaic, but with (so far) disproportionate costs, or, on the other hand, could be produced by gas, oil or coal fired plants, with a clearly worse effect on the environment.

To evaluate the environmental impact of different energy technologies, there are different indicators that can be used.
Hydropower gives no contribution to greenhouse gas, dust particles and acidification substances emissions, while impacts on landscape and noise can be minimized through the implementation of mitigation measures.

According to a study entitled “Electricity Costs externalities: a LCA Approach”, carried out by APPA (Spanish Association of Renewable Energy Producers), SHP is the technology with least environmental impacts among the ones studied (lignite, Coal, Fuel-oil, Natural Gas, Nuclear, Wind, Small Hydro).

As comes out from this study:
- the overall environmental impact of conventional energies is 31 times higher than the one of renewable energy sources;
- to produce 1 kWh of electricity with the best renewable system (small hydro) has an environmental impact 250 times lower in relation with the one generated with coal or petroleum, 125 times lower in relation with the one produced with uranium and 50 times lower than the one generated with natural gas.

Also if we consider the energy payback ratio (ratio of energy produced by a plant during normal life span divided by the energy required to build, maintain and fuel the generation equipment) of different energy technologies, we will find out that HP has one of the best energy balance of all other technologies, mainly due to the high performance of hydraulic units in terms of efficiency (often close to 90%).

So, when evaluating whether there is or not a “significantly better environmental option”, we have to keep in mind all of these elements.

→ DEFINITION OF ECOLOGICAL STATUS OF A RIVER BODY

As described in Annex V, to define the ecological status of a surface river body, there are 3 different kinds of elements that should be analysed:

- **biological elements** (aquatic flora, benthic invertebrate fauna, fish fauna);
- **chemical and physico-chemical elements** supporting the biological elements (thermal conditions, oxygenation conditions, salinity, acidification status, nutrient conditions, pollutants);
- **hydromorphological elements** supporting the biological elements (hydrological regime, river continuity, morphological conditions).

In fact chemical and biotic monitoring (like IBIs – Indices of Biotic Integrity) alone cannot deliver the complete information necessary for the set-up of RBMP and physical habitat simulation models, like classical PHABSIM or HABITAT, already support the abiotic issue.

However, these models have been developed for applications on the local scale. Upscaling of these models and tools to use them at a river basin scale, as requested by the WFD, is consequently a major task the ecohydraulics research community faces today.

In many cases, current knowledge is insufficient to assess or model precisely the impacts of hydromorphological alterations on the biological quality elements and the same consideration applies to mitigation measures involving physical modifications.

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2. If a system has a low payback ratio, it means that much energy is required to maintain it and this energy is likely to produce major environmental impacts.
CASE STUDY: MAGRA RIVER BASIN

PREMISE
A preliminary remark has to be done with reference to this section. As comes out from the Commission report on progress with implementation of the WFD (see Par. 1.2), at present Italy is greatly delayed in its fulfilment of most of the WFD requirements. This is why, so far, our country has been condemned 2 times by the European Court: the first time in January 2006 (case C-85/05), for failure to transpose the Directive within the prescribed period, and the second time in December 2007 (case C-85/07), for failure to fulfil obligations under article 5.1 and article 15.2 of the Directive.
Despite our disappointment for this, we decided anyway to test this methodology within Magra River Basin, because the river basin authority has issued a specific plan for the protection of river bodies affected by diversions, even if it is not possible at the moment to use exactly the WFD requirements as a parameter for this assessment.

DESCRIPTION OF THE AREA
The Magra river basin includes the Magra River and its tributaries and extends over an area of about 1,700 km². From an administrative point of view, the area is divided between 2 Regional administrations, Liguria (714.6 km²) and Tuscany (983.9 km²), but up to 4 provincial administrations and 46 municipalities rule over it. The population amounts to approx 153,000 inhabitants. The river basin can also be divided
into 3 distinct physiographic and socio-economic areas: the Vara valley, the lower portion of Magra valley and upper portion of Magra Valley (Lunigiana).
The study was focused on a sub-basin of Magra river (Lunigiana), that is wholly enclosed within Massa Carrara Province. The reason for this choice is that it allows to compare energy policy targets, which are related to administrative boundaries of Regions and Provinces, with water protection objectives, that are connected to a specific river body.

WATER RESOURCES AND ENERGY RESOURCES PLANNING

River Basin Authorities were instituted in 1989 and they were given the responsibility of water basin planning and water resources management. In the last decade, the national government delegated to regional and provincial administrations the competence for planning and managing both energy resources and water resources. As far as hydropower is concerned, this means that 3 different administrations, with different tasks and boundaries, rule over the same territory: a Region (Tuscany), a Province (Massa Carrara) and a River Basin Authority (Magra River Basin Authority). In the following paragraphs the specific situation of Magra river basin will be described.

