RETSCREEN DECISION SUPPORT SYSTEM FOR PREFEASIBILITY ANALYSIS OF SMALL HYDROPOWER PROJECTS

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MEHMET KÜÇÜKBEYCAN

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PLAGIARISM

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ABSTRACT

A RETSCREEN DECISION SUPPORT SYSTEM FOR PREFEASIBILITY ANALYSIS OF SMALL HYDROPOWER PROJECTS

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Renewable energy sources are getting much more important to reduce the increasing threat coming from greenhouse gases. Hydropower is the most important source of renewable energy. However, development of a hydropower project is a challenging engineering process. Several computer programs have been developed to make initial estimations on hydropower schemes. A computer program named RETScreen Small Hydro Project Model has been developed with the objective to make complete pre-feasibility studies including costing and financial analysis. Two case studies, which have been under construction in Turkey, will be used to check the accuracy of software in Turkish practice. Then in light of the results, RETScreen software will be used to make a pre-feasibility report on an existing multipurpose dam in Turkey. Electricity can be generated at existing dams which requires minor civil works. Porsuk Dam which is a 36 year old dam used for domestic, industrial and irrigation water supply will be evaluated for energy generation by constructing a penstock, powerhouse and installing electromechanical equipment.

Keywords: Small Hydropower, Feasibility, RETScreen, Multipurpose Dams

ÖZ

KÜÇÜK HİDROELEKTRİK PROJELERİN ÖN YAPILABİLİRLİK ANALİZİ İÇİN RETSCREEN KARAR DESTEK SİSTEMİ

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Şubat 2008, 123 sayfa

Sera gazlarının artan tehditlerini azaltmak için yenilenebilir enerji kaynakları daha önemli hale gelmektedir. Hidroelektrik enerji yenilebilir enerji kaynaklarının en önemlisidir. Lakin hidroelektrik projelerinin geliştirilmesi zorlayıcı bir mühendislik sürecidir. Hidroelektrik projelerinin ilk hesaplarının yapılması için çeşitli bilgisayar programları geliştirilmiştir. RETScreen Small Hydro Project Model adındaki bir bilgisayar programı maliyet ve finansal analizini de içeren ön yapılabilirlik raporu hazırlamak amacıyla geliştirilmiştir. Türkiye'de inşaatı devam etmekte olan iki vaka çalışması yazılımın Türk uygulamalarındaki hassasiyetini ölçmekte kullanılacaktır. Daha sonra sonuçlar ışığında, RETScreen yazılımı Türkiye'de mevcut çok amaçlı bir barajın ön yapılabilirlik raporunun hazırlanmasında kullanılacaktır. Mevcut barajlarda, daha küçük inşaat işleri gerektirerek, elektrik üretilebilir. Porsuk Barajı – 36 yaşında evsel, endüstriyel ve sulama suyu sağlamakta kullanılan bir baraj – bir cebri boru, santral binası inşa edilerek ve elektromekanik ekipmanlar monte edilerek elektrik üretimi için değerlendirilecektir.

Anahtar Kelimeler: Küçük Hidroelektrik Enerji, Fizibilite, RETScreen, Çok Amaçlı Barajlar

To My Parents

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LIST OF ABBREVIATIONS

CAD	Canada Dollar
DSİ	State Hydraulic Works
EIE	General Directorate of Electrical Power Resources Survey and Development Administration
EMRA	Energy Market Regulatory Authority
ESHA	European Small Hydropower Association
EU	European Union
IASH	International Association for Small Hydro
IEA	International Energy Agency
INL	Idaho National Laboratory
MENR	Ministry of Energy and Natural Resources of Turkey
OECD	Organisation for Economic Co-operation and Development
TBMM	Grand National Assembly of Turkey
TEİAŞ	Turkish Electricity Transmission Company
TNSHP	Thematic Network on Small Hydropower
USD	United States Dollar
YTL	New Turkish Lira

CHAPTER 1

INTRODUCTION

1.1. Introductory Remarks and Literature Survey

Hydropower plants, especially small scale hydropower plants, are getting more important in renewable energy technologies (Dragu et al., 2001). Hydropower provides majority of power generation in 55 countries and contributes 20 percent of the world's power generation (Altınbilek, 2005 and Dragu et al., 2001). Although large hydropower schemes are technically mature and well exploited, small hydropower has a huge untapped potential (Lins et al., 2004). Turkey has been generating electricity from small hydropower plants since 1902 (Balat, 2007).

There are several measures taken in the world especially in Europe to promote energy generation from renewable sources. Importance of the sustainable management of natural resources, including water, has been emphasized by world leaders from Stockholm in 1972 to Johannesburg in 2002 (Altınbilek, 2005). The first objective of White Paper for year 2003, which had not been achieved, is to reach total installed capacity of 12,500 MW from renewable sources at 15 member countries of European Union (Laguna et al., 2005). Turkey has a huge hydroelectric potential. Unexploited small hydropower potential of Turkey is equal to approximately 70% of unexploited potential of all European Union countries.

As of June 2006, there are 25 countries, including Turkey, in Morgen Stanley's Emerging Market Index (Morgan Stanley Capital International, 2008). Increasing industrialization and development of Turkey increases the demand for electricity rapidly. Annual increase in electricity demand of

Turkey has been expected as 7-8% by the Ministry of Energy and Natural Resources of Turkey (MENR, 2007b).

Directive 2003/54/EC concerns common rules for the liberalization of electricity market in European Union (European Parliament, 2003). According to the Directive, the deadline for the complete opening of electricity market to all customers is July 1, 2007 (Goerten et al., 2007). Similarly, Turkish energy market has been going through a privatization process. Opening of Turkish energy market to private investors has been initiated in 1984. After the foundation of the Energy Market Regulatory Authority in 2001, energy market in Turkey has been restructuring significantly (Balat, 2007). Consequently, Turkish and foreign private companies have involved in energy market by gathering licenses from Energy Market Regulatory Authority.

1.2. The Scope of the Study

Development of a hydropower project is a challenging engineering process. The main problem in designing small hydropower plants is defining the optimum parameters to maximize the economics benefits. Several computer programs have been developed to make initial estimations on hydropower schemes.

Small Hydro Project Model software has been developed by RETScreen International under the management of Canada Natural Resources with the contribution of several governmental and non-governmental organizations and academia. One of the objectives of RETScreen software is to reduce the cost of pre-feasibility studies (RETScreen, 2007).

