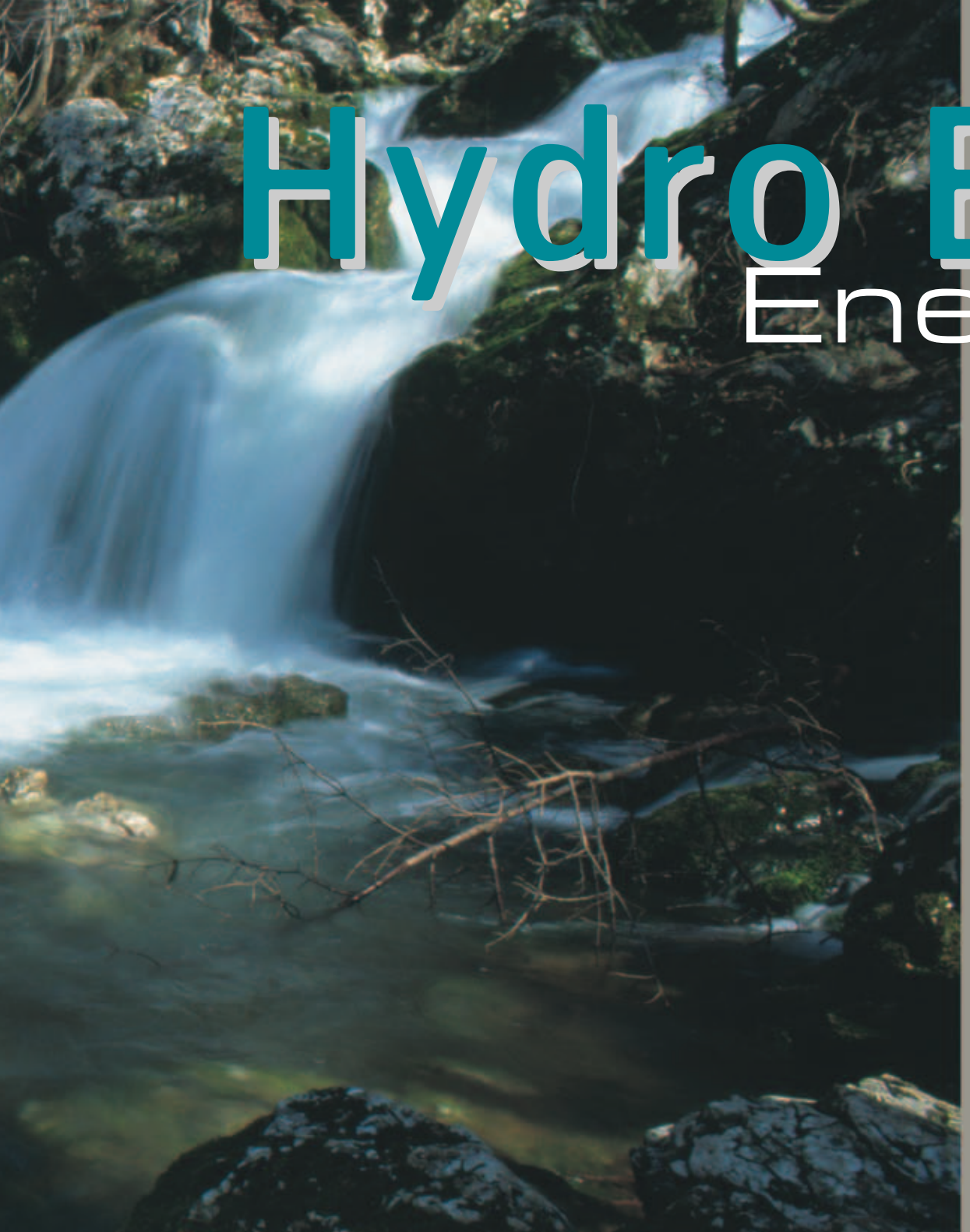

Hydro Energy

Energija vode

Hydroelectric power

Through the ages, the force of falling water has been animportant source of power and Energy for the mankind. The origins of waterwheels can be traced back to the ancient Egypt, Persia and China where they were used for irrigation as well as grinding grain or flour. At the end of the last century and the beginning of this century, the primary objective in developing hydropower was to utilize it through a mechanical drive to the driven machinery. These devices consisted of ropes, belts and some types of gear trains. The early hydraulic units were relatively small and their outputs rarely exceeded few hundred kilowatts. Even today, hydropower remains a significant source of electricity in all parts of the world. Tremendous strides have been made in the field of hydro-dynamics in order to develop and improve the equipment to meet increasingly complex requirements of larger and larger hydroelectric power plants.

The increase in gas and oil prices in all countries, and the increased concern about adverse environmental impacts of coal burning and nuclear energy, have improved the relative attractiveness of small scale hydro. Similar concerns are now visible in many industrialized and developing countries. This has resulted in a renewed interest in abandoned small hydro sites in various parts of the world accompanied by the development of modern hydro turbines, which can work under low head and small flow conditions.

Small hydropower projects include those installations that have low head (generally under 40 meter) and small capacity (nominally under 15,000 kW). Hydroelectric power is obtained in two stages: the potential energy in the water is first converted into mechanical energy by causing it to flow through and thereby rotate a hydraulic turbine, and then into electric energy by means of a generator driven by the rotating turbine. The electrical energy produced by such a system depends on the flow of available water, and the difference in elevation between the source of water flow and the location of discharge after passing through the generating station. This difference is called the head (H) of the plant. Most hydroelectric facilities require construction of a dam. The dam provides the means

