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Review of small hydropower in the new Member States and Candidate Countries in the context of the enlarged European Union

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Abstract

This article gives a general picture of the small hydropower (SHP) sector in the European Union's new Member States (the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia—EU-10) and those wishing to join (Candidate Countries—CC)—Bulgaria, Romania and Turkey). The differences and similarities of the SHP sectors mainly related to the technical aspects, on one hand—the former EU-15, on the other hand—EU-10 and CC are revealed in particular (except legal, regulatory, environmental and other issues).

SHP technical aspects expressed by quantitative estimates are briefly discussed here, namely: SHP potential; plants in operation and contribution to the gross and renewable electricity generation mix; manufacturing industry and support mechanism; SHP development environmental issues; forecast of SHP installed capacity and electricity generation. SHP legal, regulatory framework, economic and

Abbreviations: CC, Candidate Countries for EU membership (EU Accession countries); EIA, Environmental impact assessment; ESHA, European Small Hydropower Association; EU, European Union; EU-10, 10 new Member States (MS); EU-15, EU before enlargement (before 1 May 2004); EU-25, EU after enlargement (after 1 May 2004); RES, Renewable energy sources; RES-E, Directive 2001/77/EC of the European Parliament and of the Council on the promotion of electricity from renewable energy sources in the internal electricity market (Official Journal L 283 of 27.10.2001); Renewable energy sources for electricity generation; SHP, Small hydropower, Small hydropower plant (installed capacity $P<10\,\mathrm{MW}$); TNSHP, Thematic network on Small Hydropower. The project funded by EC DG TREN (2003–2006, Contract No NNE5/2001/886) and coordinated by ESHA

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main barriers to the SHP promotion, which are crucial for sector development are also briefly considered in this article.

The approach of this study was mainly focused on a questionnaire distributed to key SHP experts in each country. It addresses SHP, i.e. hydropower plants of installed capacity less than 10 MW. In most investigated countries this SHP capacity limit is officially approved. The indicated capacity is lower in Hungary and Poland—5 MW, in Latvia—2 MW and Estonia—1 MW.

For more than 100 years SHP has been harnessed in most of the surveyed countries, with the exceptions of Malta and Cyprus. The leading countries are the Czech Republic, Romania, Poland, Turkey, Bulgaria, Slovenia and Slovakia. The biggest share of SHP economically feasible potential has been exploited in the Czech Republic, Romania, Slovenia and Bulgaria (between 40% and 60%). A very small part of this potential has been harnessed in Turkey (only 3%). The remaining economically feasible potential amounts to some 26 TWh/year in the surveyed countries.

There are approximately 3200 plants installed in these countries, corresponding to a capacity of about 1430 MW of SHP. Conversely, a much larger number of SHP plants are installed in the EU-15 (some 14 000 with the total capacity of 10 000 MW). The average size of a SHP plant is about 0.44 MW (0.70 MW in EU-15). In almost all analyzed countries hydropower is a dominant source of energy in renewable electricity production. SHP is the second largest (after large hydro) contributor. The Czech Republic and Slovenia are the main countries with highest levels of turbine manufacturing industry. In some surveyed countries some opposition to SHP, mainly related to fish protection, visual impacts, enlargement of protected areas, has been identified.

The current technical state of the SHP sector in the surveyed countries in terms of generating capacities and contribution to total electricity generation is relatively low by comparing with that of the former EU-15. Despite the fact that in the EU-10 and CC so far has been exploited just about 30% and 6% of economically feasible potential, they will never achieve the strength in terms of generating capacities of the SHP sector of the former EU-15 (more than 82% developed so far). The CC may slightly bridge this gap by harnessing their untapped SHP potential (especially in Turkey).

A brief profile of SHP sector of the surveyed countries is provided at the end of the paper.

Keywords: European Union; New Member States and Candidate Countries; Small hydropower

Contents

1. Introduction

On 1 May 2004 eight Eastern European and two Mediterranean countries (the Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia) joined the European Union (EU). Bulgaria, Romania and Turkey are expecting to join the EU in the near future. The new Member States and Candidate Countries (CC) are shown on the map (Fig. 1).

The Renewable Electricity Directive (RES-E) is a policy tool to assist the EU in the development of a sustainable energy sector [1]. According to this directive the renewable generators should provide 21% of electricity by 2010 in the existing states of the enlarged European Union (EU-25). Reference values for CC national indicative targets for the contribution of electricity produced from renewable energy sources to gross electricity consumption by 2010 are presented in Table 1.

For more than 100 years small hydropower (SHP) has been harnessed in these countries, with the exceptions of Malta and Cyprus. The leading countries are the Czech Republic, Romania, Poland, Turkey, Bulgaria, Slovenia and Slovakia. As it will be shown hereinafter at present in almost all analyzed countries hydropower is a dominant source of energy in RES-E production. SHP is the second largest contributor after large hydro.

To understand the present and the future it is useful to look into the past. The history of small hydro in Europe (mainly represented by the former EU-15) can be characterized by the following periods [2].

- Phase 1: decentralized energy demand by industry (up to 1940/1950);
- Phase 2: economic-driven decrease until 1970;
- Phase 3: energy crisis and boom until 1990; and
- Phase 4: decrease driven by environmental concerns up to present.

The same history of SHP in EU-10 and CC followed a bit different way: phases 1 and 2 were lagged, energy crisis did not touched and the decrease did not take yet place in

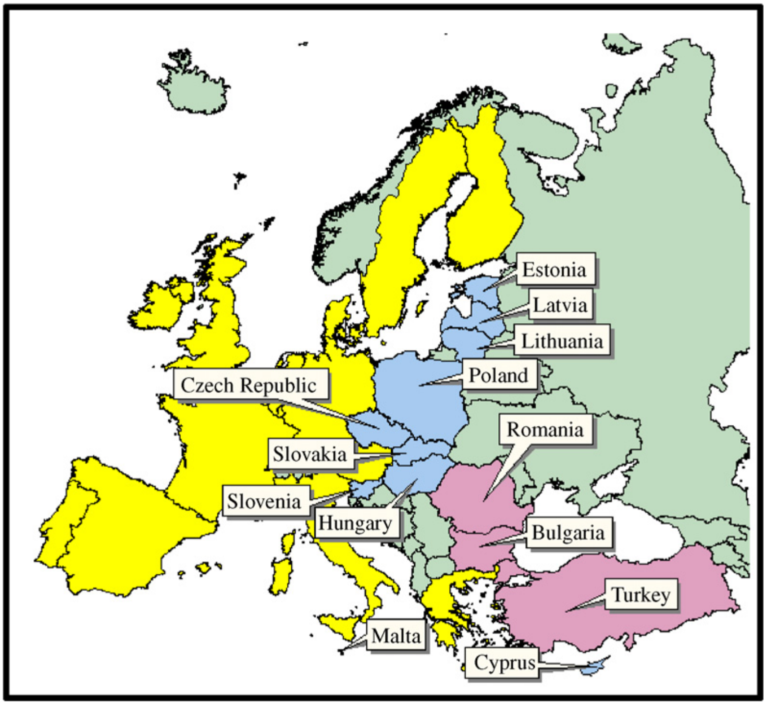

Fig. 1. Map of the European Union. Yellow—Pre-May 1, 2004 EU Members; Blue—May 1, 2004 New Member States; Lavender—Post-May 1, 2004 Candidate Countries.

these countries:

- Phase 1: decentralized energy demand by industry (up to 60–70 s) (except Romania up to 1990);
- Phase 2: economic-driven decrease until 1990 (for instance, the Baltic States—republics of the former Soviet Union. Stagnation in Hungary);
- Phase 3: ongoing boom, initiated by the EU RES-E directive up to present (stagnation in Hungary). This phase might last at least up to 2010–2015 (since present slow progress driven by environmental concerns in the Czech Republic and Baltic States).

2. Methodology of analysis

This article is based on the outcomes of the TNSHP project (work package "Small Hydropower situation in the Accession countries" completed during 2003–2004) [3]. The activities covered in the project were:

- Compilation of a database of key SHP statistics and information in the new Member States and CC,
- Analysis of SHP statistics, existing potential for SHP, technical and environmental aspects, water and energy industries and service capability,

Table 1
National indicative targets for the contribution of electricity produced from RES-E

	RES-E TWh, 1999	RES-E %, 1999	RES-E %, 2010
EU-15[a]	338.41	13.9	22
EU-25[b]	355.2	12.9	21
New Member States			
Czech Republic	2.36	3.8	8
Cyprus	0.002	0.05	6
Estonia	0.02	0.2	5.1
Hungary	0.22	0.7	3.6
Latvia	2.76	42.4	49.3
Lithuania	0.33	3.3	7
Malta	0	0	5
Poland	2.35	1.6	7.5
Slovakia	5.09	17.9	31
Slovenia	3.66	29.9	33.6
Candidate Countries			
Bulgaria[c]	2.8	7.3	8.7
Romania[c]	18.3	36.1	n/a
Turkey[c]	35.0	30.1	n/a

[a]Data refer to 1999.
[b]Data refer to 1997–2000.
[c]International Energy Agency (IEA) and authors' own estimation.

- A review of institutional, economic and regulatory issues of the legislation in force relating to SHP,
- Identification of the preliminary targets of SHP contribution in implementing the EU RES-E Directive,
- Comparison of the SHP sectors both in the new EU Member states and CC, and the former EU-15.

Some preliminary results of this study have been given in [4,5]. All above items are considered in this paper including political, legal, institutional, economical and other SHP development or operating issues in the surveyed countries. The differences and similarities of both entities' SHP sector (on one hand—the former EU-15, on the other hand—EU-10 and CC) are revealed in particular.

The project approach largely focused on a questionnaire. The reason for this approach was that information on the SHP sector is very scarce, non-existent or different SHP plant classification is applied (mostly in terms of capacity) in the surveyed countries. To overcome these barriers a detailed questionnaire, was prepared to obtain first-hand information regarding the current situation for SHP in these countries. It consists of two main parts (a total of 63 questions):

- Technical, Environmental and Industrial issues;
- Institutional, Economic and Strategic issues.

The questionnaire was sent out (early 2004) to the experts of 11 countries (8 New EU Member States; the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia and 3 CC; Bulgaria, Romania and Turkey), except Malta and Cyprus where hydropower sector is non-existent. In the latter country only one SHP plant is operating and there are no hydroplants under construction or planned. The list of respondents is given at the end of the article. The survey showed that only some general statistics on SHP were available from national statistical offices. A lion's part of information was gathered through SHP national associations, unpublished reports, by individual contacts with SHP developers and producers. The enquiry revealed that some countries (e.g. Slovakia, Estonia) are not in possession of SHP databases or their data are not easy accessible.

The questionnaire addresses SHP, i.e. SHP plants of installed capacity less than 10 MW (standard adopted by the ESHA, European Commission and International Union of Producers and Distributors of Electricity). In most investigated countries this SHP capacity limit is officially approved. The indicated capacity is lower in Hungary and Poland—5 MW, in Latvia—2 MW and Estonia—1 MW. It has to be noted that SHP maximum installed capacity is often related to the subsidiary policy of buy-back rate of energy delivered to the grid.

SHP potential was estimated according to the definitions commonly used in hydropower resources assessment practice [6–8]. Hydropower potential is usually divided as follows: A—gross theoretical potential (natural), B—technically feasible potential, C—economically feasible potential (Fig. 2).

It is absolutely clear that relative accuracy can be achieved for gross theoretical and technically feasible potential. In contrast the estimation of economically feasible SHP potential (of small and medium size streams) is a more complicated task when comparing with large streams. Furthermore, for some surveyed countries the evaluation of SHP power potential dates back to 1970–1980s. Remaining economically feasible SHP potential was determined by subtracting average electricity production or capacity of existing SHP plants from evaluated economically feasible potential.

Estimates have been made to understand the economically feasible potential due to existing environmental constraints (for example, protected territories and rivers exempted from hydropower development). Only a few countries were able to supply this very

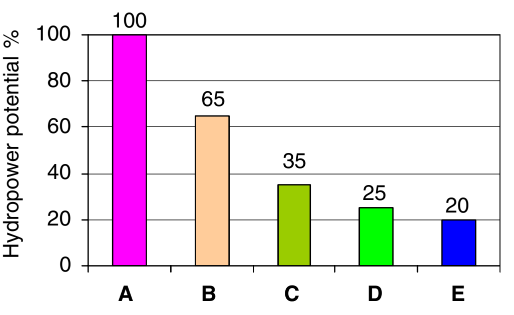

Fig. 2. Small hydropower potential and its reduction due to various constraints (hypothetical picture) [6]. A—Gross theoretical hydropower potential (natural); B—Technically feasible hydropower potential; C—Potential taking into account environmental constraints; D—Economically feasible potential (taking into account economic constraints); E—Remaining potential (taking into account technical, environment and economic constraints).

important information, which reflects the real SHP potential to be harnessed. Due to the lack of sufficient data it has not been possible to compare the individual countries in this regard. SHP experts of Sweden estimate this share to be in the range of some 20–30% of the natural (gross theoretical) potential [6].

The enquiry had an ambitious task to evaluate SHP industry capabilities in the analyzed countries. The following main categories of players can be distinguished in the SHP industry market:

- Manufactures of turbines, generators, electrical equipment, etc;
- Civil works contractors;
- Consulting services, project developers, etc.