Magra River Basin Authority

A specific “Protection plan for rivers affected by diversions” was issued in 2001. The objective of the plan is to protect the river ecosystem and to promote a rational water use, also trying to find a point of balance with the demand of water for irrigation and hydropower. The plan is so focused on the definition of criteria and environmental requirements for issuing new hydropower licenses and for the renewal of existing ones, with the purposes to limit their uncontrolled growth and to avoid unsustainable effects on river environment, allowing only hydropower plants that fulfil all the requirements of the plan itself. The search for a compromise between ecological requirements and production needs led to the definition of 4 rules:

1) identification of no-go areas: some river stretches with a high ecological value need to be maintained in natural conditions, so they are not available for new diversions (see map below);
2) control of diversion “density”: upstream and downstream an existing diversion, a river stretch with a length proportioned to the diversion stretch should be left unexploited, in order to allow the recovery of the river ecological functionality (see map below); since the plan provides flexibility, another license can
be issued downstream an existing one whether a significant hydrological contribution derives from the mountainside and tributaries downstream the first intake, but in this case reserved flow for the new plant is increased by a factor related to the length of the two diversions.

3) release of Reserved Flow (RF): since irrigation is considered a priority, a different value of RF has been issued for agricultural and non-agricultural uses. For hydropower, the general formula of Po River Basin Authority has been adopted, even if some more parameters have been included in order to take into account the local environmental characteristics. A numerical model was developed to simulate the impact of RF on existing plants and to assess which could be the value of RF acceptable for hydropower producers and suitable to safeguard the river ecosystem, with an equilibrated balance between “ecological sacrifice” and “production sacrifice”;

4) other environmental requirements: other environmental requirements, such as the realization of fish passes and installation of flow rate gauges, have been set both for new and existing plants (with a phased implementation for the last ones); furthermore, to ensure transparency in the management of hydropower plants, the main data regarding flow rate (withdrawals, reserved flow) should be made visible from outside on a display, in order to allow everyone to check them (see pictures).

➡️ Tuscany Region

- A Regional Energy Plan (PIER) was issued in 2008. The objective of the plan, in line with the new European strategy, is to achieve a 20% share from renewable energy by 2020. Even if hydropower resources have been already widely exploited, the plan recognizes the importance of promoting the exploitation of the residual potential through the realization of small HP plants (P<3MW) and mini HP plants (P<100 kW), especially within integrated systems (artificial channels, aqueducts). According to a first rough assessment, based on the current sector developing trend, the overall regional residual potential amounts to about 100 MW. Two main instruments are foreseen to promote HP:
  - simplification in the authorization procedure
  - territorial planning (map of more suitable areas) with involvement of Provinces

- A Regional Water Protection Plan (PTA) was issued in 2005. The plan provides a first characterization of water bodies and their quality status and sets environmental objectives in line with the requirements of Legislative Decree 152/99 (GES by 2016).

➡️ Massa Carrara Province

A Provincial Energy Plan (PEP) was issued in 2006. The objective of the plan is to promote energy saving and energy production from RES. At present, the HP installed capacity is about 37 MW, distributed among 1 big plant and about 12 small plants. In order to limit the environmental impact, the plan aims at:
  - repowering existing plants, in order to increase their efficiency;
  - using existing infrastructures (weirs) and facilities (multipurpose schemes)
As far as new plants are concerned, small HP plants have to be preferred to big plants.
RESULTS

According to the premise, a comparison between the regional and provincial energy plans and the River Basin Authority plan was carried out. A first meeting with the River Basin Authority was organized, to deeply analyze the effects of their plan on existing plants and new plants.

Then was organized a meeting with all the administration involved (Region, Province, River Basin Authority), with the aim to discuss together the following issues:

- is it possible to assess the residual HP potential with the information available at the moment?
- which could be the administration in charge for this task?
- how will it change the present scenario when the WFD will be completely implemented?

The following conclusions were drawn:

■ as far as the environmental constraints of the water body protection plan are considered (no go areas, limitation to diversion density: see map below), a future increase of 10-15% in installed capacity compared to the current situation can be expected (from today’s 37 MW to about 41-43 MW, that corresponds to an increase in production of around 15 GWh). This is a rough estimation, based on the number of requests for new licenses at present under evaluation;

■ none of the administrations involved has ever carried out an assessment on the residual hydro-power potential based on the actual water resource availability and on integrated approach, that takes into account environmental protection objectives together with targets for renewable energy sources development.