Hidroelektrična energija

Hidroenergetski potencijal vodotokova predstavljao je vekovima važan izvor energije, a tragovi korišćenja vodotokova mogu se pratiti još od drevnog Egipta, Persije i Kine, gde su korišćeni za navodnjavanje kao i za mlevenje zrnevlja i pravljenje brašna. Na kraju devetnaestog i početkom dvadesetog veka osnovni cilj razvoja hidroenergije bio je mehaničko pokretanje mašina korišćenjem kaiševa, konopaca i prenosnih zupčanika. U ranoj fazi eksploatacije hidroenergetskih potencijala generisana električna energija retko je prelazila nekoliko stotina kilovata. Čak i danas hidroenergija predstavlja važan izvor električne energije u svim krajevima sveta. Veliki napredak je učinjen u razvoju i poboljšanju opreme u cilju zadovoljavanja sve kompleksnijih zahteva koje postavlja rad i održavanje sve većih hidroelektrana, tako da danas hidroelektrične instalacije služe milionima ljudi širom sveta.

Povećanje cene nafte u svim zemljama i povećana zabrinutost o negativnim uticajima sagorevanja uglja, nuklearne energije, pa i velikih hidroelektrana, na prirodnu okolinu, povećali su zanimanje za korišćenje hidroenergetskog potencijala malih vodotokova u raznim delovima sveta. To je uslovilo razvoj modernih hidro turbina, koje mogu da rade pod uslovima malih protoka i malih padova vodene mase.

Projekti koji podrazumevaju korišćenje hidroenergetskog potencijala malih vodotokova uključuju one instalacije koje imaju mali pad (obično ispod 40 metara) i mali kapacitet (nominalno manje od 16 000 kW). Hidroelektrična energija se dobija kroz dve faze. U prvoj fazi potencijalna energija vodene mase pokreće hidrauličnu turbinu i pretvara se u mehaničku energiju, a u drugoj fazi ova mehanička energija pokreće generator koji je pretvara u električnu energiju. Snaga generisane električne energije zavisi od protoka vodene mase i razlike u nivou između izvora vodotoka i ispusta akumulacije (pad).