To obtain the comprehensive information on the above hydropower market players was out of the study scope. Only general picture, giving the main ideas on SHP manufacturing industry, related mainly with small water turbine production, is given in the paper. In the surveying countries it was even difficult to identify the manufacturers acting purely in SHP sector ($P<10\,\text{MW}$). In many cases SHP and large hydro industries are mixed or they overlap. Only a qualitative estimate has been made of the SHP turbine manufacturing capability of each surveyed country (on the scale of 5 points).

There is no in-depth consideration of the institutional, economic and regulatory issues of legislation in force relating to the SHP sector of the surveyed countries. Only reported information on the above issues are given without identifying the strengths or weaknesses of a particular country. To describe the support mechanism available for SHP producers a simple indicator—feed-in tariff (buy-back rate)—has been used.

Financial SHP estimates should be considered as indicative and with some caution. To determine them no special investigations, which would have required a lot of human resources, were made. In fact they are expert estimates.

Environmental requirements related to SHP development and exploitation were also considered and qualitative and quantitative estimates (e.g. losses in electricity production due to maintaining compensation flow), which give a clear picture on the existing restrictions of SHP sector have been identified.

The existing resistances to SHP development have been grouped into 5 categories (Visual impact; Fishery; Water regulation; Competition with other users; Other kinds of resistances). They were evaluated on the scale of 5 points (1 = no impact and 5 = severe impact).

One of the tasks was to evaluate the contribution of SHP to the national RES-E targets set up by the EU RES-E directive (relevant only to the new EU Member States). The inquiry showed that to date (March–May, 2004) most of the surveyed countries have not yet adopted these targets, in particular for SHP. Only the Czech Republic, Hungary, Latvia, Lithuania, Poland and Bulgaria have adopted the national targets for RES-E directive so far (May 2004).

In order to make forecasts of each country's SHP installed capacity and electricity production for the short-term (to 2010) and medium-term (to 2015) extrapolations were made from recent trends based on historical data. To avoid the complicated descriptions these have been omitted in the text; only the final results are presented.

Information gathered from the questionnaires, mainly related to SHP potential and historic statistics (number of SHP plants, installed capacity and electricity generation) was checked for consistency with other relevant sources of data from the hydropower and renewable sectors, notably: [6–12]. This comparison of SHP statistics revealed existing differences in these data. Table 2 summarizes the main SHP statistics of the EU-10 and CC according to a variety of information sources and as revealed by this study (referred to in the table as TNSHP). In most cases the responses to the project questionnaire were deemed to provide accurate and reliable information. In a very few cases, where the data of surveyed countries was not available or believed to be unreliable, the information sources referred to above have been used.

Besides these sources of data statistics of renewable electricity including hydropower was used from [11–14]. The outputs of 'BlueAGE' study [6], the most comprehensive study on SHP strategic issues ever carried out in the EU, considering also eastern and south-eastern Europe and other ESHA's produced reports [15,16], have been extensively used for comparison to the results of this study. The reference year for the results is 2002. For some surveyed countries data for 2003 is also available.

When estimating hydropower share in RES-E generation mix pumped-storage power plants have been excluded.

3. General overview of SHP sectors of the former EU-15, 10 new Member States (EU-10) and 3 Candidate Countries (CC)

A large number of indicators (more than 15) have been used to describe the SHP sector in concise way. By comparing these indicators of each entity's SHP sector, their importance, level of development and future prospects are shown (Fig. 3).

3.1. SHP potential

Fig. 3(a) clearly shows the part of economically feasible potential that has so far been developed in these entities. More than 82% of all economically feasible potential has been exploited in the former EU-15 so far. The SHP resource exploitation rate in the EU-10 is less than half of that in the EU-15 and very small, only 5.8% in the CC. For the latter, the lion's share is due to SHP potential of Turkey.

Fig. 3(b) illustrates the remaining SHP potential, expressed in GWh/year, to be developed in the future. The figures represented do not take into account the extra potential that can be exploited by upgrading existing SHP plants or recovery of abandoned plants. This average extra potential ranges between 10% and 15% of the remaining potential in the former EU-15 [6]. The remaining SHP potential is more or less similar between the former EU-15 and CCs. In the latter entity the largest contribution is due to Turkey (more than 80%). By comparison the EU-10 shows considerably less developed potential at around a fifth of the EU-15 and CC's.

3.2. SHP plants in operation and contribution to gross electricity generation

About 14 000 SHP with average size of 0.7 MW operate in EU-15 (Fig. 3c). In EU-10 and CC here are around 2770 and 390 SHP plants installed, respectively. The average plant size in the new Member States is 0.3 and 1.6 MW in the CCs. Unlike the former EU-15 considerably smaller plants (less than half) are prevalent in the new Member States.

Table 2
Main SHP statistics according to the different information sources

No.	Country	Number of SHP plants			Installed SHP capacity MW					Generation (GWh/year)					Technically feasible potential GWh/year			Economically feasible potential					
		BlueAGE [6]	Hydropower & Dams [7]	TNSHP	BlueAGE [6]	Hydropower & Dams [7]	WEC [8]	Eurostat, 2002 [10]	TNSHP	BlueAGE [6]	Hydropower & Dams [7]	WEC [8]	Eurostat, 2002 [10]	TNSHP	BlueAGE [6]	Hydropower & Dams [7]	TNSHP	BlueAGE [6]	Hydropower & Dams [7]	WEC [8]	TNSHP	TNSHP	TNSHP
1	The Czech Republic	1136	1200	1302	250	200	276	238	273	677	680	1010	749	750	1148	500?	2800	700	n/a	n/a	1480	465	800
2	Estonia	10	23	25	1	3.9	n/a	3	3.8	5	n/a	n/a	6	20	55	210?	210	20	n/a	n/a	130	26	116
3	Hungary	35	26	34	9	8.8	9	8	8.4	38	n/a	28	28	28	68	n/a	279	68	28.2	n/a	68	22	32
4	Latvia	57	107	149	2	30	21	19	25	14	n/a	30	30	33	150	n/a	900	150	30	70	280	62	225
5	Lithuania	29	60	50	9	15	15	15	15	30	40	37	37	37	585	854	854	186	185	185	287	65	126
6	Poland	472	~500	610	127	130	486	210	233	705	200	1300	847	962	1600	500	5050	1600	n/a	n/a	2500	605	1538
7	Slovakia	180	200	200	31	67	66	7	67	175	250	160	29	250	261	1200?	1200	n/a	n/a	1000	1000	268	750
8	Slovenia	413	n/a	478	77	n/a	n/a	156	110	270	n/a	n/a	417	259	1300	n/a	1000	780	n/a	n/a	700	180	417
9	Bulgaria	n/a	64	84	n/a	141	65	133	156	n/a	412	355	17	355	n/a	n/a	755	n/a	n/a	755	706	319	393
10	Romania	9	278	234	44	279	278	346	275	n/a	n/a	416	436	416	n/a	821?	3630	n/a	n/a	n/a	3510	1060	3080
11	Turkey	67	70	71	138	176	175	201	177	500	651	654	411	673	n/a	n/a	30000	n/a	n/a	3623	20 000	6500	19 336

Notes: Data refer to: BlueAGE [6]—1999; Hydropower & Dams [7]—2002 or 2003; WEC [8]—2002; Eurostat [10]—2002 (for Turkey 2001), TNSHP (current paper)—2002–2003.
n/a—data are not available.
?—Indicates data might also be attributed to the economically feasible potential.

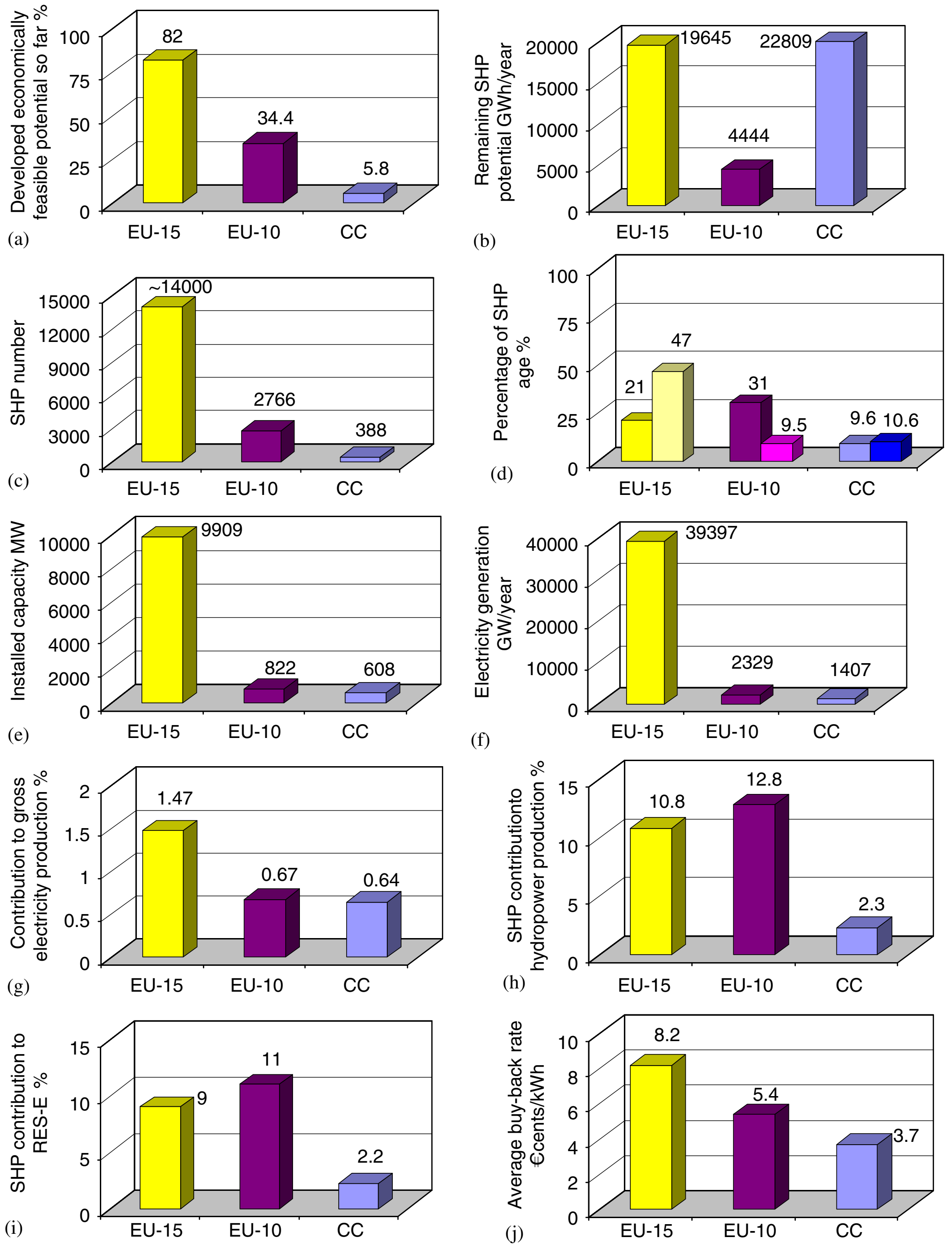

Fig. 3. Comparison of SHP sectors (former EU-15, new Member States—EU-10 and Candidate Countries—CC). (a) Percentage of developed economically feasible potential so far; (b) Remaining small hydropower potential; (c) Total number of operating SHP plants; (d) SHP age distribution (first column indicates the percentage of plants in range of 40 and 59 years old and the second one the plants over 60 years old); (e) Installed capacity; (f) Electricity generation;. (g) SHP contribution to gross electricity generation; (h) SHP contribution to hydropower production (only pure hydro); (i) SHP contribution to RES-E generation mix; (j) Average buy back rate (price level 2003 and 2004). Source for EU-15: [6,15,16].

Conversely, the situation in the CC's is the opposite in that most schemes are approximately 2 times bigger than the EU-15.

The SHP plants situated in the former EU-15 are also the oldest (Fig. 3d). The surveyed countries have the highest share of young SHP plants, especially the CC. The total installed capacity of SHP plants in the surveyed countries is at least 7 times smaller than in the former EU-15 (Fig. 3e).

Fig. 3(f) illustrates SHP production, which is a real economic value that provides SHP sector in each category. Electricity generation by SHP in the former EU-15 is considerably higher by comparison to the EU-10 and the CC's; production is nearly 15 times greater that of the EU-10 and 30 greater times that generated in the CC's.

Fig. 3(g) shows that SHP in the former EU-15 plays a significantly greater role in the electricity production mix than in the surveyed countries. In the latter countries SHP plants contribute only to 0.64–0.67% of the total electricity generation. These figures reveal that this share is less than half than in the former EU-15.

It is interesting to compare the SHP share in the total hydropower production and renewable electricity (RES-E) generation mix (Fig. 3h and i). The share of SHP in the former EU-15 and EU-10 is similar, however the figure is significantly less in the CCs. In the latter case it indicates that large hydropower is totally dominant. The same tendency is observed for RES-E renewable energy mix.

3.3. SHP manufacturing industry, SHP support mechanisms and projection of capacity into the future

The former EU-15 has around 70 small-scale water turbine manufacturers [6]. In the surveyed countries—EU-10 and CCs, they are less numerous with 18 and 3, respectively.

The most widely adopted support mechanism in most countries is the feed-in tariff, which gives SHP generator a guaranteed price for their electricity (Fig. 3j). The difference between the buy-back rates between the EU-15 and EU-10 is less than the EU-15 and the CCs.

In order to carry out the forecast of SHP installed capacity and electricity generation the short and medium terms (2010 and 2015) have been used. The forecasted figures show a rising trend when compared with the reference year (2002). Installed capacity and corresponding generation is expected to increase from 11% to 30% by the year 2010 and 2015 in the former EU. About the same rate of increase will be kept for EU-10 (11–49%). The CC are expected to achieve a more significant growth of SHP sector for this period (34–72%).