General idea about the feasibility assessment of small hydropower projects in Turkey by using RETScreen software was studied by Korkmaz (2007). The adequacy of RETScreen software to Turkish practice will be evaluated by performing two case studies by RETScreen software. Results of software will be compared with data given in feasibility reports. Both projects subject to this study are under construction by a private Turkish company. Actual data supplied from electromechanical equipment manufacturers around the world will be used in the evaluation. Consequently, inaccuracies and salutary properties of the software in Turkey's conditions will be pointed out.

Small hydropower schemes can also be developed by refurbishing and renovating existing dams (Natural Resources Canada, 2008). Dams which have been constructed only for irrigation and water supply purposes can be updated for electricity generation. Using existing structures reduces the cost of civil works; consequently the cost of small hydropower development projects (Natural Resources Canada, 2008).

There are several multi-purpose dams in Turkey like Porsuk Dam in Eskişehir. Potential of Porsuk Dam will be reevaluated for electricity generation in this study. In literature similar studies had been carried out for Porsuk Dam by Bakış et al., 2005.

In Chapter 1, literature survey and objective of the study are given briefly. In Chapter 2, basic definitions related to small hydropower schemes are explained. Then in Chapter 3, increasing electricity demand and consequently the measures to supply the increasing demand are reviewed. In Chapter 4, RETScreen International Small Hydro Project Model is briefly introduced. Then, flow duration curve method which is the working principle of RETScreen software for calculating energy potential is introduced. In Chapter 5, data from feasibility studies in Turkey are used to check accuracy of the RETScreen software in Turkish practice. In Chapter 6, hydropower potential of Porsuk Dam, which is a 36 years old multipurpose dam used only for irrigation, flood control and domestic water supply purposes, is re-evaluated.

CHAPTER 2

SMALL HYDROPOWER ENERGY

2.1. Definition of Hydropower Energy

Richard Feynman, a celebrated physics teacher and Nobel Laureate, said about the concept of energy in 1961 during a lecture at the California Institute of Technology:

“There is a fact, or if you wish, a law, governing natural phenomena that are known to date. There is no known exception to this law — it is exact so far we know. The law is called conservation of energy; it states that there is a certain quantity, which we call energy that does not change in manifold changes which nature undergoes. That is a most abstract idea, because it is a mathematical principle; it says that there is a numerical quantity, which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number, and when we finish watching nature go through her tricks and calculate the number again, it is the same” (Feynman, 1964).

The generation of electricity from hydropower could be explained with the same simple fact of nature, conservation of energy. Potential energy of water, gained by hydrologic cycle, turns into mechanical energy by turbines then into electrical energy by generators of hydropower plants.

“Water constantly moves through a vast global cycle, in which it evaporates from lakes and oceans, forms clouds, precipitates as rain or snow, then flows back to the ocean known as hydrologic cycle (Figure 2.1). The energy of this water cycle that is driven by the sun can be evaluated most efficiently with hydropower” (INL, 2007).

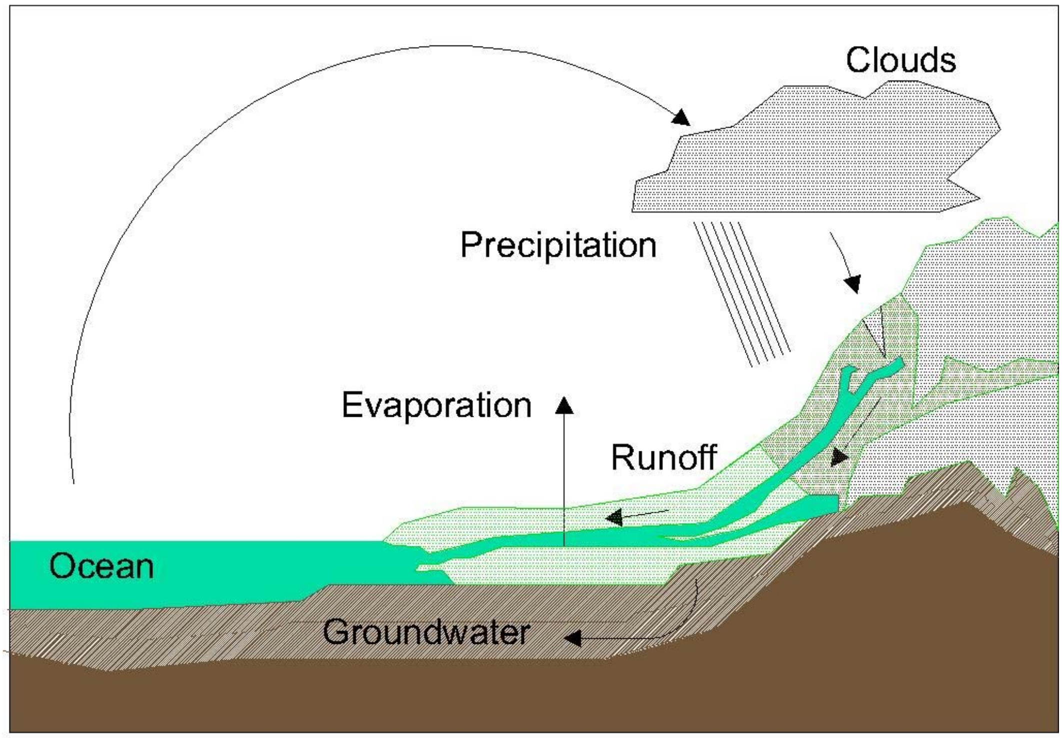

Figure 2.1. Hydrologic Cycle (Source: INL, 2007)

The potential energy of water turning into power by means of turbine is given by the following formula:

$$P = \eta.\ \rho.g.Q.H \tag{2.1}$$

where;

P is the power in Watts

η is the multiplication of the turbine, generator and transformer efficiencies

ρ is the density of water in kg/m^3

g is the gravitational acceleration in m/s^2

Q is the flow passing through the turbine in m^3/s

H is pressure head of water in meters

Hydropower potential of a basin is defined in three important terms that are gross theoretical potential, technically available potential and economic potential.

Gross theoretical hydropower potential of a basin is calculated by taking all natural flows in that basin from the beginning to the sea level to generate electricity with 100% efficiency ($\eta = 1$).