Većina hidroelektričnih instalacija zahteva izgradnju brane koja omogućava regulaciju vodotoka, ali i povećanje pada. Vodeni rezervoar koji stvara brana može da akumulira i

to regulate the flow of water, and can add to the height of the source of water, thereby effectively increasing the head (H). The reservoir created by the dam may store and regulate stream flows to make them timelier for power production, and to serve other purposes for water resource development. The main facilities of the powerhouse are the hydraulic-mechanical works consisting of turbines, upstream waterways (known as the penstock), and the downstream discharge channels with appropriate valves and gates to control the water flow. In addition, there is the electrical installation, consisting of generators, transformers, switchgear and the control equipment. The current trend in small hydro is to take advantage of the dam and existing flow release patterns at a site to avoid the technical and environmental complexities that could develop from altering water use, release patterns, and increasing the storage behind the dam. Small hydropower plants offer several advantages: facilities are small and can be both environmentally and aesthetically acceptable; effects upon stream ecology are minor compared to those caused by large hydroelectric facilities. In some cases, small dams may, in fact, enhance streams by maintaining water depths sufficient to support aquatic life. It appears that after years of experimentation in many countries, small-scale hydropower is becoming an attractive and environmentally acceptable source for electricity in many parts of the world. Costs are comparable to new coal and nuclear capacity, and the impact of new dams (if necessary) appears to be minimal in relation to large-scale hydropower projects. The inability and unwillingness of many countries to invest in large-scale projects with long lead times, revived interest in renewable energy technologies. Also, concerns about global warming have made small scale hydropower a very important contender in the electricity generation game.

Small-scale hydroelectric potentials of Serbia

The total estimated hydroelectric potential of Serbia is around 31 000 GWh per year. The major part of that potential (around 62%) is already exploited since favorable economic and cost effective indicators justify the construction of large capacity facilities. The rest of the hydro potential may be exploited through the construction of small and more expensive systems. Some estimates of the small-scale hydropotential which encompasses micro and mini hydroelectric power plants under 10 MW, indicate that small scale water resources offer capacities of around 500 MW and annual power generation of 2 400 GWh. Half of that potential is located in the region near Užice, Niš and Kragujevac,

reguliše vodotok i da ga pripremi za upotrebu u energetske svrhe, kao i da služi drugim svrhama za razvoj vodenih resursa. Osnovni deo hidrocentrala je hidromehanički sistem, koji se sastoji od turbina, uzvodnih i nizvodnih vodotokova koji se kanališu i kontrolišu regulacijom protoka. Pored toga postoji električni sistem, koji se sastoji od generatora, transformatora, prekidača i kontrolne opreme. Trenutni pravac razvoja malih hidroelektrana podrazumeva da se iskoristi brana i postojeći vodotokovi kako bi se izbegli problemi koji mogu da se jave usled promene upotrebe vodotokova, odvodnih puteva i povećane akumulacije iza brane. Male hidroelektrane pružaju određene prednosti u tom smislu jer je instalacija relativno mala i može da bude i estetski i ekološki prihvatljiva. Efekti na prirodnu okolinu su zanemarljivi u poređenju sa sličnim efektima koje prouzrokuju velike hidroelektrane. U nekim slučajevima brane mogu da povećaju protok održavajući dovoljnu dubinu vodotokova koji mogu biti dovoljni za održavanje vodenog života. Izgleda da, posle mnogo godina eksperimentalnog rada u mnogim zemljama, male hidroelektrane postaju sve atraktivnije i ekološki prihvatljive u mnogim delovima sveta, dok je njihova cena konkurentna novim termo i nuklearnim elektranama, a uticaj novih brana na okolinu je minimalan u poređenju sa velikim hidroelektričnim projektima.