4. SHP sector of the new Member States (EU-10) and Candidate Countries

4.1. SHP potential

Fig. 4 gives an overview of the concentration of hydropower potential per unit of area (1 km^2) called specific energy in the surveyed countries. The specific energy is expressed as the gross theoretical, technically and economically feasible potential divided by the total area of a country and is expressed in the units—GWh/year/km^2. It can be seen that specific hydropower resources per unit of area are mostly concentrated in Slovenia and Turkey;

Romania, Bulgaria, Slovakia and the Czech Republic follow on form a second group. The remaining countries are characterized by relatively low hydropower specific energy.

Fig. 5 represents SHP potential and developed potential so far in absolute units of the surveyed countries. The potential that has been developed so far, i.e. the actual electricity production by SHP plants, reflects the level of harnessing of economically feasible potential. Its importance is further revealed in Fig. 6, where the reciprocal is shown i.e. the potential remaining to be developed. The main, and very large, technical and economically feasible SHP potential is located in Turkey's small and medium streams—30 000 and 20 000 GWh/year, respectively. Poland and Romania form a second group, having indicated potential 6–10 times lower than that of Turkey. The third group is composed of the Czech Republic, Slovenia, Bulgaria and Slovakia. Their technical and economically feasible potential ranges between 755 to 2800 and 700 and 1480 GWh/year, respectively. Then follow Latvia and Lithuania and finally Estonia and Hungary where comparatively little SHP potential exists.

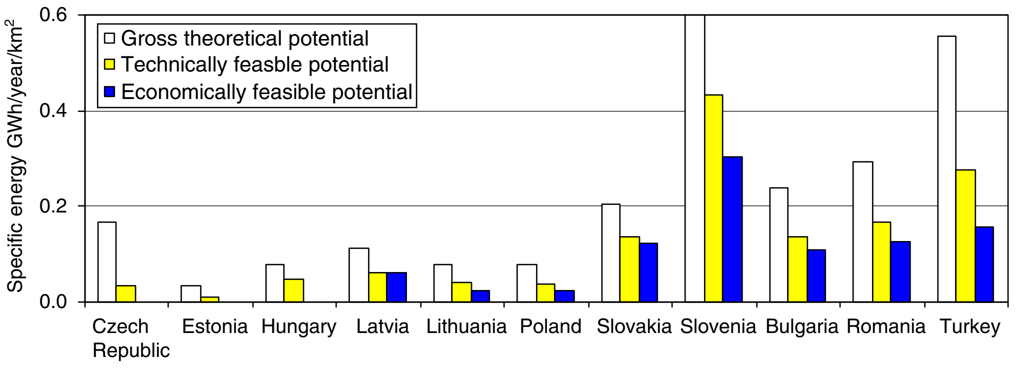

Fig. 4. Hydropower specific energy (gross theoretical, technically and economically feasible potential) in GWh/year/km^2. Data source: [7].

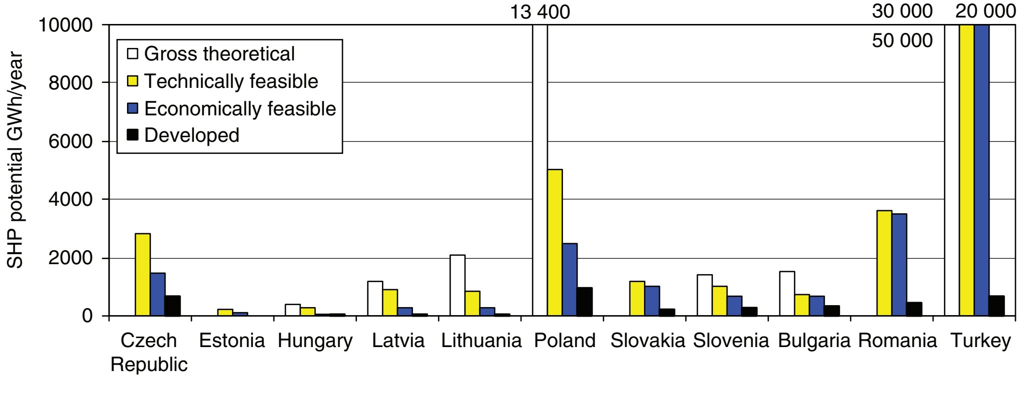

Fig. 5. Small hydropower potential (gross theoretical, technically and economically feasible potential) in GWh/year.

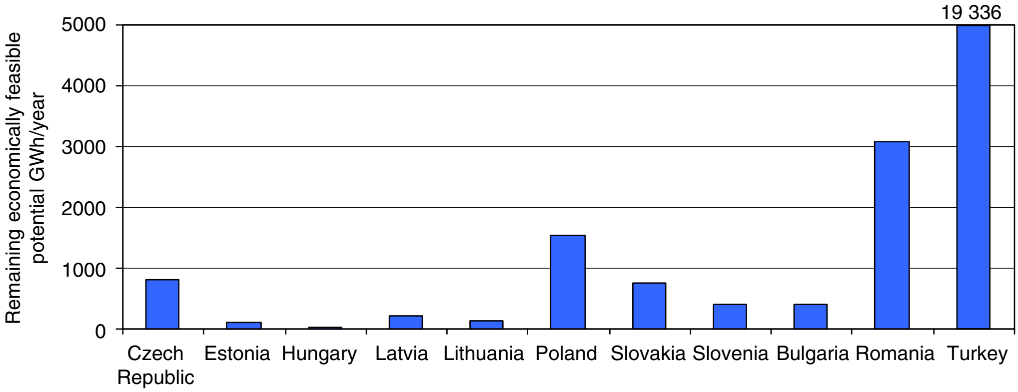

Fig. 6. SHP remaining economically feasible potential.

Estimates have been made to identify the economically feasible potential due to existing environmental constraints (for example, protected territories and rivers exempted from hydropower development). For instance, in Lithuania this percentage amounts to about 5–6%, which reveals very strict environmental constraints in force.

The biggest share of economically feasible potential (between 40% and 60%) has been exploited in the Czech Republic, Romania, Slovenia and Bulgaria. A very small part of this potential has been harnessed in Turkey (only 3%), Estonia, Latvia and Lithuania (around 15–20%). The remaining economically feasible potential amounts to some 26 TWh/year in the surveyed countries. The majority of this potential (roughly 80% or 19 300 GWh/year) is located in Turkey.

4.2. *SHP plants in operation*

Since the 1970s, SHP has been in decline in most of the analyzed countries. Many SHP plants have been shut down because of old age and competition from newer, larger plants mostly using fossil fuel. In the Baltic States, for example, almost all SHP plants were decommissioned between 1960 and 1980.

There are approximately 3200 plants installed in the 11 countries mentioned, corresponding to a capacity of about 1430 MW of SHP. Fig. 7 shows that the biggest number of SHP plants is located in the Czech Republic (1302) then follows Poland (608), Slovenia (400) and Romania (234). Hydropower is not used in Malta with almost the same situation is in Cyprus—there is only one SHP plant in operation. Romania, Czech Republic and Poland, are characterized by the largest installed capacities—275, 273 and 238 MW, respectively.

In most of surveyed countries more than a half of total SHP plants are low head power plants (gross head <5 m). This fact is especially common in Central and Eastern European countries (Fig. 8). The countries located mostly in Southern Europe (Slovenia, Bulgaria, Romania and Turkey) have the highest share of high head (>15 m) SHP plants.

The SHP plants situated in Hungary, Czech Republic and Bulgaria are the oldest, with 100%, 70% and 65% respectively being over 40 years old (Fig. 9). Eastern European countries (Estonia, Latvia, Lithuania, Poland), Slovenia, Romania and Turkey have the highest share of newer plants (up to 20 years old).

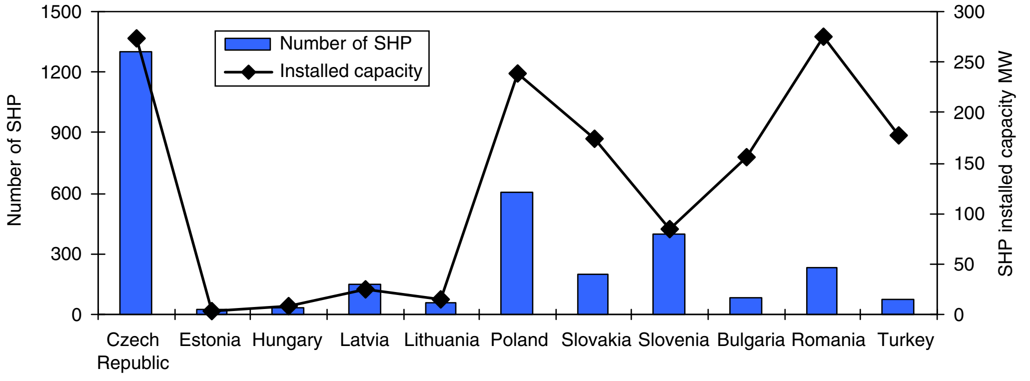

Fig. 7. Number of SHP and installed capacity.

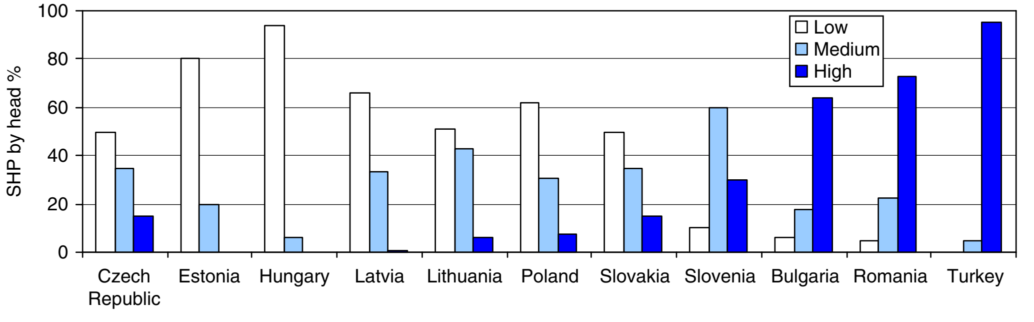

Fig. 8. Percentage of small hydropower plants by head (low head <5 m, medium head 5–15 m, high head >15 m).

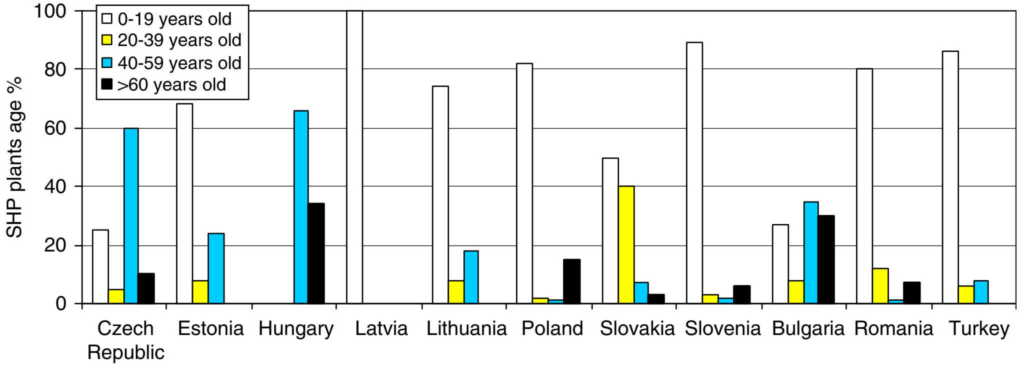

Fig. 9. SHP plants age distribution.

SHP plants are almost all privately owned in the Czech Republic (90%), Estonia (93%), Hungary (100%), Latvia (93%), Lithuania (100%), Bulgaria (84%). The private ownership of SHP plants in the terms of generating capacity is relatively low in Poland and Turkey (6% and 20%, respectively). No SHP plants have been privatized in Romania so far (the privatization process has only recently started).

4.3. SHP contribution to the gross and renewable electricity (RES-E) generation

SHP contributes some 0.7% to production of electrical energy in the new Member States and CC. The biggest SHP contribution is concentrated in Slovenia at 2% (Fig. 10). The contribution is half (just under 1%) in the Czech Republic, Latvia, Slovakia, Bulgaria and Romania. SHP contribution in Estonia, Hungary and Lithuania is very low (0.1–0.2%).

It is interesting to compare the hydropower share to renewable electricity production in the analyzed countries (Fig. 11). In almost all surveyed countries hydropower is the dominant source of energy in RES-E production. SHP accounts for approximately 4.6% of total hydro generation in the new EU Member States and CC. Currently, none of the other renewable energy sources (wind, biomass, etc) makes as much contribution to the energy mix in the surveyed countries as SHP. But this dominance is likely to be changed in the future for some surveyed countries (especially with low hydropower potential, namely the Baltic States and Hungary).