Technically available potential is the applicable amount of gross theoretical potential that is limited by the current technology (in which losses due to friction, turbine and generator efficiencies (η) are taken into consideration).

Economic hydropower potential of the Republic of Turkey has been calculated by State Hydraulic Works (DSI) and General Directorate of Electrical Power Resources Survey and Development Administration (EIE) from the master plan studies of basins. In these studies, benefits of hydropower developments are compared with other possible alternative sources of electricity generation. The reason for this comparison is to find the cheapest solution to supply a specific amount of energy at a given time (Goldsmith, 1993).

Firm energy is defined as the power available during a certain period of the day with no risk. Firm flow which is used to calculate firm energy is based on the data on flow duration curve. Generally it is taken as the flow available at least 95% of the time. Therefore, a run-of-river scheme has a low firm energy capacity. A hydropower plant with storage does, however, have considerable capacity for firm energy. If a small hydro scheme has been developed as the single supply to an isolated area, the firm energy is extremely important. As failure to meet demand, could result in power shortages and blackouts (TNSHP, 2004).

Secondary Energy is the amount of energy generated in excess of firm energy. The price of secondary energy is lower than the price of firm energy since its generation is not guaranteed all the time.

Dependable Capacity is defined as the load carrying capacity of a plant under adverse flow conditions for a certain time.

The period of time in which adverse flow conditions occurs is defined as the **critical period**. The period which is referred to as critical period varies from region to region. But in common practice, it is always referred to as the most adverse stream flow period (Progress Energy, 2005). The critical period always starts with the time when the reservoir is full. The conflict is in the definition of the end time. Some definitions refer the end time of a critical period as the time when the reservoir is empty. On the other definitions, the end of critical period is defined as the refill of the reservoir after the dry season.

State Hydraulic Works developed a methodology, called State Hydraulic Works criteria, to evaluate economical analysis of hydropower projects. According to this criterion, alternative energy generation has been taken as the combination of coal and natural gas thermal plant. The cost of firm energy is calculated from the sum of annual investment cost, annual total operation and maintenance costs and fuel cost of thermal plant. It is given per kWh. Different than the cost of firm energy, cost of secondary energy does not include investment costs. Peak capacity of a plant is calculated by using Equation 2.2 given below in order to evaluate peak capacity benefit (Dolsar Mühendislik, 2005).

$$\text{Peak Capacity} = \text{Installed Capacity} - \frac{\text{Firm Capacity}}{0.72} \tag{2.2}$$

In the calculation of incomes, firm energy benefit is taken as 6.00 Dollar cents/kWh, secondary energy benefit is taken as 3.30 Dollar cents/kWh and peak power benefit is taken as 85.00 USD/kW according to the State Hydraulic Works criteria (Arısoy et al., 2007).

2.2. Definition of Small Hydropower

There is still no internationally agreed definition of small hydropower. The upper limit varies between 1.5 and 50 MW (Table 2.1). The most widely accepted universal value is maximum 10 MW, although the definition in China stands officially at 25 MW (Paish, 2002).

Table 2.1. Upper Limit of Installed Capacity for Small Hydro

COUNTRY	UPPER LIMIT FOR SMALL HYDRO
Sweden	1.5 MW (TNSHP, 2004)
Italy	3 MW (TNSHP, 2004)
Portugal, Spain, Ireland, Greece, Belgium	10 MW (TNSHP, 2004)
France	12 MW (TNSHP, 2004)
India	15 MW (Dragu et al., 2001)
China	25 MW (Jiandong, 2004)
USA	30 MW (Dragu et al., 2001)
Brazil	30 MW (IASH, 2008)
Canada	50 MW (RETScreen ,2007)
TURKEY	**50 MW** (TNSHP, 2004)
UNISCO	10 MW (Adıgüzel et al., 2002)

The limit of small hydro has also not been clearly defined by European Union countries. Former 15 member countries of European Union – before the expansion on May 1, 2004 – accept upper limits between 1.5 MW and 12 MW (Table 2.1). However, limits up to 50 MW have been accepted for small hydropower around the world, especially in countries with higher hydropower potentials.

2.3. Types of Small Hydropower Schemes

2.3.1. Classification According to Head

Hydropower systems are generally classified according to head. However, classification given in Table 2.2 is also not rigid.

Table 2.2. Classification of Small Hydro According to Head (Başeşme, 2003)

TYPE	LIMITS
Low Head	H < 10 meters
Medium Head	10 meters < H < 50 meters
High Head	H > 50 meters

2.3.2. Classification According to Characteristic Features

Another widely used classification type is made according to the characteristic features of small hydropower schemes.

2.3.2.1. Storage (Reservoir): Flows in rivers vary from season to season and from year to year. During the seasons with high flow, extra flow can be stored in a reservoir that is located at the upstream of a hydropower facility. The stored water in the reservoir is used during low flow seasons. This control of flow is called flow regulation. The optimization of flow regulation requires reservoir operation studies.

Hydropower schemes with reservoir might further be classified according to their type of dam.

1. Concrete dams (Gravity, Arch and Buttress dams)

2. Embankment dams (Earth-fill dams and rock-fill dams)

2.3.2.2. Run-of-River (Diversion Canal or Diversion Tunnel): This type of facilities generally use head ponds with limited capacity of water storage, most of the times only a daily pondage. Since run-of-river hydropower facilities have little water storage capacity, the flow in the river must be turbined. As a result, excess water cannot be used. Therefore, it is spilled.

2.3.3. Classification According to Operating Principle

Classification of hydropower plants in the operating period is as follows;

1. Base load plants
2. Peak load plants
3. Intermediate load plants (mix plants that might serve both for base and peak loads)

2.3.4. Classification According to Position of Powerhouse

Hydropower plants might also be classified according to the position of powerhouse.

1. Free standing (external) powerhouses
2. Cavern (underground) powerhouses
3. Partially embedded powerhouses

2.4. Main Components of Run-of-River Small Hydropower Plant

Main components of a small hydropower site are diversion structures to divert water from its natural bed, intake structures, canal or pressure tunnel, head pond or surge tank, penstock, powerhouse, electromechanical equipment and tailrace structures (Figure 2.2).