Energetski potencijal malih vodotokova u Srbiji

Ukupni hidropotencijal Srbije procenjen je na oko 31.000 GWh godišnje. Veći deo tog potencijala (oko 62%) je već iskorišćen jer je ekonomski opravdano građenje većih proizvodnih kapaciteta. Ostatak hidropotencijala je iskoristiv gradnjom manjih i skupljih objekata posebno ako se računa na mini i mikro elektrane. Neke procene potencijala malih hidroelektrana, koje uključuju mini i mikro elektrane na preko 1000 mogućih lokacija sa instalisanom jediničnom snagom ispod 10 MW, kazuju da je na malim vodotokovima moguće ostvariti ukupnu instalisanu snagu od oko 500 MW i proizvodnju 2.400 GWh/god. Od toga se polovina (1.200 GWh/god.) nalazi u Užičkom, Niškom i Kragujevačkom regionu, gde može da bude korišćen u brojnim malim postrojenjima sa ukupnom instalisanom snagom od oko 340 MW raspoređenom na oko 700 lokacija.

Budući da je naš preostali neiskorišćeni hidropotencijal značajnim delom u opsegu male hidroenergetike, taj deo je i posebno izučavan. Izrađen je i katastar malih hidroelektrana za jedinične snage ispod 10 MW. Rezultat je iskazan u ukupnoj instalisanoj snazi od 453

where it can be utilized by numerous small-scale power plants with the total capacity of around 340 MW, distributed to around 700 locations.

A registry containing information on small-scale, less than 10 MW, hydroelectric power plants distributed to 868 locations shows that the total installed power is 453 MW and that annual power generation is around 1600 GWh. Table 1 contains distribution of small scale hydroelectric power units from 90 kW to 8 500 kW that could be constructed at various locations provided that accumulation of close to 1.2 billion cubic meters of water is feasible. At this moment only 31 small-scale (mini) hydroelectric power plants are in operation, whose total installed power is 34 654 MW with an annual production of 150 GWh, while out of operation are 38 small-scale installations of 8 667 MW total power and 37 GWh in annual production. Considerable opportunities exist for embedding small-scale hydroelectric plants into existing hydroelectric power facilities, which may also lower the construction and maintenance costs.

Effects of small-scale hydro on energy industry

Taking into account small-scale hydro potential and prospective for constructing small-scale power plants, it is possible to determine their effects on the energy industry sector at large, as presented in Table 5.

Investing in this energy sector will depend on government initiatives and state subsidies for renewable energy research and development. Also, legislative rules and regulations should be made to attract private capital.

Contribution of small-scale hydroelectric power plants to the energy industry

The total power produced

Table 5. Total energy effects of small scale hydro in Serbia

Categories of small scale hydro power plants	Installed power (kW)	Production MWh/year
1. New units from the small-scale hydro (SSH) registry	442 632	1 544 985
2. Embedding of SSH units into existing HE sytems	23 464	114 530
• SSH at outlets for biological minimum	1 064	7 500
• SSH at water supply units	7 000	35 000
• SSH in irrigation systems	3 000	11 000
• SSH as parts of the DTD system	10 400	54 030
• SSH at river basin transitions	2 000	7 000
3. Reconstruction of existing systems	25 769	134 000
• Reconstruction of existing SSH plants	8 769	54 000
• Embedding of SSH into wind mills	10 000	45 000
• Regeneration of existing SSH	7 000	35 000
4. Total	491 865	1793 515

MW i prosečnoj proizvodnji od 1.600 GWh/god. na oko 868 lokacija. U tabeli je prikazan raspored potencijala malih vodotokova za jedinične snage od 90 kW do 8.500 kW, koje je moguće izgraditi uz formiranje akumulacija za 1,2 milijardi kubnih metara vode.

Danas je u pogonu samo 31 mini hidroelektrana ukupne snage 34,654 MW i godišnje proizvodnje od 150 GWh. Van pogona je 38 mini hidroelekrana ukupne snage od 8.667 MW i procenjene godišnje proizvodnje od 37 GWh. Ove male HE mogu se osposobiti za pogon uz ulaganje koje je zavisno od stanja u kome se nalaze. Postoje značajne mogućnosti ugradnje malih hidroelektrana u postojećim vodoprivrednim objektima, koje se takođe karakterišu znatno nižim troškovima.