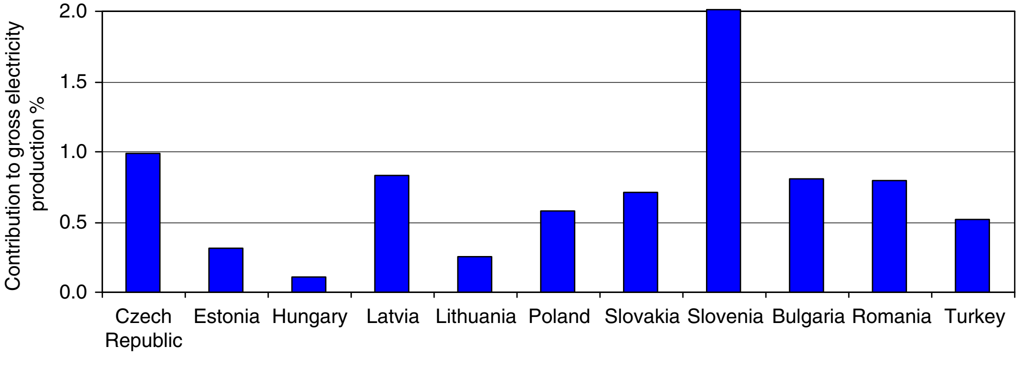

Fig. 10. SHP contribution to gross electricity generation.

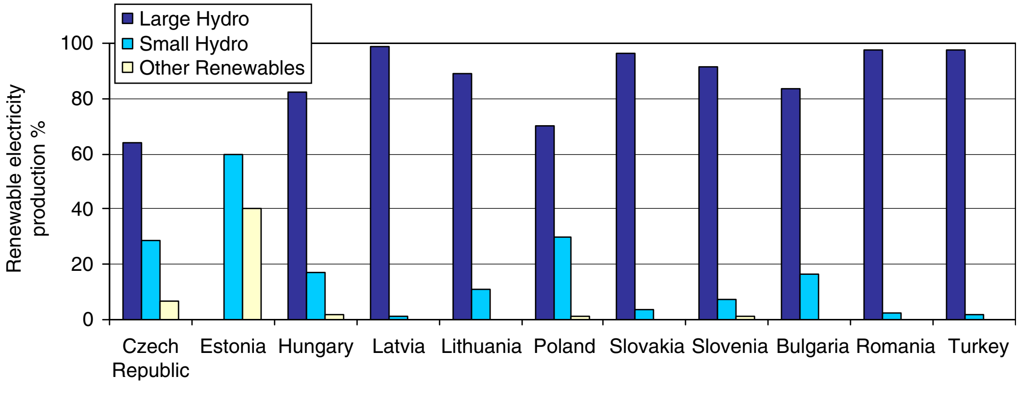

Fig. 11. Share of large and small hydro, and other renewable energy sources in the total renewable electricity generation.

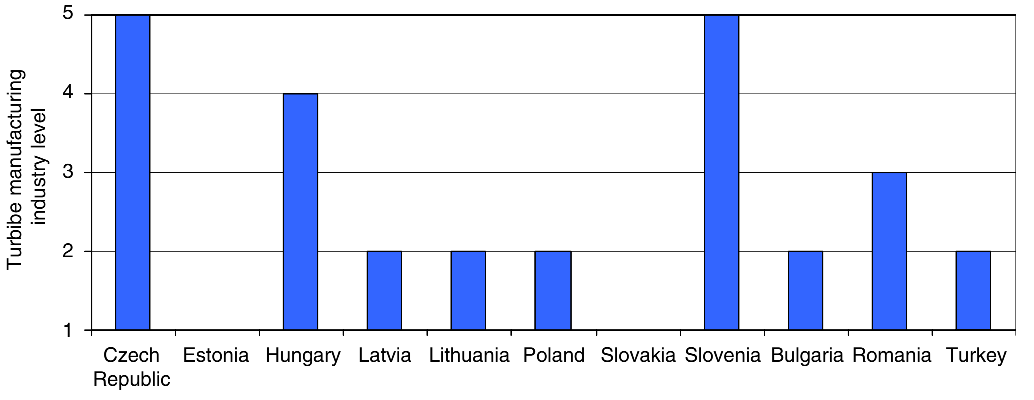

Fig. 12. SHP turbine manufacturing industry capabilities (1 = no turbine manufacturers, 5 = high capability of turbine manufacturing industry).

4.4. SHP manufacturing industry, economic issues and SHP support mechanism

The survey revealed that some 18 and 3 small-scale water turbine manufacturers exist in EU-10 and CC, respectively. In order to compare the position of manufacturers of turbines of individual countries the following categories (on the scale of 5 points) have been distinguished (Fig. 12):

- No turbine manufacturers (1);
- Turbine manufactures exist, but they are not able to cover domestic demand (2);
- Turbine manufactures exist; they are able to cover domestic demand with limited export capacities (3);
- Turbine manufactures exist; they are able to cover domestic demand with some export capacities (4);
- Turbine manufacturing industry well developed, with high export capacities (5).

The Czech Republic and Slovenia are the main countries with highest levels of turbine manufacturing industry. Hungary and Romania also have some limited turbine manufacturing capacity. Internationally recognized manufacturers exist in all of the above-mentioned countries. No SHP turbine industry was reported in Estonia and Slovakia.

Investment costs for a new plant vary between 300 and 400 €/kW (Turkey)[1] and 3000–4000 €/kW (Slovenia and Hungary) (Table 3). The range of investment costs in SHP in the former EU-15 varies a lot, but their upper limit is usually bigger than that of EU-10.

The lowest cost of producing of 1 kWh by SHP plant is in Bulgaria and Turkey (0.3–1.0 €cents), the highest one in Hungary, Poland (3.0–4.6 €cents). It is commonly known that high head schemes are less expensive to develop and operate than low head schemes.

[1]According to [43] if all civil works are to be constructed for SHP scheme, the prices per kilowatt range between US$750 and US$4000 and can be higher or lower depending on a particular site.

Table 3
Investment and electricity production costs

Country	Estimated range of investment costs for new plants (€/kW)			Range of investment costs[a] (€/kW)	Average cost of producing a unit of electricity generated by SHP scheme (€cents/kWh)		
	Low head	Medium head	High head		Low head	Medium head	High head
Czech Republic	1200–2000	800–1400	600–1000	—	3.0	2.5	2.0
Estonia	1400	1800	—	—	1.9	1.7	—
Hungary	1500–4000	2500–4000	Not appl.	—	3.8–4.6	3.8–4.6	Not appl.
Latvia	1200	800	—	—	2.7	2.2	—
Lithuania	2500	2200	—	—	3	2.5	—
Poland	800–1200	700–1000	500–800	—	3–4	n/a	n/a
Slovakia	n/a	n/a	n/a	1500–2000	n/a	n/a	n/a
Slovenia	3000	2500	1500	—	n/a	n/a	n/a
Bulgaria	n/a	1100–1500	700[b]	—	n/a	0.3–1.0	0.4–0.6[b]
Romania	n/a	n/a	n/a	n/a	n/a	n/a	2.8
Turkey	Not appl.	350–450	300–400	—	Not appl.	0.6–0.7	0.5–0.6

[a]Alternatively to previous columns.
[b]SHP associated to a drinking water supply systems.

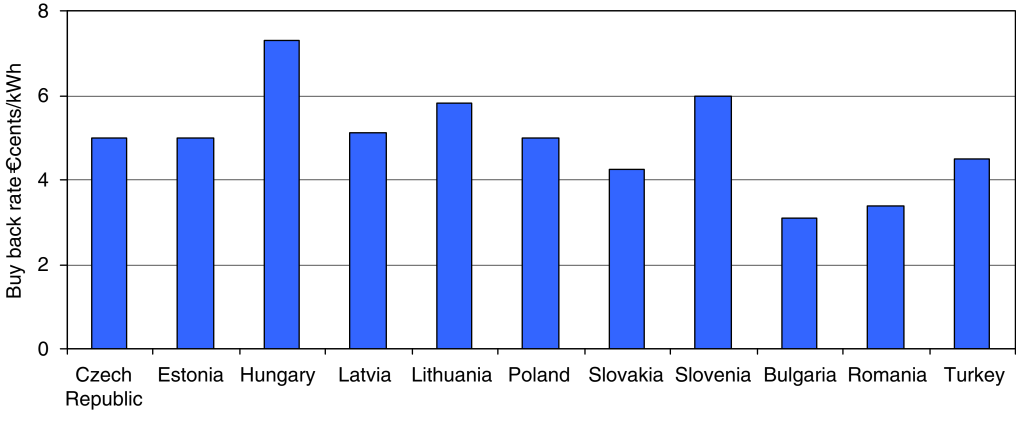

Fig. 13. Buy-back rates in the surveyed countries (price level 2003 or 2004).

The survey shows that the most widely adopted support mechanism within the analyzed countries are feed-in tariffs, which give the SHP generators a guaranteed price for their electricity. Feed-in systems clearly dominate in the EU-25 states [17]. The average buy-back rate offered to SHP producers is about 5 €cents/kWh in the analyzed countries with the lowest tariff in Bulgaria (3.1 €cents/kWh) and the highest one in Hungary—7.3 €cents/kWh (Fig. 13). Latvia has recently moved from ambitious feed-in tariff system to a quota system. The survey results clearly show that in almost all analyzed countries the indicated buy-back rates are not enough to attract private investment and secure investors confidence. There are a very few countries to have introduced extra prices based on the green certificate system: Estonia and Poland. The latter has just introduced it.

The existing price level is not that effective to attract private investments and secure investors' confidence but there is some support available for SHP developers and producers. Loans at preferential conditions are granted, income tax exemptions for a period of 4–5 years beginning from the date of SHP commissioning are in force (for example, in the Czech Republic and Lithuania). SHP producers benefit of reduced VAT (0% in Estonia, for instance). No direct fiscal aid for SHP developments is available in Latvia, Poland, Slovakia, Slovenia and Turkey.

4.5. SHP regulatory issues and main hindrances to the SHP development

One major barrier to the further development of electricity from renewable energy sources are the administrative and planning procedures that potential generators must respect. According to the EU RES-E directive [1], each country are required to review their existing legislative and regulatory frameworks concerning authorization procedures in order to reduce regulatory and non-regulatory obstacles, to rationalize and speed up administrative procedures and to ensure that the rules are transparent and non-discriminatory. At the moment of the performance of this study it was premature to find out the status of the implementation of this statement in the surveyed countries.

Regulations have to take into account various aspects (energy generation, impact on river environment, construction, connection to the grid, etc.), which are under the responsibility of different authorities. These authorities and responsibilities are different in each country depending on the political and administrative organization and on its involvement in the development of renewable energy sources. In other words, there is no "one-stop shop" for SHP developers in all countries.

There are mostly two types of licenses that a SHP producer must have: water permit ("water rights") and construction permit. Water rights are granted in order to allow the best possible access to the other uses of water (irrigation, fishing, industrial use, leisure, etc.). In some countries they are associated with site right. They are usually granted for 10 years (Bulgaria) up to 30–50 years (Lithuania, Slovenia, Slovakia) with possible renewal. The optimal duration should be at least 30 years [6]. Apart from this power generation licenses are also required in some countries. The length of their validation varies a lot: 5 years (Estonia), 10 years (Latvia), 25 (the Czech Republic), 35 (Bulgaria) and 20–40 years (Turkey).

The whole process to get licenses takes from 3 to 6 months in Poland and Estonia (without the time required to carry out EIA) to 1–2 years in the remaining countries. In the former EU-15 Member States the length of authorization procedures is undetermined or can last more than 1–2 years up to 4–6 years and more [6].

Spatial and integrated planning is one of the crucial tools to support SHP promotion in the former EU-15 [18]. The survey revealed that most of the countries have no master plan for SHP development or for some of them they were established a long time ago (mostly with only one single component—hydropower). Up to now there was no intention to develop local or regional spatial plans to guide the development of SHP project in suitable areas (with some exceptions of Lithuania, Slovenia, Slovakia and Bulgaria).

Most of the SHP producers in surveyed countries are not charged with fees for the use of water (with the exception of Slovakia, Slovenia, Bulgaria, Turkey). If any, they are comparatively low and do not represent a big constraint for SHP developer or operator. For some countries (Latvia, for instance) the water use fees are likely to be introduced in the future.

For most of SHP operators the established rules for access to the grid are fair and transparent. There is no cost of connection to the grid or they are given access at reasonable prices. In a very few cases they are responsible for covering the costs of extensions and of strengthening the grid. Generally, there is no cost for the use of the grid.

The actual difficulties faced by the hydroelectricity sector in the former EU-15 are manly linked to non-technical aspects [6,18]. Experts of each surveyed country identified the main hindrances to the SHP development and revealed non-technical barriers to SHP growth and can be summarized as follows:

1. Complicated and lengthy licensing procedures (the Czech Republic, Slovenia, Turkey);
2. Low purchase price of power from SHP (the Czech Republic; Hungary, Lithuania, Slovenia, Romania);
3. Lack of financing support (Romania);
4. Unjustified environmental constraints (the Czech Republic, Baltic States, Slovenia);
5. Ownership of the land (Estonia, Slovakia).

The recommendations to overcome the above obstacles were provided and can be summarized as follows:

1. Simplifying of the licensing process, introducing "single window" procedure;
2. Support of SHP as a green source of power;
3. Increasing of public awareness on positive SHP activities;
4. Introduction of green certificate system;
5. Revision of the list "forbidden" rivers;
6. Internalization of external costs of electricity generation from RES-E;
7. Assurance of financial return and commercial security of RES-E;
8. Introducing of national law on RES.

4.6. SHP development environmental issues

It is commonly known, that the environmental requirements, depending on their nature and scale can be crucial for SHP development. As it was mentioned in the beginning of the article in the former EU-15 a decrease in SHP development driven by environmental concerns is clearly observed. That is why this survey made an attempt to reveal this important issue.

Table 4 presents the key environmental and social factors that SHP developers are facing.