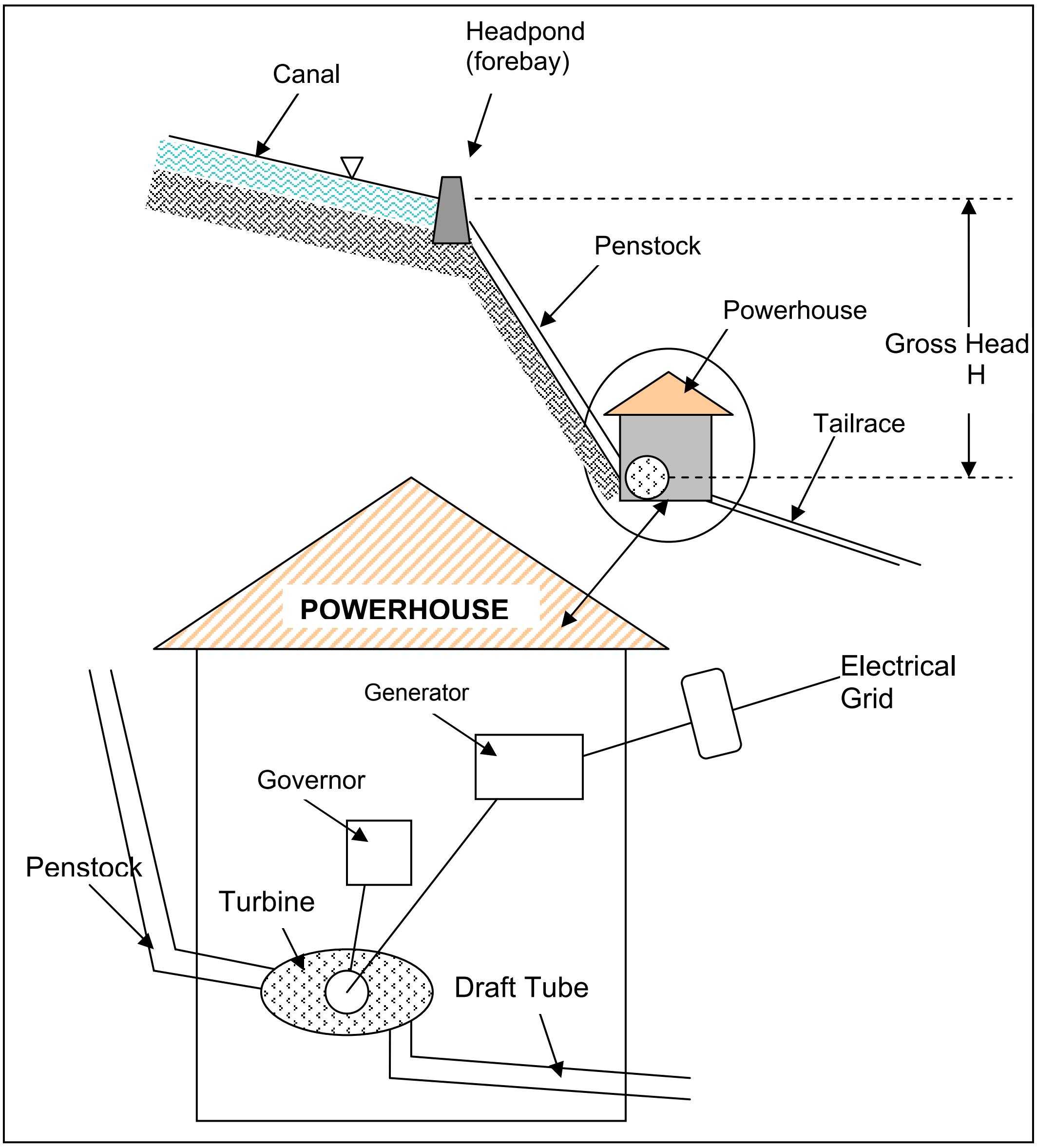

Figure 2.2. Main Parts and Structures of Small Hydropower Site

2.4.1. Diversion Canal or Pressure Tunnel

Water is diverted from its natural bed into the diversion canal. Diversion canals have relatively milder slopes than river's natural beds to gain head. Losses are minimized in diversion canals due to their relatively smoother surface, consequently lower roughness coefficient, than natural stream bed.

Another way of diverting water from its natural bed is by means of pressure tunnel. Pressure tunnels might have some difficulties in construction due to geological conditions. Pressure tunnels are generally designed in circular or horseshoe cross-section.

2.4.2. Head pond

Head pond is a reservoir at the end of diversion canal. It is used to divert water into penstock and to hold a sufficient body of water to ensure that the penstock is always fully submerged. By this way, suction of air into the turbine is prevented (Bergström et al., 2005). The forebay of a head pond may also serve as settling basin. Different designed trash racks according to the type of turbine are used at the head ponds to screen rocks, dirt, woods etc.

2.4.3. Penstock

Penstock is a pressurized water conduit that conveys water to the powerhouse. Penstocks are generally fabricated from steel, concrete, plastic or fiberglass. For different projects different number of penstocks might be considered. The principle is to use multiple penstocks in high discharge rates and low head schemes. On the other side, a single penstock is preferable if the head is high and discharge is relatively smaller. Using single penstock, where possible, without considering head is more preferable from the economical point of view.

2.4.4. Powerhouse

Powerhouse contains most of the mechanical equipment, electrical equipment and control units. It is made of conventional building materials (Dragu et al., 2001).

2.4.5. Turbine

Turbine converts potential energy of flow into mechanical energy. There are several types of turbines. The choice of the turbine will depend on the design head and the design flow. Figure 2.3 shows the application range of Francis, Kaplan, Pelton and Banki type Cross-Flow turbines given by the Mavel A.S., a Czech Republic based engineering and turbine manufacturing company (Mavel, 2007).