Ukupni energetski efekti gradnje malih hidroelektrana

Sagledavajući energetske potencijale malih vodotokova i mogućnosti izgradnje malih hidroelektrana na njima moguće je utvrditi njihove ukupne energetske efekte kako je prikazano u tabeli 5.

Ulaganja u ove kapacitete zavisiće od državnog podsticanja gradnji energetskih kapaciteta na bazi obnovljivih izvora energije shodno zakonskoj regulativi koja bi trebalo da privuče kapital privatnih investitora.

Tabela 5: Ukupni energetski efekti malih hidroelektrana u Srbiji

Kategorija malih hidroelektrana	Instalisana snaga kW	Proizvodnja MWh/god.
1. Novi objekti iz katastra malih HE	442.632	1.544.985
2. Ugradnja HE u objekte vodoprivrede	23.464	114.530
• HE na ispustu za biološki minimum	1.064	7.500
• HE na objektima vodosnabdevanja	7.000	35.000
• HE u sistemima navodnjavanja	3.000	11.000
• HE u sklopu sistema DTD	10.400	54.030
• HE na prebacivanju voda iz sliva u sliv	2.000	7.000
3. Obnova postojećih objekata	25.769	134.000
• obnova postojećih malih HE	8.769	54.000
• Ugradnja HE u vodenice	10.000	45.000
• Revitalizacija postojećih HE	7.000	35.000
4. Ukupno	491.865	1.793.515

Učešće malih hidroelektrana u elektroenergetskom sistemu

Elektroenergetski sistem Srbije ima na raspolaganju ukupni neto instalisani kapacitet od 8.789 MW, od čega u termoelektranama 5.608 MW (63,8%) i u hidroelektranama 3.181 MW (36,2%). Ukupna godišnja proizvodnja električne energije u 2000. godini bila je 31.564 GWh. Ukoliko bi svi kapaciteti

Micro hidro plant of 20kW on Albin river, Serbia
Mikro hidrocentrala od 20kW na Albinskoj reci, Srbija

by the energy industry in Serbia is 8 789 MW, of which thermal power plants produce 5 608 MW (63.8%) and hydroelectric power plants 3 181 (36.2%). The total annual production in 2002 was 31 564 GWh. If all projected and planned small-scale hydro units were constructed and operating, with existing facilities remaining unchanged, small scale hydro would share the energy market with only 5.3%. However a significant increase in consumption and price of electrical energy is expected by 2010, thus opening new investment possibilities for private shareholders.

Preparations for construction of new and reconstruction of existing facilities is in progress. The 51 MW hydroelectric power plant "Brodarevo" with an average annual production rate of 190 GWh is expected to start operating in 2008. Also, 46.7 MW hydroelectric plant "Ribarići", expected to deliver 76 GWh annually, will be built in the northern basin of river Ibar. Several projects are planned involving restructuring of existing facilities and improving water accumulation capacities.

Preparation and construction of hydroelectric plants is a long and laborious process and, since private investment funds are not expected to grow at a satisfactory rate, it is expected that only one half of planned small scale hydro projects will be realized in the next ten years. Moreover, there are several locations which require large-scale hydro facilities which are specifically less expensive, and by the year 2010 several new large-scale installations of total capacity of over 1000 MW will start operating in order to diminish energy shortage and avoid foreign electricity imports.

Although less important in the energy sense, contribution of small-scale hydro to the energy industry is strategically much more important, both from the aspect of reliability and flexibility of operation, as well as from the aspect of enhanced economic opportunities for local residents. Moreover, the technology of power generation is essentially non-polluting and releases no heat, such that adverse environmental impacts are negligible and, for small installations, may be totally eliminated.