In some analyzed countries the official environmental bodies, usually under pressure from Non-Governmental Organizations (NGOs) on nature protection or Green parties do not see small hydro as a green, renewable energy. Besides the existing conventional protected watercourses (e.g. nature conservation areas), lists of "forbidden" rivers for

Table 4
Effect on SHP development and operation of the key environmental and social factors

Country	SHP status (MW)	Rivers exempted from damming[a]	Environmental impact assessment (EIA)	Residual flow	Social acceptance of SHP projects
Czech Republic	<10	No	1	4	1–2
Estonia	<1	Yes	3	1	2–3
Hungary	<5	No	1	1	n/a
Latvia	<2	Yes	2	2	2–3
Lithuania	<10	Yes	5	1	1–2
Poland	<5	No	4	1	1–2
Slovakia	<10	No	1	4	1–2
Slovenia	<10	No	2	4	2–3
Bulgaria	<10	No	5	4	1
Romania	<10	No	5	n/a	1–2
Turkey	<10	No	1	n/a	1–2

[a]Except conventional protected areas—strict nature reservations or protected areas with overall restricted economic regime.

hydropower development have been recently (2002–2004) introduced in Latvia, Lithuania and Estonia. The rivers exempted from damming adversely affect SHP potential. For instance, the introduction of forbidden rivers in Lithuania resulted in the decreasing of SHP potential more than twice. Even in comparison to the Member States of the former EU-15 its remaining potential can be regarded as one of the lowest (when comparing in relative units) [23].

EIA procedures with regard SHP projects vary a lot in analyzed countries. According to applying them to SHP projects they were categorized into 3 main groups:

1. For hydropower projects in the protected areas, national parks, etc.;
2. For all hydropower projects, regardless their size;
3. For hydropower project depending on its installed capacity or alternatively dam height or reservoir area.

The "severity" of EIA procedures with regard to SHP was evaluated on the scale of 5 points: 1 (no impact: 1st group); 5 (severe impact: 2nd group and depending on the specific provisions might be attributed the 3rd group).

When operating SHP plant the most crucial issue is maintaining of residual (reserved, compensation, ecological) flow. It is related to the losses in power production. If its imposed value is too big, a hydro scheme can be uneconomically operated [6]. The losses in SHP electricity production were quantified as follows: from 1 point (negligible) to 5 points (big losses, i.e. >5–10% of electricity generation).

SHP acceptance by general public in the surveyed countries was evaluated also (1 = positive, 2 = neutral and 3 = negative). Nearly all of them emphasized the facts of negative position of NGOs against development of any size of SHP plant. Estonia, Latvia and Slovenia are the countries where their people might not tolerate SHP further expansion. This reluctance is not only related to the environmental issues, but also to the

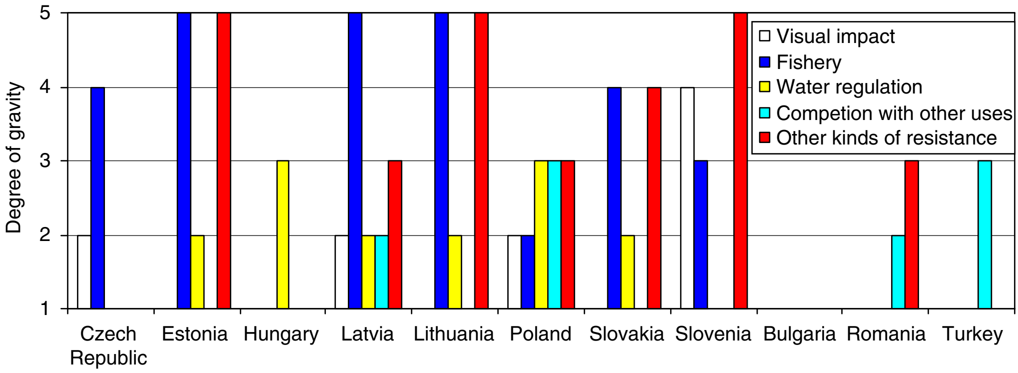

Fig. 14. Resistances to SHP development (1—no impact, 5—severe impact).

economical ones (high prices for purchase of electricity delivered to the grid). Many people in the Eastern European countries fear that support of RES will increase energy prices [14].

Apart from the above evaluation the existing resistances to SHP development were quantified on the scale of 5 points, which are summarized in Fig. 14.

Visual impacts related to the intrusion of SHP powerhouses and infrastructure etc. on the landscape is a significant barrier for small hydro development in Slovenia. Fish protection is one of the crucial issues to almost all countries with the exceptions being Romania, Turkey and Bulgaria. In Bulgaria no resistance to SHP has been reported. Other kinds of resistance constitute the enlargement of protected areas including watercourses under NATURA 2000 (EU network of protected areas), implementation of unjustified requirements of the EU Water Framework Directive, land ownership, water quality degradation due to creation of a small impoundment.

4.7. Forecast of SHP installed capacity and electricity generation

Figs. 15 and 16 indicates forecasted values of SHP installed capacity for the short (2010) and medium terms (2015). In all surveyed countries, SHP capacity and electrical output is expected to grow.

4.8. SHP promoting organizations

Beside the lack of domestic financial sources, the cognitive environment belongs to the major obstacles for the development or RES in EU-10 and CC. One of the biggest differences between the former EU-15 and EU-10 and CC concerning the chances for RES is the public awareness, which is very high, especially in Northern Europe [14]. RES promoting associations in the investigated countries have to play a more active role in campaigning for the cause of renewable energies.

The collapse of the Soviet Union and decentralization of power sector benefited to the creation of SHP organizations (e.g. in Latvia—Small Hydropower Association, Lithuania—Lithuanian Hydropower Association, Slovenia—Association of Small Hydro-Power Plants Societies, Slovakia—National Association of Owners of SHP). Furthermore,

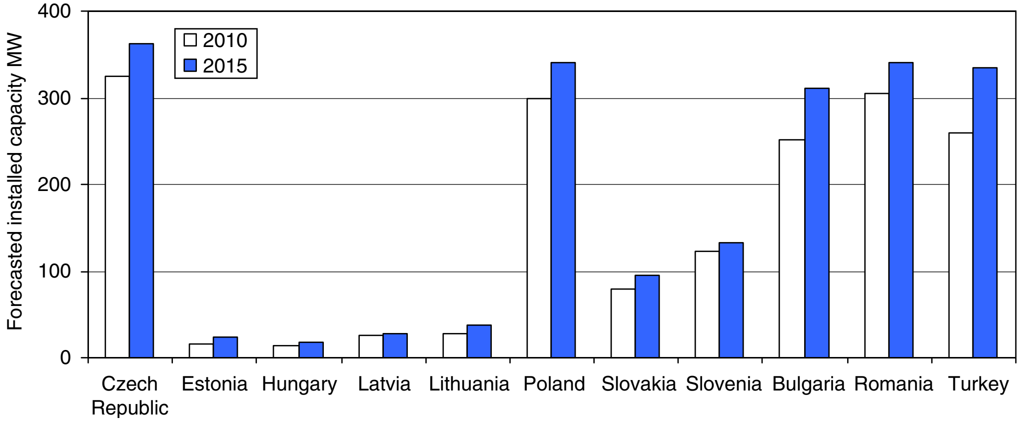

Fig. 15. Forecasted SHP installed capacity (MW) by 2010 and 2015.

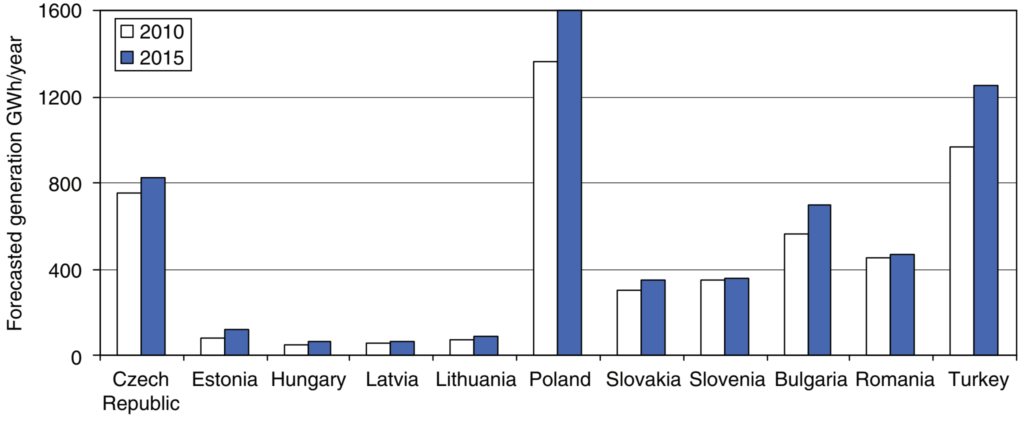

Fig. 16. Forecasted SHP electricity generation (GWh/year) by 2010 and 2015.

SHP organizations have served as a good model to establish other RES organizations. To date the membership of the branch organizations in the field of RES are not so much numerous like hydropower associations. However this situation is likely to be changed in the future. In some surveyed countries SHP interests are represented by joint head organizations. This is the case of the Czech Republic (Union of Entrepreneurs for Utilization of Energy Resources) and Bulgaria (National Union of Independent Energy Producers "Ecoenergy"). In the big country Poland there are two hydropower associations: Society for Development SHP Plants represents the interests of private owners and the Polish Hydropower Plant Association mainly deals with large hydro, however the interests of state owned SHP plants are represented also.

No SHP organizations have been reported in Estonia, Hungary (the association for RES is likely to be established in the latter in the near future), Romania and Turkey (except for large hydro).

Some of the above-mentioned organizations (Lithuania, Poland, Slovenia, for instance) have already joined the umbrella association—European Small Hydropower Association (ESHA), others are under way of joining.

5. Conclusions

This article provides a general picture of the SHP sector of the new Member States (EU-10) and Candidate Countries (CC). Beside this the differences and similarities of the SHP sectors mainly related to the technical aspects, on one hand—the former EU-15, on the other hand—EU-10 and CC are revealed in particular (except legal, regulatory, environmental and other issues).

For more than 100 years small hydropower (SHP) has been harnessed in most of the surveyed countries, with the exceptions of Malta and Cyprus. The leading countries are the Czech Republic, Romania, Poland, Turkey, Bulgaria, Slovenia and Slovakia. The Czech Republic and Slovenia are the main countries with highest levels of turbine manufacturing industry. In some surveyed countries some opposition to SHP, mainly related to fish protection, visual impacts, enlargement of protected areas, has been identified.

In almost all analyzed countries hydropower is a dominant source of energy in renewable electricity production. Currently SHP is the second largest (after large hydro) contributor.

The current technical state of the SHP sector in the surveyed countries in terms of generating capacities and contribution to total electricity generation is relatively low by comparing with that of the former EU-15. Despite the fact that in the EU-10 and CC so far has been exploited just about 30% and 6% of economically feasible potential, they will never achieve the strength in terms of generating capacities of the SHP sector of the former EU-15. The CC may slightly bridge this gap by harnessing their untapped SHP potential (especially in Turkey).

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Appendix A. Profile of SHP sector of the new Member States and Candidate Countries

There are presented historic data regarding SHP number, installed capacity and electricity generation during 1995(96)–2002(03), existing small hydropower (SHP) potential and a brief description of the main characteristics of plants in operation. The forecasted capacity and power production in the short- (till 2010) and long-term (till 2015), SHP potential are given.

Further details on SHP sector can be found: for the Czech Republic [19–21], the Baltic States [22–29], Poland [30–35], Slovakia [36–37], Slovenia [38–39], Romania [40–42] and Turkey [43–45].

A.1. Czech Republic

There is an upward trend of SHP characteristics, especially in the number of plants, over the last 8 years (Fig. A1). The forecasted figures for SHP growth show moderate annual increase in electricity generation to 2010 and 2015 (751 and 862 GWh, respectively).[2]

The majority of SHP plants (around 60%) are relatively old in the Czech Republic, generally built 40–60 years ago and only one quarter of SHP plants can be considered as recently built (0–19 years). Around 90% of all SHP generating capacity (MW) are privately owned.

Low head power plants followed by medium head are prevailing in the Czech Republic. The percentage of SHP plants according to their gross head is as follows: Low head (up to 5 m)—50%; Medium head (5–15 m)—35% and High head (more than 15 m)—15%.

Small hydro amounts to almost 1% of the electricity capacity in the Czech Republic but for electricity generation the total hydro contribution is three times bigger—at around 3% of the total generation. With respect to contribution of the renewable energy-based electricity supply, small and total hydro production is dominant in the Czech Republic, at 29% and 64%, respectively.

The gross theoretical SHP potential is unknown in the Czech Republic (Table A1). The technically and economically feasible potential is evaluated at 2800 and 1480 GWh/year, respectively. So far, nearly a half of economically feasible potential (or 46%) has been developed.

Table A2 indicates SHP and other RES development progress up to 2030 planned by official authorities.

It shows that after 2010 there will not be any further SHP development. However survey's estimates regarding forecasted production for 2010 and 2015 are less optimistic (see footnote 2). On the other hand remaining economically feasible potential is evaluated at some 800 GWh/year. However a variety of environmental constraints might decrease this potential, which quantitative estimate was not derived from the survey.

A.2. Estonia

The installed capacity and electricity generation increased considerably over the reference period and the same pace of growth in SHP is expected in the future (Table A3).

[2]The official estimates are much more optimistic (see Table A2).