All these administrations declared their intention to cooperate more and to exchange information. The possibility to set up a specific working group with the task to carry out a more detailed analysis, in line with the methodology proposed in this report is currently under evaluation. The outcome of this activity will be useful not only for the administration in charge of energy planning (Region and Provinces), but also for the River Basin Authority, who will soon be asked to implement properly the WFD, as well as to the hydropower sector in general, as far as suitable and non suitable areas for new HP plants would be outlined.
While the WFD provides for the harmonisation at EU level of environmental protection, energy, transport, infrastructure and flood protection policies remain more national determined policies within the EU framework.

With the release of the WFD, to manage rivers within a river basin context has become the real European water policy. This new era in Europe’s approach to rivers is actually challenging water administration, river managers and hydropower companies throughout the EU.

On the other hand, we shouldn’t forget that SHP is a main cornerstone in the renewable energy mix, which is necessary to reach the RES-e electricity targets.

**CONSIDERATIONS ON THE ASSESSMENT OF HP POTENTIAL**

We want to point out that, at the moment, the last comprehensive study on the small hydropower potential in Europe was carried out in 2000 within the BlueAGE Project (Blue Energy for A Green Europe - Strategic study for the development of Small Hydro Power in the European Union – Fourth Framework Programme). The conclusions of this study were the following:

- according to this study, the remaining potential from SHP will be some 2 700 MW and 11.5 TWh annually at 2015, which is less than the 18 TWh in the year 2010 that was estimated by the EU Commission in the White Paper issued in 1997;

- based on the present annual production of 40 TWh, we have estimated the possible total production from SHP in the EU at **51.5 TWh** at 2015 with a capacity of some **12 850 MW**, while the EU White Paper foresees 55 TWh from 14 000 MW at 2010;

- if the economic situation for producers improves, and the environmental constraints decrease, the total contribution from SHP in the EU 15 member countries could probably reach 60 TWh at 2020 – 2030.

In the framework of the preparatory works for the issuing of a new directive on the promotion of renewable energy sources (foreseen for 2009), which will set binding national targets, Member States are carrying out studies to evaluate internal residual potential for each renewable source. Therefore it is expected that soon new updated data on the residual hydropower potential in each Member State will be spread.

It is crucial to understand how an underestimation or an overestimation of the residual potential could affect the hydropower sector, both on the market side and on the institutional side.
In fact an underestimation can influence negatively the commitment of a State in supporting the hydropower sector, since the majority of the potential seems to have been already exploited and a small development of the sector is expected. On the other side, an over-estimation can cause a State to be condemned for the delay or failure in achieving the national target for renewable energy production, since the new targets will be mandatory and no longer indicative.

**CONSIDERATIONS ON “TERRITORIAL ENERGY PLANNING”**

The advantage of pre-planning mechanisms to facilitate the identification of suitable areas for new hydropower projects is well recognized. These pre-planning mechanisms should take into account WFD and other environmental criteria as well as socioeconomic aspects, including other water uses. The use of such preplanning systems could also assist the authorization process to be reduced and implemented faster.

Regarding the definition of “go” and “no-go” areas, we think that a “black-&-white” approach may not be appropriate. Even in “no-go” areas, there could be cases of new hydropower projects which have a little environmental footprint and could meet the WFD non-deterioration clause.

So at least 3 categories of areas should be distinguished for pre-planning: suitable, less favourable and non-favourable areas. These categories should be identified with the involvement of all stakeholders.

**CONSIDERATIONS ON POLICY MAKING**

At policy development level, integration between water, energy, transport and flood management policies is beneficial since it will create synergies, avoid potential inconsistencies and mitigate possible conflicts between water users and environmentalists. It is paramount that the different policies are implemented in a coordinated way, because it will otherwise result in delays, increased costs and/or lowest levels of ambition for all of them.

Recognition of the need and the legitimacy of each policy is the pre-requisite for integration. In addition to policy definition, the planning and programming level is a main key to success in ensuring integrated development strategies.

Other essential elements are an increase of transparency in decision making, not only in data and procedures, but also in economic considerations, and an enhancement of the dialogue and the co-operation between the different competent authorities, stakeholders and NGOs, to achieve a good balance between water uses and protection.

Territorial priorities for objectives and actions should be set in the river basin management plans, taking into account the ecological status, the available budgets and the different water uses. The establishment of those priorities should proceed from an integrated approach. For example, it will generally be more appropriate to restore river continuity on a catchment or sub-catchment level and not only on the level of single water bodies or sites.