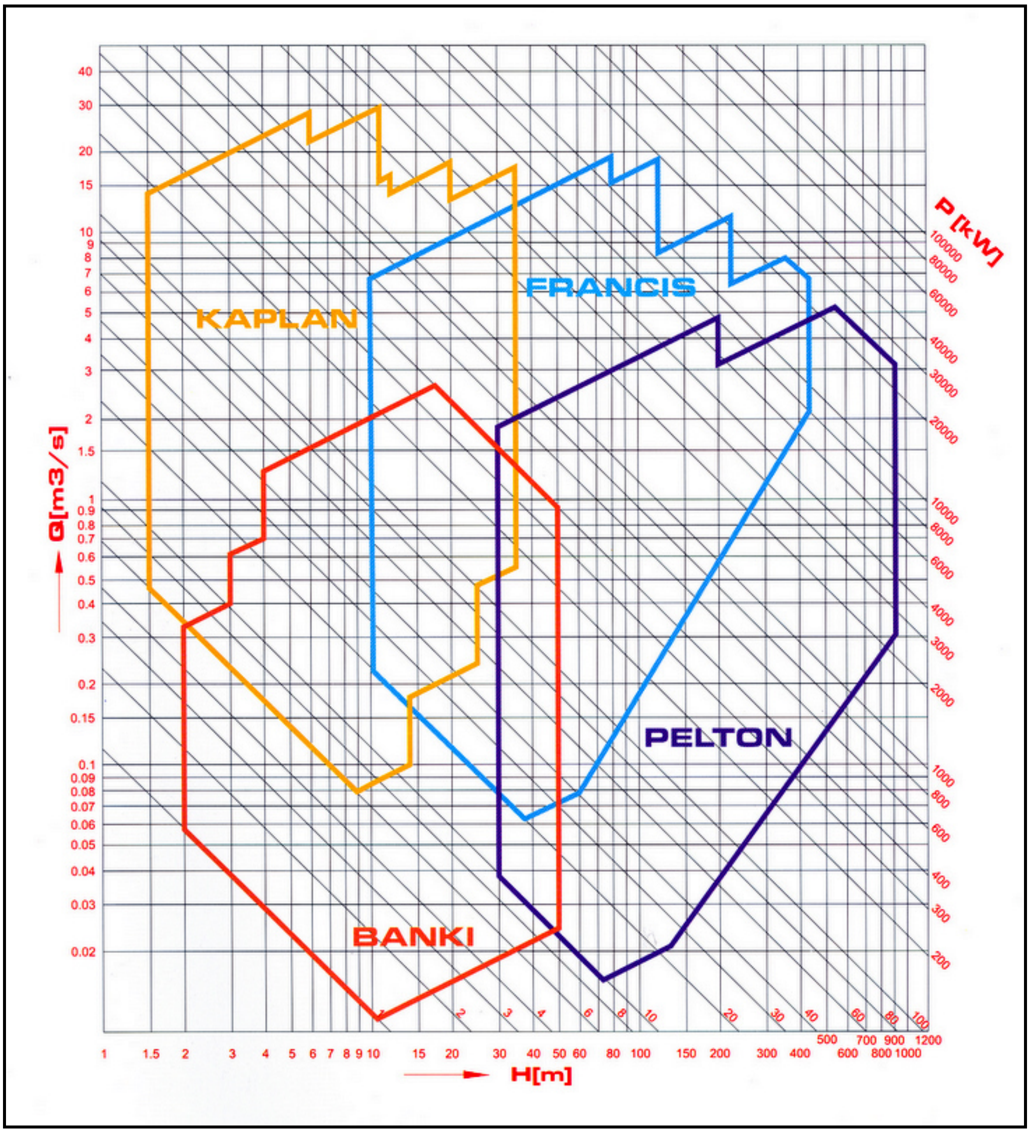

Figure 2.3. Turbine Application Range (Mavel, 2007)

Turbines are generally classified into two main groups; impulse turbines and reaction turbines (Table 2.3).

Table 2.3. Impulse and Reaction Turbines according to Head (Paish, 2002)

Turbine Type	Head Classification		
	High Head	**Medium Head**	**Low Head**
Impulse	Pelton Turgo Multi-jet Pelton	Cross Flow Turgo Multi-jet Pelton	Cross Flow
Reaction		Francis	Francis Propeller Kaplan

The working principle of *impulse turbines* is explained by Newton's second law of motion which is "Net force on an object is equal to its rate change of momentum (impulse)". Potential energy of water is turned into kinetic energy by means of nozzles. Blades of impulse turbines are driven by hitting of high speed water jet coming from nozzles.

The working principle of *reaction turbines* is explained by Newton's third law of motion which is "For every action there is an equal and opposite reaction". The blades of reaction turbines are arranged so that they develop torque from the changing pressure of water passing through the turbine. The reaction turbines must contain a pressure casement or they must be fully submerged in water.

2.4.6. Generator

Generators are units where mechanical energy of turbine shaft transforms into electrical energy.

2.4.7. Governor

Governor is a turbine flow control mechanism which is used to maintain the rotational speed at a constant level irrespective of the load on the turbine.

2.4.8. Draft Tube

According to experimental studies, adequate design of draft tubes has some positive effects in turbine efficiency. Formation of vortices in the draft tube, variable with the variations in the speed and flow of water coming out from turbine, makes use of mathematical calculations almost impossible. Therefore, model experiments and studies are widely used in the design of draft tubes (Başeşme, 2003).

2.4.9. Tail Water Canal / Tunnel

Tail water tunnel is used to convey water coming from turbines back to natural stream bed.

2.5. Development of Small Hydropower Projects

Project development process of a hydropower scheme given in Figure 2.4 requires involvement of many professional disciplines. Civil engineers play a key role in the project development. Moreover, almost all different divisions of civil engineering, which are hydromechanics, hydrology, geotechnical engineering, structural mechanics, construction materials, transportation and construction management, involve in project development. Other than civil engineers; geological engineers, mechanical engineers, electrical engineers, economists, investors and lenders involve in different phases of small hydropower project development.