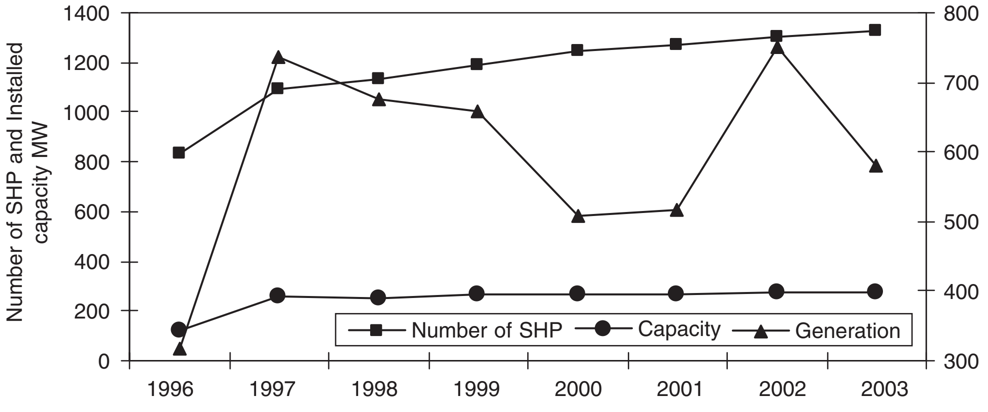

Fig. A1. SHP plants number, installed capacity (MW) and electricity generation (GWh) in the Czech Republic.

Table A1
Small hydropower potential in the Czech Republic

Potential	Generation		Capacity (MW)
	GWh/year	%	
Gross theoretical	n/a	n/a	n/a
Technically feasible	2800	n/a	1134
Economically feasible	1480	n/a	465
Economically feasible potential that has been developed	680	46	275
Remaining economically feasible potential	800	54	190
Remaining economically feasible potential taking into account environmental constraints	n/a	n/a	N/a

Table A2
SHP and total RES-E production in the Czech Republic [19]

	Unit	2000	2005	2010	2015	2020	2025	2030
SHP	GWh/year	520	800	1050	1050	1050	1050	1050
Total RES-E (including large hydro)	GWh/year	1710	4160	8170	9840	11 580	14 200	15 060

The bulk of SHP plants in Estonia have been constructed in the last few years. Around 93% of all generating capacity of SHP plants is in private hands.

Low head hydropower plants are the most common in Estonia. According to the gross head of SHP plants their percentage is as follows: Low head—80%; Medium head—20% and high head—0%.

Small hydro contributes only 0.32% to the electricity mix in Estonia and there are no large hydropower plants. Total hydro proportion of the renewable energy-based electricity production is dominant in Estonia at over 60%.

Table A3
Small hydropower (<10 MW) evolution and forecast in Estonia

	1997	1998	1999	2000	2001	2002	2003	Forecast	
								2010	2015
Total number of SHP	5	n/a	n/a	n/a	10	25	27	100	150
Capacity MW	0.8	n/a	1.0	n/a	1.8	3.8	4.0	16	24
Generation GWh	n/a	n/a	5.0	n/a	n/a	20	24	80	120

Table A4
Small hydropower potential in Estonia

Potential	Generation		Capacity (MW)
	GWh/year	%	
Gross theoretical	n/a	n/a	n/a
Technically feasible	210	n/a	n/a
Economically feasible	130	n/a	26
Economically feasible potential that has been developed:	24	18.4	4.0
Remaining economically feasible potential	116	81.6	22.0
Remaining economically feasible potential taking into account environmental constraints	n/a	n/a	n/a

Estonia's SHP potential is not significant and about 18% of economically feasible potential has been developed so far (Table A4).

In 2010 the SHP's installed capacity it is planned to be 16 MW and total RES-E 150 MW.

A.3. Hungary

Since 1970s there have been only a few SHP developments in Hungary. The same tendency has been kept for the past years (Fig. A2).

Almost all SHP plants in Hungary can be regarded as old ones. No new SHP plants, except refurbishment, have been constructed during the last 40 years. All SHP plants are privately owned (100%).

Low head SHP plants are the most developed in Hungary. According to the gross head of SHP plants their percentage is as follows: Low head—94%; Medium head—6% and High head—0%.

Small hydro contributes only 0.11% to the electricity mix in Hungary and total hydro contribution is also insignificant at around 0.5% of total electricity generation. Small hydro and total hydro contributions in the renewable energy-based electricity production are dominant in Hungary (17.3% and 82.2%, respectively).

The last RES potential evaluation, including small hydro, took place in 2004. The gross theoretical SHP potential of Hungary is 420 GWh/year (Table A5). The technically and

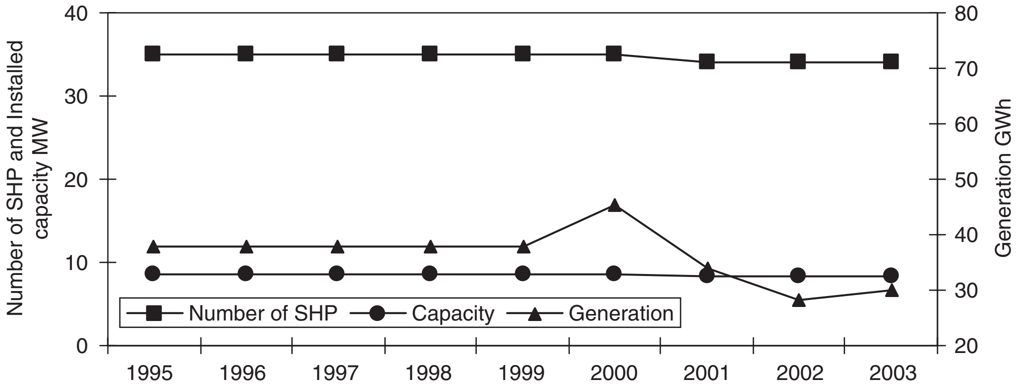

Fig. A2. SHP plants number, installed capacity (MW) and electricity generation (GWh) in Hungary.

Table A5
Small hydropower potential in Hungary

Potential	Generation		Capacity (MW)
	GWh/year	%	
Gross theoretical	420	100	100–130
Technically feasible	279	66	90
Economically feasible	68	16	22
Economically feasible potential that has been developed:	36	53	8
Remaining economically feasible potential	32	47	14
Remaining economically feasible potential taking into account environmental constraints	n/a	n/a	n/a

Table A6
National indicative targets for small and large hydro, and total RES-E in Hungary

	Unit	2003	2004	2005	2006	2007	2008	2009	2010
Small hydro-power	MW	8.4	9	9	10	11	12	13	13
	GWh/year	28	34	34	36	37	40	45	45
Large hydro-power	MW	39.5	39.5	39.5	39.5	39.5	50	60	60
	GWh/year	166	166	166	166	166	200	240	240
Total RES-E	MW	84	120	200	300	350	400	450	500
	GWh/year	197	300	550	700	850	1000	1150	1350

economically feasible potential is 279 and 68 GWh/year, respectively. So far, slightly more than a half of economically feasible potential (or 53%) has been developed.

Due to the insignificant remaining economically feasible potential a slight growth of SHP is foreseen in the future in Hungary (Table A6).

A.4. Latvia

There is a very impressive upward trend of number of SHP plants (Fig. A3). However, the forecasted figures for 2010 (and even for 2015 according to the survey's estimates) are not as remarkable as previous years (Table A8).

All Latvian SHP plants are regarded as recently built. The percentage of generating capacity (MW) privately owned for SHP plants in Latvia is 93%.

Low head SHP schemes are prevailing in Latvia. According to the gross head of SHP plants their percentage is as follows: Low head—66%; Medium head—33% and high head—<1%.

Small hydro contributes only 0.84% to the electricity mix in Latvia but total hydro contribution is very significant at more than 70% of total electricity generation. Small hydro and total hydro contributions to renewable energy-based electricity production are dominant in Latvia (1.2% and 98.8%, respectively).

The gross theoretical SHP potential of Latvia is 1160 GWh/year (Table A7). The technically and economically feasible potential is 900 and 280 GWh/year, respectively. So far, 20% of economically feasible potential has been exploited.

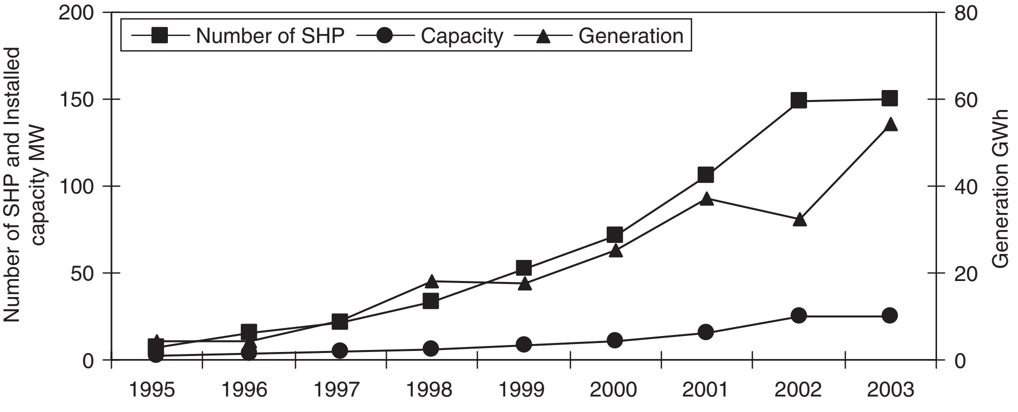

Fig. A3. SHP plants number, installed capacity (MW) and electricity generation (GWh) in Latvia.

Table A7
Small hydropower potential in Latvia

Potential	Generation		Capacity (MW)
	GWh/year	%	
Gross theoretical	1160	100	132
Technically feasible	900	78	103
Economically feasible	280	24	62
Economically feasible potential that has been developed:	55	20	25
Remaining economically feasible potential	225	80	37
Remaining economically feasible potential taking into account environmental constraints	220	78	n/a

Neither small hydro nor large hydro is expected to grow in the future in Latvia (Table A8). As above table indicates there are still remaining economically feasible potential for SHP development.

A.5. Lithuania

There is a clear upward trend for SHP plants over the reference period (Fig. A4).

Almost all Lithuanian SHP plants can be regarded as recent developments. All SHP plants are in private hands (100%).

Low head SHP schemes are prevailing in Lithuania. According to the gross head of SHP plants their percentage is as follows: Low head—51%; Medium head—43% and high head—6%.

Small hydro contributes 0.25% to the electricity mix in Lithuania and the total hydro contribution is not significant—about 3% of total electricity generation. Small hydro and total hydro contributions to renewable energy-based electricity production are dominant in Lithuania (11.2% and 88.9%, respectively).

The gross theoretical SHP potential of Lithuania is 2094 GWh/year (Table A9). The technically and economically feasible potential is 854 and 287 GWh/year, respectively. So far, 14% of economically feasible potential has been exploited.

Table A8
National indicative targets for small and large hydro, and total RES-E in Latvia

	Unit	2003	2004	2005	2006	2007	2008	2009	2010
Small hydro-power	MW	24.8	24.8	25.0	25.2	25.4	25.6	25.8	26.0
	GWh/year	54.5	54.9	55.4	55.9	56.4	57.0	57.6	58.1
Large hydro-power	MW	1547	1547	1547	1547	1547	1547	1547	1547
	GWh/year	2760	2760	2760	2760	2760	2760	2760	2760
Total RES-E	MW	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	GWh/year	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table A9
Small hydropower potential in Lithuania

Potential	Generation		Capacity (MW)
	GWh/year	%	
Gross theoretical	2094	100	239
Technically feasible	854	41	195
Economically feasible	287	13.7	65
Economically feasible potential that has been developed	41	14	15
Remaining economically feasible potential	246	86	50
Remaining economically feasible potential taking into account environmental constraints	126[a]	44	29

[a]Taking into account the consequences of the order of the Ministries of Environment and Agriculture (of 16 January 2003, No. 27/3D-13) related to the list of forbidden rivers for damming or hydropower development.

Table A10
National indicative targets for small and large hydro, and total RES-E in Lithuania

	Unit	2004	2005	2006	2007	2008	2009	2010
Small hydro-power	MW	16	21	25	28	29	30	31
	GWh/year	53	80.4	99.8	114.8	125.6	132.0	134.2
Large hydro-power	MW	101	101	101	101	101	101	101
	GWh/year	350	350	350	350	350	350	350
Total RES-E	MW	117	404.5	409.7	414.4	423	416.2	406.2
	GWh/year	n/a	439.9	521.9	579.4	659.1	784.2	931.8

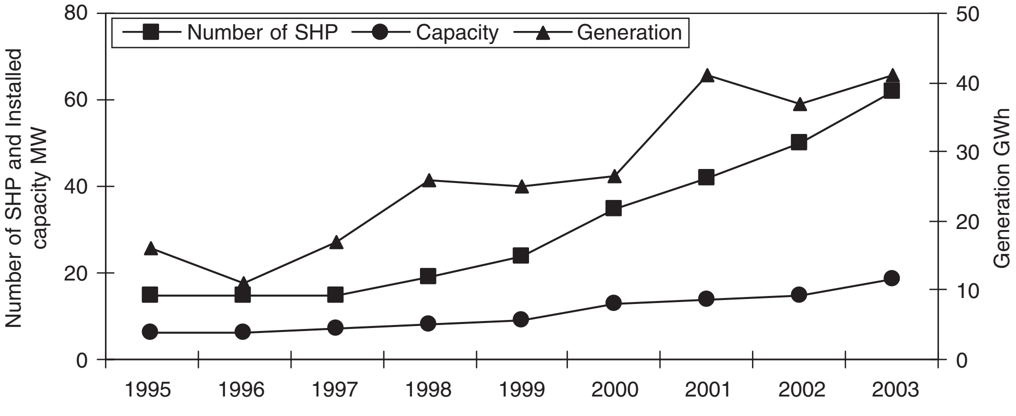

Fig. A4. SHP plants number, installed capacity (MW) and electricity generation (GWh) in Lithuania.

