SMALL HYDROPOWER FOR SUSTAINABLE ENERGY AND ENVIRONMENTAL BENEFITS: A CASE STUDY IN TURKEY

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Abstract. Hydropower throughout the world provides 17% of our electricity from an installed capacity of some 730 GW is currently under construction, making hydropower by far the most important renewable and sustainable energy for electrical power production. The contribution of small hydropower (SHP) to the worldwide electrical capacity is more of a similar scale to the other renewable energy sources, amounting to about 47 GW (53%) of this capacity is in some developing countries such as China, India and Turkey. Over the last two decades, global electricity production has more than doubled and electricity demand is rising rapidly around the world as economic development spreads to emerging economies. Not only has electricity demand increased significantly, it is the fastest growing end-use of energy. Therefore, technical, economic, and environmental benefits of hydroelectric power make it an important contributor to the future world energy mix, particularly in the developing countries.

Keywords: Small hydropower; sustainable energy; environmental benefits; energy technology

1. Introduction

Modern renewable energy technologies turn widely available but intermittent resources into usable forms of thermal, chemical, mechanical, and electrical energy. Among the renewable energy options that are currently in wide use in some regions and are now ready for large scale introduction in many areas of the developing world [1,2]. Some of these areas as follows:

- Biogas for decentralised cooking and electricity,
- Small hydropower for local electricity,
- Small wind power for water pumping and local electricity,
- Solar photovoltaic for local electricity,
- Solar collectors for water and space heating,
- Ethanol and biodiesel for agriculture and transportation,
- Large hydropower for grid electricity,
- Large wind power for grid electricity and
- Geothermal energy for heat and grid electricity

Renewable energy projects developed in scores of developing countries-many with international donor assistance-have demonstrated that renewable energy can contribute to poverty alleviation directly by providing the energy needed for creating business and jobs, turning locally available resources into productive economic assets.

Hydropower throughout the world provides 17% of our electricity from an installed capacity of some 730 GW is currently under construction, making hydropower by far the most important renewable energy for electrical power production. Approximately 70% of the earth's surface is covered with water, a resource that has been exploited for many countries.

2. Small hydropower (SHP)

Small hydropower (SHP) schemes are mainly "run of the river", with little or no reservoir impoundment, using the flow of water within the river's natural range. Run-of-river projects can use all the river flow or only a fraction of it and have limited environmental impact.

Therefore, SHP is not simply a smaller version of a large hydropower plant. Specific equipment is necessary to meet fundamental requirements with regard to simplicity, high energy output, maximum reliability, and easy maintenance by non-specialists.

To develop both small and micro hydropower schemes, the principal technical requirements are [1,3]:

- Suitable rainfall catchments area,
- Hydraulic head,
- A means of transporting water from the intake to the turbine, such as a pipe or a millrace,
- A turbine house containing the power generation equipment and valve gear and
- A tailrace to return the water to its natural course.

There is another definition of small and large hydropower. The EU definition classifies as large hydropower schemes as those with over 10 MW_e of

installed capacity, and small hydropower schemes as those up to 10 MW_e of installed capacity. The definition of small hydropower schemes also covers micro schemes (those with installed capacity up to 1 MW_e).

3. The advantages of small hydropower

Small hydropower plants combine the advantages of hydropower with those of decentralised power generation, without the disadvantages of large-scale installations. Small hydropower can be economically attractive, sometimes even offering the least-cost method of generating electricity.

Small hydropower has the ability to generate electricity instantly, to supply both base and peak load generation, has a long life is easy to maintain and is highly reliable [1,4].

In addition, small hydropower development brings prosperity and raises the standard of living due to educational facilities, public health benefits, roads, electricity power and other infrastructure developments. Table 1 shows some advantages and disadvantages of hydropower.

4. Environmental impact and cost of small hydropower

Small hydropower, especially the very small and the low-head plants, can normally only compete where allowance are made for the external costs associated with fossil fuels and nuclear power. Because SHP projects are generally considered to be more environmentally favourable and sustainable than both large hydro and fossil fuel powered plants, small-scale hydropower is more economically competitive than small-scale fossil fuel/steam-electrical power.