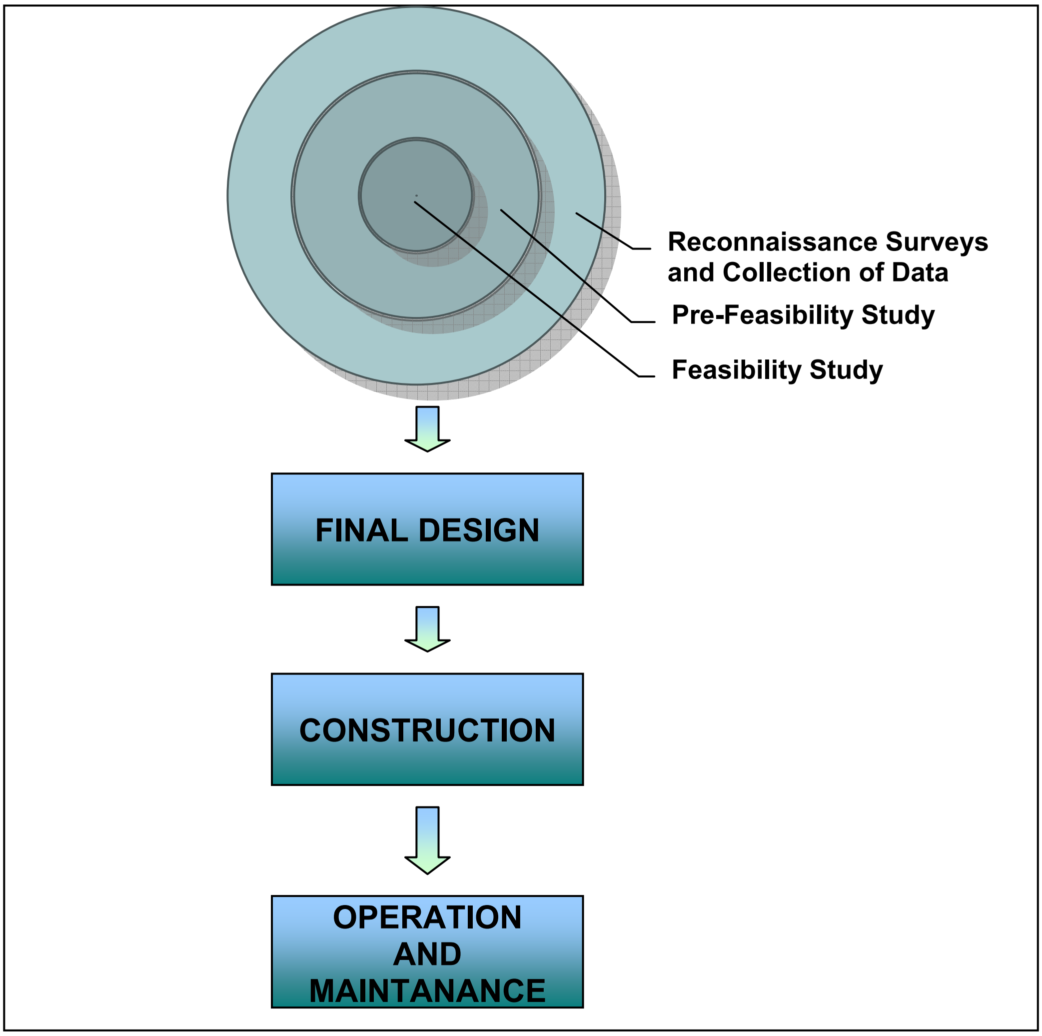

Figure 2.4. Project Development Processes

The project development process starts with searching and surveying for project locations and continues with elimination of alternatives to find highest possible head and flow. Through many probable locations, the ones which are not sustainable or have adverse impact on environment should also be eliminated. Then, operational studies followed by economical analysis in order to choose the location with the highest profitability should be carried out. After the optimization of project characteristics, necessary applications should be made in order to get permits to start construction, licenses to generate and sell electricity. Depending on the financial power of the project developer, external investors or credit to finance the project might be arranged. Finally with the completion of the construction, operation period starts. This period involves selling of energy and requires good maintenance of the plant.

2.5.1. Reconnaissance Surveys and Collection of Data

At the first stage of project development; data for hydrology, geology, topography and environmental impacts should be collected.

Hydrologic data and studies are very crucial for project development. Since power is directly proportional to the availability of water, in common practice minimum 30 years of hydrological data are necessary. Together with the availability of water, its timely variation is also very important. Stream records, meteorological data, basin characteristics should also be collected.

Map studies of possible project locations, sometimes site visits, are needed in this stage. Studies are carried out on maps to set the general layout of the site and basin.

Geological studies aims to provide data for reservoir evaluation and locations of all structures in the project. This process starts with the earliest stages of project development and might continue throughout the all project.

Another issue that must be considered is the impacts of the possible projects to environment. Data for the settlement, flora and fauna, historical places, valuable lands like farms, mines and existing facilities in the project area should be investigated.

2.5.2. Pre-Feasibility Study

Geological investigations would continue in pre-feasibility stage of project development. Laboratory and in-situ tests, drilling of investigation holes are used to prepare geological structure of the site.

Also in this stage, availability of construction materials and locations of borrow areas should be studied. This information might be vital for the selection of dam type.

The main objective of pre-feasibility study is to estimate the hydropower potential of the site. This estimation, including installed capacity, is used for economical studies. Benefit and cost estimate of a particular project shows whether further studies should be carried for that project or not.

2.5.3. Feasibility Study

The objective of the feasibility study is the determination and optimization of the project characteristics.

At the end of feasibility study, a feasibility report which includes detailed hydrologic studies, geologic studies, reservoir operation studies, topographical surveys, preliminary designs, benefit/cost estimates, economical justification and environmental impact assessment is prepared.

Regulation was published by the Ministry of Energy and Natural Resources of Turkey on Official Newspaper number 26248 on February 8, 2007 (MENR, 2007a) to change some clauses of Water Usage Rights Regulation (No 25150 Date June 23rd, 2003). Attachment – 3A of the regulation gives the index of feasibility reports requested by State Hydraulic Works (Table 2.4).

Table 2.4. Attachment-3A
(Headlines in the Feasibility Report requested for DSİ/EİE Projects)

PART 1	SUMMARY
1.1.	Managerial Information Form (Attachment-7)
1.2.	Project Location
1.3.	Schematic Plan Showing the Relation of the Project with other Facilities inside Basin

Table 2.4. Continued

1.4.	Suggested Facilities
1.5.	Project Characteristics
PART 2	INTRODUCTION OF PROJECT LOCATION
PART 3	DEVELOPMENT PLAN
3.1.	Existing Facilities
3.2.	Suggested Facilities
PART 4	CLIMATE AND WATER RESOURCES
4.1.	Climate (Meteorological Stations, Precipitation, Temperature, Evaporation)
4.2.	Water Resources
4.3.	Utilization of Water and Water Rights
4.4.	Water Requirements
4.5.	Returned Water
4.6.	Operation Studies
PART 5	GEOLOGY
PART 6	FACILITIES TO BE CONSTRUCTED
PART 7	ENVIRONMENTAL EFFECTS
PART 8	COST OF FACILITY
PART 9	ECONOMIC ANALYSIS
9.1.	Annual Incomes
9.2.	Annual Expenses
9.3.	Benefit/Cost Ratio
9.4.	Internal Rate of Return of the Project
PART 10	COST DISTRIBUTION FOR MULTIPURPOSE PROJECTS

Table 2.4. Continued

PART 11	ALTERNATIVES
11.1.	Alternatives of Reservoir
11.2.	Alternatives of Energy Facilities

2.5.4. Final Design

Final design process starts with the review of the alternatives given in feasibility report. After spending considerable amount of effort and study, detailed calculations and relevant drawings of the best alternative are prepared.