To comply with the EU RES-E Directive Lithuania has already adopted its targets. According to Table A10 power generation from SHP is likely to grow remarkably by 2010 (nearly 3 times when comparing with production in 2004). However the forecast based on the data given in Fig. A4 does not show so promising future for SHP, especially for electricity generation (around 70 GWh/year by 2010).

A.6. Poland

SHP development has followed a constant and an impressive upward trend over the reference period and the SHP sector will continue to grow in the future (Fig. A5).

A lion's share of the total number of SHP is recently built plants. About 15% of all plants are older than 60 years. The percentage of privately owned SHP generating capacity (MW) in Poland is about 6% (about 500 mini and micro hydroplants).

The percentage of SHP plants according to their gross head is as follows: Low head (up to 5 m)—61.8%; Medium head (5–15 m)—30.6% and High head (more than 15 m)—7.6%. Low head schemes are most common followed by medium head ones.

Small hydro contributes almost 0.6% to the electricity mix in Poland and total hydro contribution is not very significant either at only 2% of total electricity generation. Small

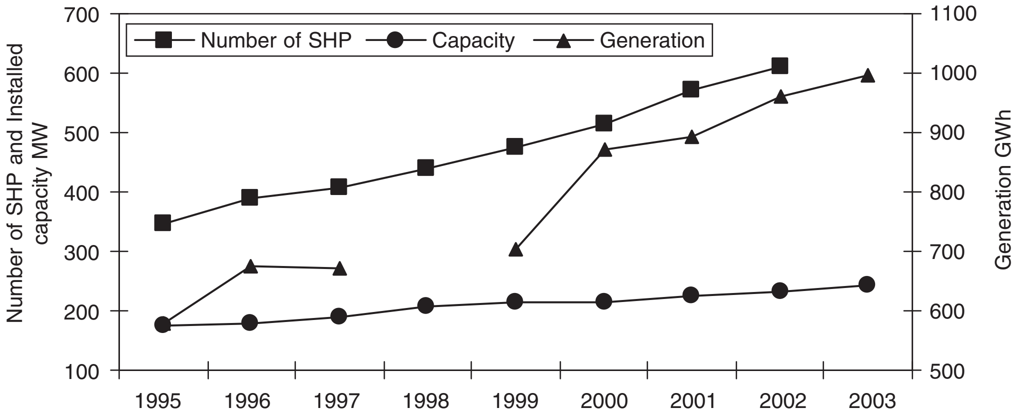

Fig. A5. SHP plants number, installed capacity (MW) and electricity generation (GWh) in Poland.

Table A11
Small hydropower potential in Poland

Potential	Generation		Capacity (MW)
	GWh/year	%	
Gross theoretical	13 400	100	n/a
Technically feasible	5050	37.7	n/a
Economically feasible	2500	26.1	605
Economically feasible potential that has been developed:	962	38.5	233
Remaining economically feasible potential	1538	61.5	372
Remaining economically feasible potential taking into account environmental constraints	1500	60.0	310

hydro and total hydro contribution in the renewable energy-based electricity production in Poland are dominant (30% and 69%, respectively).

The gross theoretical SHP potential of Poland is 13 400 GWh/year (Table A11). The technically and economically feasible potential is 5050 and 2500 GWh/year, respectively. More than a third of economically feasible potential has been developed so far.

Regardless the different estimates given in Table A12 small hydro has much more promising future than large one in Poland.

A.7. Slovakia

The statistics on SHP in Slovakia supplied by various information sources [1,7,8] differ considerably. Even the domestic energy data holders (Ministry of Economy, Energy Centre of Bratislava) are not in possession of reliable SHP data of capacity less than 10 MW. This is mainly due to the different approach of scaling SHP plants according to their installed capacity (up to 60 kW and up to 30 MW).

At the end of 2002 there were about 200 SHP plants operating with totalled installed capacity of 67 MW and power generation of 250 GWh/year. A further 35 SHP are planned

Table A12
National indicative targets for small and large hydro, and total RES-E in Poland

	Unit	2003	2004	2005	2006	2007	2008	2009	2010
Small hydro-power*	MW	280 (242)	300 (250)	320 (258)	340 (266)	360 (274)	380 (282)	400 (290)	420 (298)
	GWh/year	935 (998)	953 (1049)	972 (1100)	990 (1151)	1009 (1203)	1027 (1254)	1046 (1305)	1064 (1356)
Large hydro-power	MW	664	664	664	664	664	664	664	675
	GWh/year	1150	1150	1150	1150	1150	1150	1150	1200
Total RES-E	MW	1363	1560	1755	1950	2144	2340	2535	2730
	GWh/year	25 861	4230	5870	7515	9155	10 800	12 440	14 080

NB. Expert's predictions are given in brackets (based on extrapolation of a multiyear trend).

Table A13
Small hydropower potential in Slovakia

Potential	Generation		Capacity (MW)
	GWh/year	%	
Gross theoretical	n/a	n/a	n/a
Technically feasible	1200	n/a	n/a
Economically feasible	1000	n/a	268
Economically feasible potential that has been developed:	250	25	67
Remaining economically feasible potential	750	75	201
Remaining economically feasible potential taking into account environmental constraints	n/a	n/a	n/a

(55 MW, 240 GWh/year). A half of the total number of SHP plants in Slovakia has been constructed in the last 20 years, and 40% of all plants within the period of 20–40 years ago. Nearly a half of SHP generating capacity (30 MW) is in private hands (45%).

According to the gross head of SHP plants their percentage is as follows: Low head—50%; medium head—35% and high head—15%. Low head power plants followed by medium head are prevailing in Slovenia and high head SHP plants are relatively rare.

Small hydro contributes 0.71% to the electricity mix in Slovakia but total hydro contribution is more remarkable—around 17% of total electricity generation. Small hydro and total hydro contribution in the renewable energy-based electricity production is dominant in Slovakia (3.7% and 96.0%, respectively).

The gross theoretical SHP potential is unknown in Slovakia (Table A13). The technically and economically feasible potential is 1200 and 1000 GWh/year, respectively. So far, about a quarter of the economically feasible potential has been developed.

A.8. Slovenia

There is an upward growth trend for SHP number and electricity generation over the reference period (Fig. A6). The forecasted figures show a similar pace of SHP growth (122 MW and 132 MW in 2010 and 2015, respectively).

The bulk of Slovenia's SHP plants (or 88% of the total number) are relatively recently built, less than 20 years ago. Nearly a half of SHP generating capacity (MW) is in private hands (47.2%).

The percentage of SHP plants according to their gross head is as follows: Low head—10%; Medium head—60% and high head—30%. Medium head power plants followed by high head are prevailing in Slovenia.

Small hydro contributes 2.01% to the electricity mix in Slovenia but total hydro contribution is 10 times bigger (23.8%) of total electricity generation. Small hydro and total hydro contribution in the renewable energy-based electricity production is dominant in Slovenia (7.5% and 91.5%, respectively).

The technically and economically feasible potential is 1000 and 700 GWh/year, respectively (Table A14). So far, around 40% of economically feasible potential has been

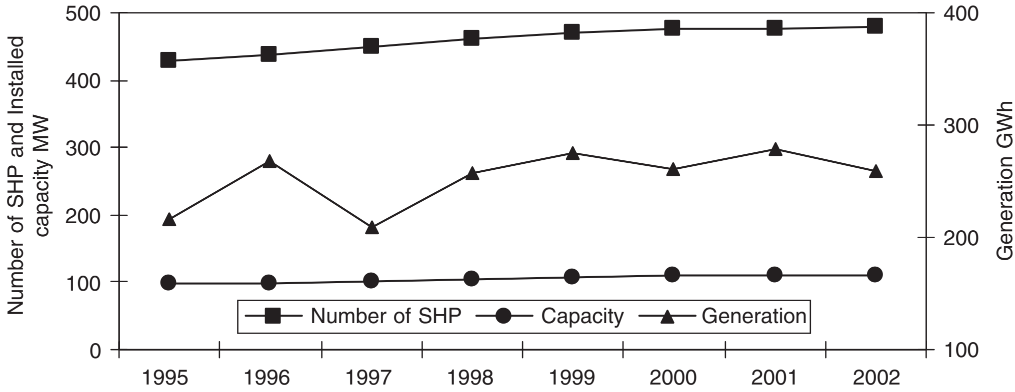

Fig. A6. SHP plants number, installed capacity (MW) and electricity generation (GWh) in Slovenia.

Table A14
Small hydropower potential in Slovenia

Potential	Generation		Capacity (MW)
	GWh/year	%	
Gross theoretical	1400	100	365
Technically feasible	1000	71	250
Economically feasible	700	50	180
Economically feasible potential that has been developed:	283	40.4	110
Remaining economically feasible potential	417	59.6	170
Remaining economically feasible potential taking into account environmental constraints	150	21.4	40

exploited. When taking into account a variety of enviromental constraints the remaining economically feasible potential (i.e. 417 GWh/year) decreases 2.8 times (150 GWh/year).

A.9. Bulgaria

The number of SHP plants and installed capacity has grown steadily over the reference period and the same pace is to be kept in the future (Fig. A7).

More than a half of all SHP plants in Bulgaria can be regarded as old ones, exceeding 40–60 years. Around a quarter were constructed as earlier as 20 years ago. Most SHP plants, according to their generating capacity, are privately owned at 84%.

The percentage of SHP plants according to their gross head is as follows: Low head (up to 5 m)—18%; Medium head (5–15 m)—18% and High head (more than 15 m)—64%.

Small hydro contributes 0.81% to the electricity mix in Bulgaria. Total hydro contribution is about 3.6% of total electricity generation. Small hydro and total hydro contributions in the renewable energy-based electricity production is dominant in Bulgaria (16.5% and 83.5%, respectively).

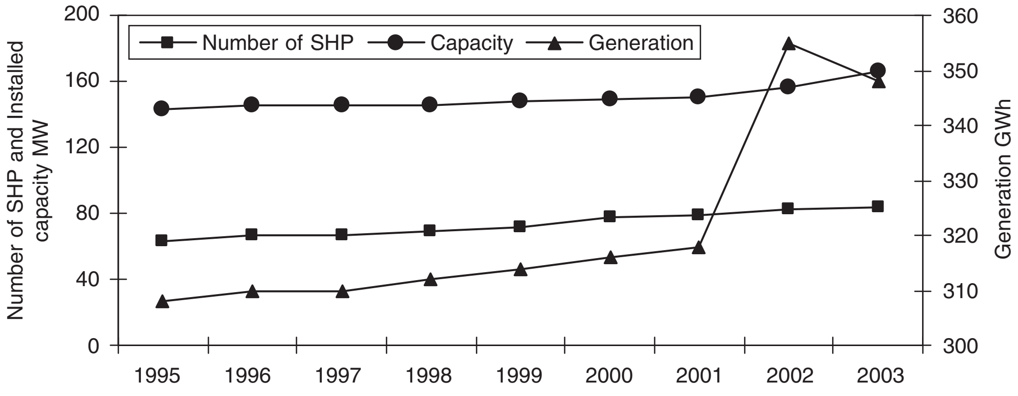

Fig. A7. SHP plants number, installed capacity (MW) and electricity generation (GWh) in Bulgaria.

Table A15
Small hydropower potential in Bulgaria

Potential	Generation		Capacity (MW)
	GWh/year	%	
Gross theoretical	1527	100	305
Technically feasible	755	49.4	240
Economically feasible	706	46.2	319
Economically feasible potential that has been developed	313	44.3	166
Remaining economically feasible potential	393	55.7	153
Remaining economically feasible potential taking into account environmental constraints	n/a	n/a	n/a

The last SHP potential evaluation took place in 1998–2000. The gross theoretical SHP potential was evaluated at 1527 GWh/year (Table A15). The technically and economically feasible potential is 755 and 706 GWh/year, respectively. So far about a half of economically feasible potential (or 44.3%) has been developed.

Bulgaria has not still joint the EU and it is not formally obliged to implement RES-E directive. Despite this the national indicative targets has been set for RES-E, including hydropower (Table A16). Small hydro is likely to double its capacity in the long-term period (2010–2014); the pace of development of large hydro will be also impressive.