The capital required for small hydropower plants depends on the effective head, flow rate, geological and geographical features, continuity of water flow, equipment such as turbines and civil engineering works.

Apart from the investment and production costs, the other principal cost element is operation and maintenance, including repairs and insurance, which can account from 1.5-5% of investment costs. Both the production and investment costs differ considerably depending on the plant's head height. Small hydropower projects are generally considered to be more environmentally favourable and sustainable than both large hydro and fossil fuel powered plants.

Table 1. Advantages and disadvantages of the hydropower option

ADVANTAGES	DISADVANTAGES
Economic Aspects	
Provides low operating and maintenance costs	High upfront investment
Provides long life span (50 to 100 years and more)	Precipitation
Provides reliable service	Requires long-term planning
Includes proven technology	Requires long-term agreements
Provides highest energy efficiency rate	Often requires foreign contractors and funding
Generates revenues to sustain other water	
Creates employment opportunities and saves fuel	
ADVANTAGES	DISADVANTAGES
Environmental Aspects	
Produces no atmospheric pollutants and only very few GHG emissions	Inundation of terrestrial habitat
Enhances air quality	Modification of hydrological regimes
Produces no waste	Modification of aquatic habitats
Avoids depleting non-renewable fuel resources	Water quality needs to be managed
Often creates new freshwater ecosystems with increased productivity	Temporary introduction of methylmercury into the food chain needs to be monitored/managed
Helps to slow down climate change	Barriers for fish migration, fish entrainment
Neither consumes nor pollutes the water it uses for electricity generation purposes	Sediment composition and transport may need to be monitored/managed

Source: Ref. [5]

5. Development of Small hydropower and focus on Turkey

Development of small hydropower began in the year 1902 in Turkey. Since then, many small hydropower plants have been installed by government organisations, private sector, and local municipalities in many parts of the country [1,6,7]. In Turkey, during last three decades the average annual increase of SHP capacity was 5-10%. As of 2002, the total development of SHP capacity that is accepted as small hydropower according to the Electrical Power Resources Survey and Development Administration [8], which is less than 10 MW, in Turkey was 849,1 MW and total annual energy production was 3,623 (Table 2). At the beginning of 2004, total number of SHP plants in operation throughout the country was 62, with a total installed capacity of 190 MW, about 1.5% of the total hydropower potential in Turkey [1,9].

Table 2. Small hydropower development in Turkey

Status of SHP	Number of SHP	Installed Capacity (MW)	Energy Generation (GWh)
In operation	70	175.4	654
Under construction	6	21.7	130
In final design	7	38.8	168
Infeasibility and pre-feasibility	120	613.2	2,671
Total	203	849.1	3,623

Source: Ref. [8]

Total installed projects capacity of SHP is 2.45% and the total energy potential is about 2.96%, which have installed capacity less than 10 MW. At the end of 2004, about 96% of the all ready-exploited potential is from dams and HEPPs, and the remainder is from run-off river and canal SHP. Neglecting the geothermal, wind, and solar generation, about 65% of the electricity is produced by thermal power plants, and hydropower plants produce about 35% of the remaining electricity [10].

6. As a sustainable energy technology SHP

Small hydropower projects are generally considered to be more environmentally favourable and sustainable than both large hydro and fossil fuel powered plants. So, small-scale hydropower is more economically competitive than small-scale fossil fuel/steam-electrical power particularly if the hydro sites are located near electricity demand centres [1,11] and are truly sustainable when they 'internalize' their environmental and social costs [1,12].

Sustainable development is the management and conservation of natural resources such as land, water, plant and animal genetic resources. Some of the main objectives of the sustainable energy developments are [1,4]:

- Ensure security of energy supply,
- Maximize efficiency of generation and emphasize the use of renewable energy sources,
- Promote energy conservation by users,
- Minimize emissions of greenhouse gases and other pollutants,
- Maintain local air quality and limit and reduce the contribution to regional and global environmental issues,
- Underline economic development by creating employment and export opportunities in the energy industry and
- Ensure the availability of effective energy services for future generation.