Economic effects of small-scale hydro development in Serbia

Investment and direct economic effects

As mentioned earlier, small-scale, less than 10 MW, hydroelectric power plants may be built on 868 locations generating projected power of 453 MW with the annual production rate of around 1600 GWh. Production of this amount of energy in thermal power plants would require 2.3 million tones of lignite or 400 000 m3 of imported natural gas. Small-scale hydro industry could therefore generate savings of close to $US 52 million. In order to put into effect such an ambitious plan, it is necessary to obtain a high quality historical database comprising stream flow records and other hydrological data for a number of years, detailed information concerning topological characteristics of the terrain etc, in order to make an adequate choice of hydraulic turbines, electrical and mechanical equipment. The economic feasibility of a small hydro development depends on a favorable combination of site topography, hydrology, location and market conditions. Currently, such databases are not available so it is hard to asses the investment opportunities.

Indirect economic effects of small hydro development

Hydropower generation is a non-consumptive, utilizing renewable resource, which is made continually available through the hydrological cycle by the energy of the sun. It is

planiranih malih hidroelektrana bili izgrađeni, a postojeći kapaciteti ostali nepromenjeni, relativno učešće malih hidroelektrana u ukupnoj instalisanoj neto snazi bilo bi samo 5,3%.

Međutim, u periodu do 2010. godine računa se na rast potrošnje i cena električne energije, što može da prouzrokuje povećanje interesovanja privatnih investitora za gradnju novih kapaciteta.

U toku je priprema gradnje novih i povećanje snage postojećih hidroelektrana. Protočna hidroelektrana „Brodarevo“ treba da bude u pogonu od 2008. godine, a njena predviđena instalisana snaga je 51 MW sa prosečnom godišnjom proizvodnjom od 190 GWh. U gornjem toku Ibra gradiće se elektrana „Ribarići“ snage 46,7 MW i proizvodnje od 76 GWh/god. Na još nekoliko objekata će se izvršiti povećanje instalisane snage ili povećanje dotoka i akumulacija vode.

Priprema i gradnja hidroelektrana je dug proces, a investiciona sposobnost privatnih investitora neće brzo rasti pa se očekuje da u sledećih desetak godina bude realizovano maksimum polovina potencijala malih vodotokova. Na manje interesovanje za male hidroelektrane utiče i to što postoji značajan deo neiskorišćenog hidropotencijala za gradnju većih kapaciteta koji su specifično jeftiniji.

Na taj način relativno učešće malih hidroelektrana bi bilo još manje, tim pre što se do 2010. godine računa na puštanje u pogon novih kapaciteta termoelektrana preko 1.000 MW da bi se domaćom proizvodnjom mogla podmiriti potrošnja i izbegao uvoz električne energije.

Međutim, iako manje značajan u energetskom smislu, značaj malih hidroelektrana je strateški mnogo veći, kako sa stanovišta sigurnosti snabdevanja lokalnih potrošača električnom energijom proizvedenom iz obnovljivih izvora koji ne ugrožavaju životnu sredinu za razliku od velikih sistemskih termoelektrana na ugalj, tako još više sa stanovišta zapošljavanja domaćih kapaciteta za proizvodnju opreme i izvođenje radova.

Ukupni ekonomski efekti gradnje malih hidroelektrana u Srbiji

Investicije i direktni ekonomski efekti gradnje malih hidroelektrana

Energetski značaj procene registrovanog hidropotencijala vodotokova na teritoriji Srbije ukazuje da je moguće izgraditi 867 malih hidroelektrana ukupne instalisane sna

non-polluting and releases no heat. Even small hydro installations replace fossil fuel exploitation (close to 1.4kg per each kWh of produced electricity) or the use of natural gas. In the remote areas, using relatively simple technology small hydro industry can be a catalyst in mobilizing productive resources and creating improved economic prospects for local residents. Small hydro usually provides more local employment in construction of civil works than in case of large-scale projects.