At the end of the final design process, final design drawings and related technical specifications are prepared in order to construct the hydropower project.

2.5.5. Construction Period

Construction period of hydropower projects varies from one year to six or seven years. This period is directly proportional to the size of the project, experience of contractors and also the financial power of the investors.

During the construction period, some drawings might be changed. These drawings, called shop drawings, should be prepared by contractors or suppliers. Shop drawings are more detailed than final design drawings and they are produced according to the actual conditions at the site.

As-built drawings are prepared at the end of the construction period with enclosing and implementing shop drawings into design drawings. Also detailed operation and maintenance manuals should be prepared by contractors, suppliers and manufacturers for the ownership and maintenance period.

2.5.6. Operating Period and Maintenance

Operation of hydropower plants could be differently organized depending on the place, available resources and local infrastructure (Ravn, 1992).

Operation period requires good management skills and active maintenance plan to minimize expense and downtime.

Modern hydropower schemes are usually automated in operation. Ordinary maintenance of them includes simple tasks like clearing of trash-racks. However, major maintenance works should be carefully planned according to the flow regime since generating equipment would be shut down while their maintenance works are carried out (Ravn, 1992).

2.6. Strengths and Weaknesses of Small Hydropower Energy

There are three main types of power plants which are thermal power plants, nuclear power plants and renewable energy plants. Hydropower energy is the most widely used source of renewable energy. Wind energy, solar energy, biomass energy and geothermal power plants are the other types of renewable energy sources.

Thermal power plants are generating power by burning fossil fuels. Most common used fuel types in Turkey are coal, fuel oil and natural gas. Nuclear power plants generate electricity from the nuclear fission of radioactive elements. Small hydropower schemes use hydrological cycle as a renewable source to generate electric energy. In other words, they do not consume any natural sources like fuel, coal or gas.

As a sustainable resource, small hydropower meets the needs of the present without compromising the ability of future generations to meet their own needs (Lins et al., 2004). Altınbilek emphasizes role of hydropower in sustainability by stating that “Hydropower has a huge potential to improve economic viability, to preserve ecosystems and to enhance social justice” (Altınbilek, 2005).

Condensation type thermal and nuclear power plants have long start-up and shutdown times up to several hours. In other words, they are not flexible in operation. Even for a gas turbine thermal power plant, it takes at least 15 minutes to start up. Small hydropower technology allows fast start-up, only 1 or 2 minutes, and shutdown in accordance with the changes in demand (Dragu et al., 2001). Therefore another advantage of small hydropower plants is the reliability and flexibility of operation.

Hydropower is a “secure” source of energy generation. Small hydropower, except the ones constructed at cross boundary rivers, is available within the borders of one country. Therefore, it is not subject to disruption by international political events. This guarantees its security of supply (Lins et al., 2004). In addition they are not dependent on price and availability of fossil fuels since they are not using them.

Hydropower facilities have long life and related to this they have long operation period with little maintenance.

Small hydropower plants have almost no environmental impact (Paish, 2002). They do not release heat or pollute environment. Moreover, green house gas emissions are abated by using hydropower plants instead of thermal plants.

One of the most important disadvantages of small hydropower is that they have adverse effects on fish life. Firstly dams block fish species to move freely. Fish ladders are built to overcome this obstacle. Second adverse effect on fish life is the mortalities due to turbine blades. Less fish mortality is aimed with the improving turbine technology. Thirdly; while water passes through spillways, it gets saturated with gases in the air. Fish tissue, surrounded with bubbles, absorbs the gas and this leads to huge damages in fish and even their death. Lastly; because of the reservoirs, warm water may be collected at the surface and cold water may be collected at the bottom. Many fish species cannot survive in such environment (Dragu et al., 2001).

Another drawback of run-of-river type small hydropower plants is the variability of energy generation with the seasons. Rate of firm energy is generally very low considered to possible peak energy (Paish, 2002). Hydro schemes with reservoir overcome this problem by storing water for dry seasons. Nonetheless, larger hydropower developments with reservoir have other adverse effects. The places that will remain under water must be purchased or expropriated. Most of the time, local people show resistance because they have to resettle their houses, farms or lands. Involuntary resettlement involves people of all ages and genders and eviction of people spotlights a number of problems. Therefore efficient resettlement planning should be carried out which makes resettling people real beneficiaries of the project (Yen, 2003 and Tortajada, 2001). Since reservoirs of small hydropower projects are not as large, they do not require expropriation of very large land. So considering the oppositions of local people and environmental organizations, small hydropower is favorable.

2.7. Small Hydropower in the World

There is an increasing trend in the world to generate energy from renewable energy sources which are clean and sustainable. Hydropower is one of the oldest ways of electricity generation and its technology has been developed over many years. All of the energy generation from hydropower was from small hydropower schemes until the beginning of the 20th century. In the 20th century, construction of larger dams and energy generation from cheap petroleum products were resulted in a severe abandonment of small hydropower plants (Adıgüzel et al., 2002). Since developed countries have been almost completely using their economical capacities in large scale hydropower energy, other renewable sources – especially small hydropower – is getting more important. In contrast to this situation, according to the White Paper, only about 20% of the economic potential for small hydro power plants has been so far exploited in European countries (European Commission, 1997). Also small hydropower is getting more attention from the investors around the world due to relatively less investment costs than large ones.

As Figure 2.5 presents, China has the world's largest hydropower potential which is 6,083,000 GWh/year gross theoretically. China with its huge industry and crowded population has a rapidly growing energy demand. In gross theoretical hydropower potential, India is in the third raw after United States of America. With their huge potential, India and China from Asia is set to become leaders in the world energy market (Lins et al., 2004). Especially Chinese government encourages small hydropower development by tax reductions and soft loans (Taylor et al., 2006). In the South America, Brazil has the largest hydropower potential. As a developing country, Brazil has also an increasing energy demand. Consequently, Brazilian energy market is growing 5% per year (The International Journal on Hydropower & Dams, 2007a).