**CONSIDERATIONS ON SOCIO-ECONOMIC ASPECTS**

The WFD is the first piece of EU water legislation that explicitly integrates economic principles and methods for the management of Europe’s waters.

Key tools include the following:

- **cost-benefit analysis**: compares the overall costs and benefits of an initiative. It can be valuable in decisions such as the test of “disproportionality”;
- **cost-effectiveness analysis**: looks at the costs of alternative actions to reach a specific objective, which provides ways to choose the least-cost solution.
For their river basin plans, Member States will need to estimate the costs of implementing different possible measures. They can use these estimates to:

- identify the most cost-effective set of measures that can improve the status of their water bodies. It may be that more than one measure could achieve the same ecological improvement: in such cases a judgment will need to be made about which option is the most effective. This should ensure that the targets of the WFD are met at the lowest possible costs and allow to maximise the ecological potential and the HP production at the same time.

- evaluate if a mitigation/restoration measure is disproportionately too expensive to be implemented. In these cases some “exemptions” could be applied. Assessing “disproportionality” means to make a comparison between the costs and the environmental benefits, but the evaluation of environmental costs and benefits in terms of money is a difficult target and so is the comparison. More investigations are needed soon, especially when applying for exemptions this information will be needed.

We also want to point out that the energy sector, including hydropower, is characterized by high and long-term investments. Thus HP operators need a certain level of investment security and certainty. Investment costs for the improvement of water ecological status at HP facilities (especially existing facilities) can be considerable and so compensation measures should serve to reduce energy production losses. These measures could be monetary compensation, but also eco-labelling, simplifications in authorisation, increase of flow or increase of the headwater level.

CONSIDERATIONS ON EXEMPTIONS

It should be kept in mind that the WFD is an environmental directive and exempting from its objectives should not be the rule, but exceptional. At the same time one should not forget that exemptions are an integral part of the environmental objectives set out in Article 4 and of the planning process.

The WFD provides flexibility to take into account water uses and it should be implemented in the frame of an overall ecologically coherent strategy.

In conclusion, this report doesn’t aim at pointing out a decisive solution for all the problems related to the conflicts between water and energy policies, but it is meant to provide a basis for the discussion between public authorities and stakeholders.

In the case of hydropower, energy production and environmental preservation can be achieved by a realistic balance of the actual social needs.

We think that different policies do not always have to automatically conflict and there is room for significant progress in policy integration by enhancing the recognition of the different interests, fostering the co-operation between the different competent authorities and stakeholders and promoting more integrated development strategies. This will require efforts and acceptance from all parties involved.

This report began with the question: HYDRorPOWER?
We want to conclude it with a positive statement: HYDRO&POWER!
This is our wish for all the people that, all over Europe, are working hard towards this ambitious target.
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This brochure has been developed under the SHERPA project – Small Hydro Energy Efficient Promotion Campaign Action. SHERPA is a European Funded Project in the framework of the Intelligent Energy for Europe Programme (IEE). SHERPA aims to make a significant contribution in reducing the barriers that are currently hindering the development of SHP, addressing the challenges and contributing to the uptake of SHP in the new enlarged European Union. The results of SHERPA will not only increase the awareness of politicians and decision makers on SHP as a key renewable energy source, but will also create favorable framework conditions for the further uptake of SHP within the European Union. The project specifically addresses the issue of environmental performance of SHP plants, as well as a comprehensive territorial planning approach at the level of water bodies.

ESHA, the European Small Hydropower Association, is the European co-ordinator of this project, which includes eight additional partners: SSHA (Slovenia), LHA (Lithuania), APER (Italy), SERO (Sweden), IED (France), IWHW (Austria), EC BREC/CLN (Poland) and ADEME (France).

SHERPA aims at developing and implementing a concise, well targeted and thematic approach to ensure the dissemination and market uptake of SHP in Europe, through publications, workshops, policy fora etc. The main deliverables are:

- Report on Status of SHP Policy Frameworks & Market Development in EU-25;
- Public image folders for SHP;
- Report on technical and operational procedures to better integrate Small hydro plants in the environment;
- Report on ISO 14001 and SHP;
- Assessment of power productivity with reference to objectives and targets set by WFD and RES-e directives;
- Economic analysis of environmental mitigation activities and equipment for SHP;
- SHP local plans in France and Italy;
- Good practice brochure of participatory approach for SHP development;
- SHERPA Policy session in Hidroenergia 2008, Bled, Slovenia;
- SHP National Policy Fora in Lithuania, France, Italy, Poland and Sweden.

More information about the project is available at: [www.esha.be/sherp](http://www.esha.be/sherp)

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