Dynamics of small hydro development

Present economic situation in Serbia is unfavorable for investments in the renewable energy industry and this may cause increased dependence on fuel imports in the future leading the country into extensive debts. Considering the circumstances, it is reasonable to predict that only a smaller part (10%-15%) of the available hydro resources will be utilized by 2005, while by the end of 2010 the exploitation level may reach 40%-60%.

The fact that hydro development requires large initial investment clearly calls for a strong government initiative both in the economic as well as legislative sector. Economic feasibility is improving when compared to other fossil fuel-based energy systems and, with more efficient economic evaluation methods, small hydropower should become increasingly desirable. The scope should include facts such as full recognition of the value of non consumptive water use, reduced or completely eliminated fuel import dependence, minimal environmental impact, as well as new job opportunities. As the energy price is expected to increase considerably in the future, the role of direct economic effects, on the other hand, may significantly increase in the next 50 years, and therefore make the small hydropower even more attractive now.

ge 453 MW i godišnje proizvodnje od 1.600 GWh. Za ovaj obim proizvodnje električne energije u termoelektranama bi trebalo da se utroši 2,3 miliona tona lignita ili 400.000 m^3 prirodnog gasa iz uvoza. Male hidroelektrane bi ovako gledano uštedele godišnje oko 52 miliona USD. Da bi se ostvario ovako ambiciozan plan potrebno je za svaku pojedinačnu lokaciju nužno raspolagati odgovarajućom tehničkom dokumentacijom koja obuhvata detaljnu analizu svih karakteristika, kako bi bio obezbeđen najbolji izbor agregata, mašinske i elektro opreme. Na taj način bi se dobio najbolji odnos ulaganja sredstava u opremu i građevinske radove. Takva dokumentacija za sada ne postoji za ove objekte pa je zbog toga teško proceniti mogućnost investiranja.

Indirektni ekonomski efekti gradnje malih hidroelektrana

Polazeći od toga da za pogon koristi obnovljiv izvor energije, svaka, pa i mala hidroelektrana zamenjuje potrošnju uglja (oko 1,4 kg po svakom kWh proizvedne električne energije) ili prirodnog gasa, te je u funkciji održivog razvoja ne samo u pogledu očuvanja postojećih prirodnih resursa, već i u pogledu zaštite životne sredine od emisije oksida sumpora i azota i oksida ugljenika. Ovi gasovi sa efektom staklene bašte izazivaju globalno zagrevanje i prete da izazovu nepovratni proces promene klime na Zemlji.

Značajni ekonomski efekti gradnje malih hidroelektrana mogu nastati i zbog relativno velikog domaćeg učešća radne snage i industrije, praktično bez uvoza opreme iz inostranstva. Domaće učešće u ovakvim malim projektima je mnogo verovatnije i veće nego što je u slučaju velikih postrojenja.

Dinamika i efekti gradnje malih hidroelektrana

Ekonomska situacija u Srbiji ne ide na ruku razvoju i investiranju u obnovljive izvore energije i to će se odraziti u budućnosti povećanim uvozom energenata i većim zaduživanjem. U takvoj situaciji do 2005. godine mogao bi da bude priveden eksploataciji samo jedan manji deo (10 - 15%), a do 2010. godine još 40 - 60% raspoloživog hidro potencijala.

The turbine of a micro power plant of 20 kW
Turbina mikroelektrane od 20 kW

Sama činjenica da se radi o relativno velikim početnim ulaganjima jasno ukazuje da je inicijativa države neophodna i da je prvenstveno potrebno doneti i sprovesti zakonsku regulativu uz finansijski podsticaj. Državi treba da bude najveći interes upravo u indirektnim efektima koji će se ogledati u smanjenju uvoza električne energije, korišćenje obnovljivih izvora energije radi čuvanja neobnovljivih i smanjenja zagađivanja životne sredine, regulisanje vodotokova i zapošljavanje domaće industrije. Cena električne energije u Srbiji u budućnosti treba znatno da poraste i tada direktni efekti u periodu eksploatacije od 50 godina mogu da budu mnogostruko veći.