A.10. Romania

After the fall of the political regime in 1989 development of RES in Romania stagnated due to decreasing investments from the public budget [14,40]. Hydropower sector, especially large hydro, has been affected enormously since it is the dominant RES in the country. There were 194 SHP plants with installed capacity of 230 MW and annual generation 322 GWh operating in 1990. Despite these difficulties SHP construction has

Table A16
National indicative targets for small and large hydro, and total RES-E in Bulgaria

	Unit	2003	2004	2005	2006	2007	2008	2009	2010
Small hydro-power	MW	166	166.26	170.34	170.5	171	n/a	251	309.8
	GWh/year	347	348	383	383	386	n/a	564	697
Large hydro-power	MW	2333	2333	2725	2725	2725	n/a	2985	2985
	GWh/year	2100	2166	2608	2608	2608	n/a	3075	3075
Total RES-E	MW	2499	2499	2895	2895	2896	n/a	3236	3294
	GWh/year	2447	2514	2991	2991	2993	n/a	3639	3772

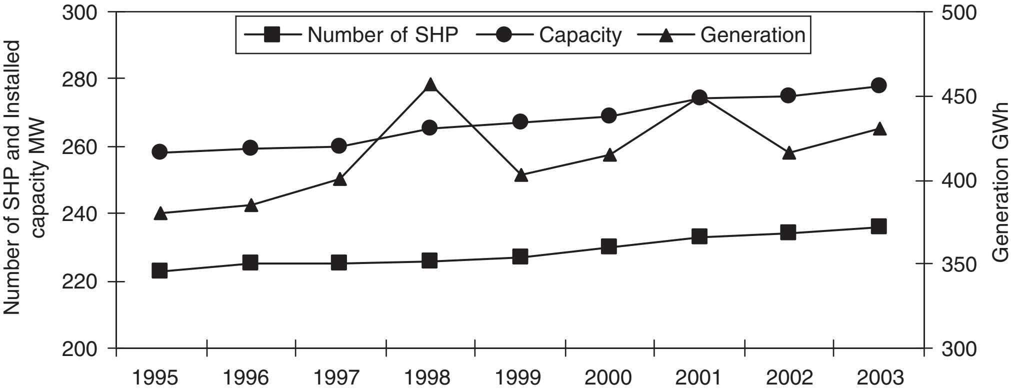

Fig. A8. SHP plants number, installed capacity (MW) and electricity generation (GWh) in Romania.

continued to keep its growing trend (Fig. A8). The forecasted figures for the installed capacity and power generation are also promising: 305 MW and 450 GWh/year by 2010, and 340 MW and 467 GWh/year by 2015, respectively.

The bulk of all SHP plants (80%) in Romania are recently built plants. They were constructed 20 years ago. The largest SHP owner is state utility HIDROELECTRICA SA. Until 2002 there were no privately owned SHP plants but their privatization has recently started.

According to SHP plants gross head their percentage is as follows: Low head—4.5%; Medium head—22.55% and high head—73%. High head SHP plants are mostly exploited in Romania.

Small hydro contributes only 0.79% to the electricity mix in Romania but total hydro contribution is more remarkable—around 30% of total electricity generation. Small hydro and total hydro contributions in the renewable energy-based electricity production are dominant in Romania (2.6% and 97.4%, respectively).

The gross theoretical SHP potential of Romania is unknown (Table A17). The technically and economically feasible potential is 3630 and 3510 GWh/year, respectively. Considerable untapped potential exists for SHP in Romania. Slightly more than 10% (12.2%) of economically feasible potential is developed so far.

Table A17
Small hydropower potential in Romania

Potential	Generation		Capacity (MW)
	GWh/year	%	
Gross theoretical	n/a	n/a	n/a
Technically feasible	3630	n/a	n/a
Economically feasible	3510	n/a	1060
Economically feasible potential that has been developed:	430	12.2	278
Remaining economically feasible potential	3080	87.8	782
Remaining economically feasible potential taking into account environmental constraints	n/a	n/a	n/a

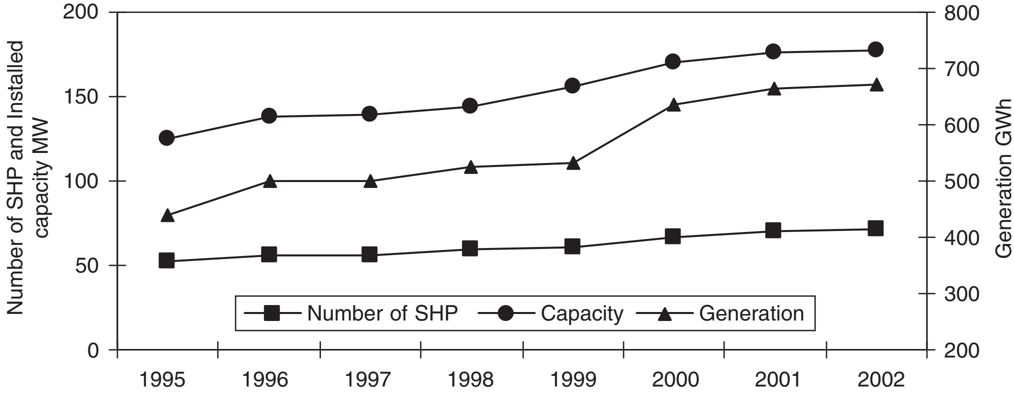

Fig. A9. SHP plants number, installed capacity (MW) and electricity generation (GWh) in Turkey.

A.11. Turkey

There is a clear growth trend for SHP plants (Fig. A9). Since 1990 SHP number and their capacity more than doubled. The same trend of SHP installed capacity and power generation is expected to be kept in the short (260 MW and 968 GWh/year by 2010) and long-term period (335 MW and 1250 GWh/year by 2015).

The bulk of all SHP plants (85%) are constructed recently in Turkey, within a period of 20 years. Around 20% of generating capacity of SHP plants are in private hands.

According to their gross head the percentage of SHP plants is as follows: Low head (up to 5 m)—0%; Medium head (5–15 m)—5% and High head (more than 15 m)—95%. High head SHP plants are mostly exploited in Turkey.

Small hydro contributes 0.52% to the electricity mix in Turkey but total hydro contribution is more remarkable—around 34% of total electricity generation. Small hydro and total hydro contribution in the renewable energy-based electricity production is dominant in Turkey (2% and 97.7%, respectively).

Only rough estimates on SHP potential can be given for Turkey (Table A18).

Table A18
Small hydropower potential in Turkey

Potential	Generation		Capacity (MW)
	GWh/year	%	
Gross theoretical	50 000	100	16 500
Technically feasible	30 000	60	10 000
Economically feasible	20 000	40	6500
Economically feasible potential that has been developed:	664	3.3	175
Remaining economically feasible potential	19 336	96.7	6325
Remaining economically feasible potential taking into account environmental constraints	~19 300	96.7	6325

The gross theoretical SHP potential of Turkey is 50 000 GWh/year. The technically and economically feasible potential is 30 000 and 20 000 GWh/year, respectively. Consequently, a huge untapped potential exists for SHP in Turkey. Only 3.3% of economically feasible potential is developed so far.

References

[1] Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market. Official Journal of the European Communities, 27 October 2001, L283/33.

[2] Pelikan B. SHP engineering: a new approach and a key for the future. Int J Hydropower Dams 2005;12(3):57–60.

[3] ESHA, Lithuanian Hydropower Association. Small hydropower situation in the new EU Member States and Candidate Countries. Thematic Network on Small Hydropower (TNSHP), 2004 (Available from http://www.esha.be/).

[4] Punys P. Small hydropower in the new EU Member States. In: Proceedings of the international conference "HIDROENERGIA 2004", ESHA and SERO, Falkenberg, Sweden, 17–19 June 2004 (CD).

[5] Punys P, Laguna M. Small hydropower has to much to offer. Renew Energy World 2005;8(5):154–9.

[6] ESHA, SERO, IEFE. Blue energy for a green Europe (BlueAGE). Strategic study for the development of small hydropower in the European Union. Report of Altener Programme. Brussels: ESHA; 2001 (Available from http://www.esha.be/).

[7] The International Journal on Hydropower & Dams. 2002 and 2003 World Atlas & Industry Guide. Aqua-Media International Ltd, 2002 and 2003.

[8] World Energy Council. 2004 survey of energy resources, 20th ed. Amsterdam: Elsevier; 2004.

[9] Black and Veatch. Strategic assessment of the potential for renewable energies in EBRD countries of operation. Black and Veatch, April 2003 (Available from http://www.ebrdrenewables.com/sites/renew/default.aspx).

[10] Eurostat. Unpublished data on SHP Statistics in the Accession countries, 2003.

[11] IEA. Renewables information. IEA Statistics (2002 edition).

[12] WWF. Progress report on the EU Renewable Electricity Directive in Accession countries. Gland, Switzerland, January 2004.

[13] EREC. Renewable energy policy review in Accession countries. A series of 9 reports with collaboration of local partners in Accession countries/New Member States (Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia), May 2004 (Available from http://www.erec-renewables.org/projects/proj_res_eu_cc.htm).

[14] Reich D, editor. Handbook of renewable energies in the European Union. II—Case studies of all accession states. Frankfurt am Main, 2003.

[15] ESHA. Report on small hydropower statistics. General overview of the last decade (1990–2001), 2003.
[16] ESHA. TNSHP: political aspects related to SHP. ESHA working paper, 2004.
[17] Bechberger M, Reiche D. Europe banks on fixed tariffs. New Energy 2005;2(April):14–7.
[18] Beutin P. An integrated approach to SHP development: from R&D to market deployment. Int J Hydropower Dams 2005;12(3):68–9.

Further references (individual countries)

The Czech Republic

[19] The State Energy Concept approved by the Czech Government on 10 March 2004 (Resolution No. 211).
[20] Renewable energy sources and the possibilities of their use in the Czech Republic. Edition: CEZ, Prague; 2003 (in Czech).
[21] Tosnar J, Krejci A. Innovative exploitation of hydropower potential. In: Proceedings of the conference "Hydro 2000", 2–4 October 2000, Bern, Switzerland, p. 37–40.

The Baltic States (Estonia, Latvia and Lithuania).

[22] Jablonskis J, Jarockis A, Punys P. Hydropower primary potential of Lithuanian rivers. Water Manag Eng 2004; 25(45)1: 88–98 [in Lithuanian].
[23] Streimikiene D, Burneikis J, Punys P. Review of renewable energy uses in Lithuania. Renew Sustain Energy Rev 2005;9:29–49.
[24] Baltic Environmental Forum. Renewable energy sources in Estonia, Latvia and Lithuania. Strategy and policy targets, current experiences and future perspectives. Riga, Latvia, 2003.
[25] Saks A, Velner H-A, Parnapuu M. Estonian hydropower and environment. In: Proceedings of the international conference "Hidroenergia 2004", Falkenberg, Sweden, 17–19 June 2004, p. 8 (CD).
[26] Velner H-A. Small hydropower in Estonia. In: Proceedings of the international conference on small hydro, 23–25 May 2001, Kaunas, Lithuania, p. 1/37–1/40.
[27] Silke K, Strubergs Y. Small hydropower in Latvia. In: Proceedings of international conference on small hydro, 23–25 May 2001, Kaunas, Lithuania, p. 1/59–1/64. [in Russian].
[28] Burneikis J, Punys, Zibiene G. Hydropower development and environmental requirements in Lithuania. In: Conference proceedings "Hydropower in the new millennium", 20–22 June 2001, Bergen, Norway, p. 207–14.
[29] Punys P, Ruplys B, Vansevičius A. Prospects for installing small hydro at existing dams in Lithuania. In: Proceedings of the conference "Hydropower into the next century-III", 18–20 October 1999, Gmunden, Austria, p. 99–107.

Poland

[30] Kulagowski W. Hydropower engineering in Poland—present state and development perspectives. Gospodarka wodna (Water Management), vol. 3, 2001 [in Polish].
[31] Reymann Z, Steller K, Litorowicz J. Activities of the Polish Academy of Sciences. Institute of Fluid-Flow Machinery Concerning Development of Small Water Power Plants; 1989, 90/91. p. 149–71.
[32] Hoffmann M, editor. Małe elektrownie wodne. Poradnik, Nabba Sp. z O.O, Warszawa, 1991 [in Polish].
[33] Steller K, Steller J. Research and development activity on small hydropower in Poland. Energy Sources 1993;15:37–49.
[34] Ministry of Environment of Poland. Development strategy of renewable energy sector. Presentation of major topics; 2002.
[35] Steller J. Problems of hydropower industry development. Arch Energetiki 2003;XXXII(3–4):35–69 [in Polish].

Slovakia

[36] Breza P. Realised and prepared Slovak small hydropower. In: Proceedings of the international conference "Hidroenergia 99", 11–13 October 1999, Vienna, Austria, p. 8 (CD).

[37] European Commission and Energy Centre Bratislava. Energy sector of Slovakia. January 2001.

Slovenia

[38] Jerkovic B, Mravljak J, Plavcak V. Male hidroelektrarne (small hydropower stations), Ministry for Economic Affairs, Maribor, 1996 [in Slovenian].

[39] Maksic R, Gospodinjacki M. The programme of using renewable energy sources—part I—Hydroenergy, Report No. 1486, EIMV Hajdrihova 2, Ljubljana, Slovenia, 2000 [in Slovenian].

Romania

[40] Taiachin A, Ionesku C. Small hydropower in Romania: a critical point of view. In: Proceedings of the conference "Hidroenergia 95", 18–20 September 1995, Milan, Italy. p. 99–105.

[41] Moclinda A, Gheorghiesku P, Bucuta R. Romania 2000: searching business opportunities in the existing "unfinished" hydropower schemes. In: Proceedings of the conference "Hydro 2000. Making hydro more competetive", 2–4 October 2000, Bern, Switzerland, p. 41–50.

[42] Moclinda A, Gheorghiescu P, Bucuta R. Hydropower generation under the new energy market conditions in Romania. In: Proceedings of the conference "Hydro 2002. Development, management, performance", 4–7 November 2002, Kiris, Turkey, p. 767–76.

Turkey

[43] Adiguzel F, Tutus A. Small hydroelectric power plants in Turkey. In: Proceedings of the conference "Hydro 2002", 4–7 November 2002, Kiris, Turkey. p. 283–93 (pub. The International Journal on Hydropower & Dams).

[44] Orhon M, Pasin S, Naderer R. Dam and hydropower potential in Turkey. In: Proceedings of the conference "Hydropower into the next century—III", 18–20 October 1999, Gmunden, Austria, p. 21–9 (pub. The International Journal on Hydropower & Dams).

[45] Kaygusuz K. Hydropower potential in Turkey. Energy Sources 1999;21(7):581–8.