Table 3. The comparison of energy amortization time and emissions of various energy technologies.

Technology	Energy pay back time in months	SO_2 emission in kg/ GWh	NO_2 emission in kg/ GWh	CO_2 in Ton/ GWh
Coal fired	1.0-1.1	630-1370	630-1560	830-920
Gas(CCGT)	0.4	45-140	650-810	370-420
Large hydro	5-6	18-21	34-40	7-8
Micro hydro	9-11	38-46	71-86	16-20
Small hydro	8-9	24-29	46-56	10-12
Wind turbine				
4.5 m/s	6-20	18-32	26-43	19-34
5.5 m/s	4-13	13-20	18-27	13-22
6.5 m/s	2-8	10-16	14-22	10-17
Photovoltaic				
Mono-crystalline	72-93	230-295	270-340	200-260
Multi-crystalline	58-74	260-330	250-310	190-250
Amorphous	51-66	135-175	160-200	170-220

Source: Ref. [13].

7. Recommendations for sustainable development of SHP

Looking to the future, there are good reasons to support small hydropower in Europe and worldwide. First and foremost, it is a source of renewable energy, which, if used on a small scale and handled sensitively, has few environmental risks. Increased use will help to reduce CO_2 emissions and help countries to achieve their Kyoto obligations as well as to stave off global warming. Secondly, the depletion of oil and natural gas deposits will lead to higher generation costs for thermal plants, helping to improve the economics of SHP. It will also serve to enhance economic development and living standards, especially in remote areas with limited or no electricity. Rural communities have been able to attract new industries (mostly related to agriculture) owing to their ability to draw power from SHP stations.

In countries such as China, India, Turkey and South Africa, rapid SHP development has also boosted the development of local manufacturers to support these hydropower plants. In addition, the ability of SHP to be combined with water infrastructure projects will allow it to become a regular feature in developing countries as they overhaul their irrigation, water supply and sewerage systems [1,14]. Some recommendations for a sustainable development of hydropower include:

- Governments should establish an equitable, credible and effective environmental assessment process that takes into account both environmental and social concerns, with a predictable and reasonable schedule.
- Developing countries should developed energy policies that clearly set out objectives regarding the development of power generation options, including small hydropower.
- Project designers should apply environmental and social criteria when comparing project alternatives, in order to eliminate unacceptable schemes early in the planning process.
- Project design and operation should be optimised by ensuring the proper management of environmental and social issues through the project cycle.
- Local communities should benefit from a small hydropower project, both in the short and the long-term.

8. Conclusions

Small hydropower is a good solution to the other alternatives energy sources. Because Small hydropower can be successfully developed as long as it produces electricity at competitive prices and under conditions that respect the environment. On the other hand, small hydropower's main challenges relate to both economics and ecology.

Small hydropower represents an alternative to fossil fuel generation, and doesn't contribute to either greenhouse gas emissions or other atmospheric pollutants. However, developing the remaining hydropower potential offers many challenges and pressures from some environmental action groups over its impact has tended to increase over time.

Moreover, in the context of the restructuring of the electricity sector, markets may favour more polluting and less costly options.

On the other hand, small hydropower's main challenges relate to both economics and ecology. Small hydropower can be successfully developed as long as it produces electricity at competitive prices and under conditions that respect the environment.

Turkey as developing country has abundant SHP resources, which are economically feasible for development. In this country the majority of people live in rural areas.

In recent years, increases in population and environmental damage have caused climate changes, natural disasters, inadequate energy supply, deforestation and soil erosion in the some developing countries, especially in China, India and Turkey.

In most rural areas of these countries, because of lack of potable water, electricity and convenient transportation, the local economy remained underdeveloped and people were very poor. So, if it is developed of SHP projects in rural areas of these countries, a lot of problems discussed above could be solved.

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