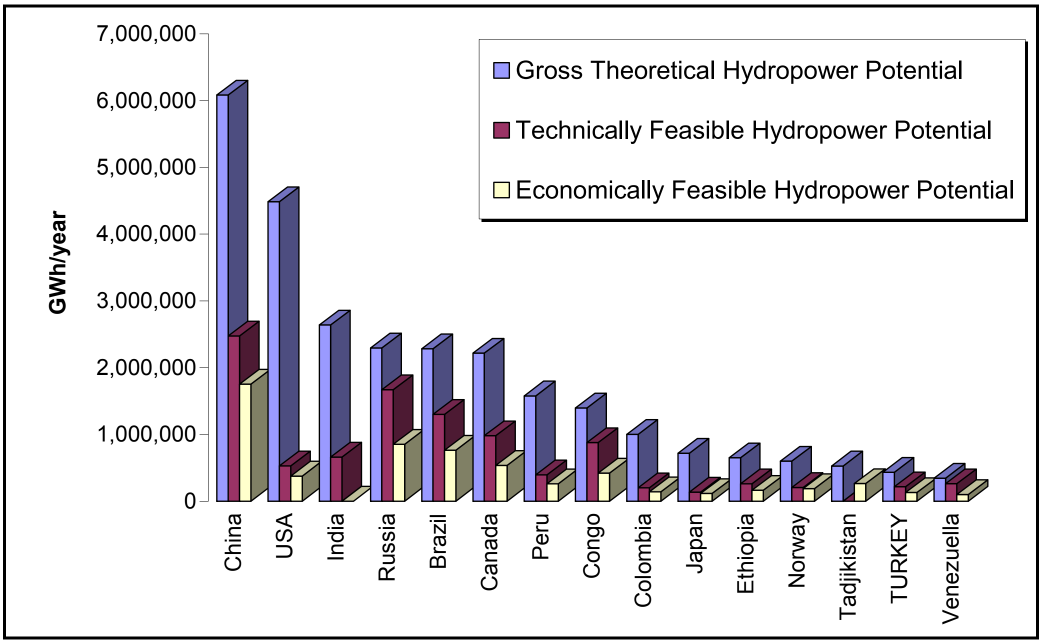

Figure 2.5. Hydropower Potential in the World (Source: The International Journal on Hydropower & Dams, 2007a)

According to the report prepared by Thematic Network on Small Hydropower, there are 16,770 small hydro plants operating with an average size of 0.63 MW at 25 European Union countries in 2004. The number of small hydro plants increased to 17,090 with average capacity of 0.65 MW after the participation of Bulgaria and Romania to European Union in 2007. The average contribution of small hydropower plants to total hydropower production is more than 10% in European Union countries (Marketing Working Group of the TNSHP, 2004).

According to Eurostat figures for 2002, Italy accounted for about 21% of the total small hydropower capacity installed in the European Union, followed by France (17%) and Spain (16%). From the new member countries Romania and from the candidate countries Turkey represent about 25% and 15%, respectively, of the total small hydropower installed capacity in 2002 (Lins et al., 2005).

According to Lins et al., 2005, “more than 82% of all economically feasible potential has already been exploited in the former 15 member countries of European Union with the remaining 18% amounting to some 20 TWh/year. In the new Member States and the candidate countries, this figure is around 26 TWh/year. The majority of this potential is located in Turkey. Poland and Romania rank second, having indicated potential 6–10 times lower than that of Turkey. The third group is composed by the Czech Republic, Slovenia, Bulgaria and Slovakia” (Lins et al., 2005).

2.8. Hydropower in Turkey

Turkey is divided into 26 hydrological basins with a total surface area of 779,452 km^2. Hydropower potentials of 17 basins out of the total 26 basins are given in Table 2.5. Two main branches of Shatt-al-Arab basin, which are the Euphrates (Fırat) and the Tigris (Dicle) rivers, are running through the Southeastern Turkey (Altınbilek, 1997). Especially the Euphrates basin, consisting 16.3% of the total surface area, has 31.3% of the total energy generation potential of Turkey.

Table 2.5. Hydropower Potential of Some of the Selected Basins in Turkey (Kaygusuz, 2002)

Basin	Land Area (km^2)	Stored Water (hm^3)	Installed Capacity (MW)	Average Generation (GWh)
Susurluk	22,399	3,509.3	537.0	1,697
Gediz	18,000	3,369.4	250.0	425
B.Menderes	24,976	2,722.1	214.5	848
B.Akdeniz	20,953	1,836.6	674.7	2,495
Antalya	19,577	2,885.3	1,251.6	4,411
Sakarya	58,160	6,920.3	1,062.5	2,362
B.Karadeniz	29,598	2,518.8	592.7	2,110
Yeşilırmak	36,114	6,301.8	1,657.6	6,468
Kızılırmak	78,180	21,260.0	2,007.0	6,512
D.Akdeniz	22,048	9,121.5	1,495.9	5,176
Seyhan	20,450	6,124.5	1,885.6	7,117
Ceyhan	21,982	7,719.5	1,408.7	4,634
Fırat	127,304	112,791.5	9,844.8	38,939
D.Karadeniz	24,077	1,522.5	3,323.1	10,927
Çoruh	19,872	7,544.4	3,227.4	10,614
Aras	27,548	4,084.8	585.2	2,291
Dicle	57,614	30,295.0	5,081.9	16,876
Total	*779,452*	*240,763.6*	*35,309.2*	*124,568*

Economical and technical potential of Turkey was calculated as 124,568 GWh in 2002 by Kaygusuz given in Table 2.5 (Eroğlu, 2007). Economical and technical potential had been increased to 130 GWh in 2006 according to State Hydraulic Works (Figure 2.6). Uneconomical but technical hydropower potential of Turkey, which is 86 Billion kWh, could be evaluated by means of incentive measures taken by governments. Guaranteed price for electricity generated from hydropower is a good example of such a support mechanism. Green house tax is another incentive measure applied in European countries to encourage and support renewable energy. According to a study carried out, technically available and economical potential of Turkey is calculated as 188,169 GWh by re-evaluating some benefits of hydropower energy (Yüksel et al., 2005).

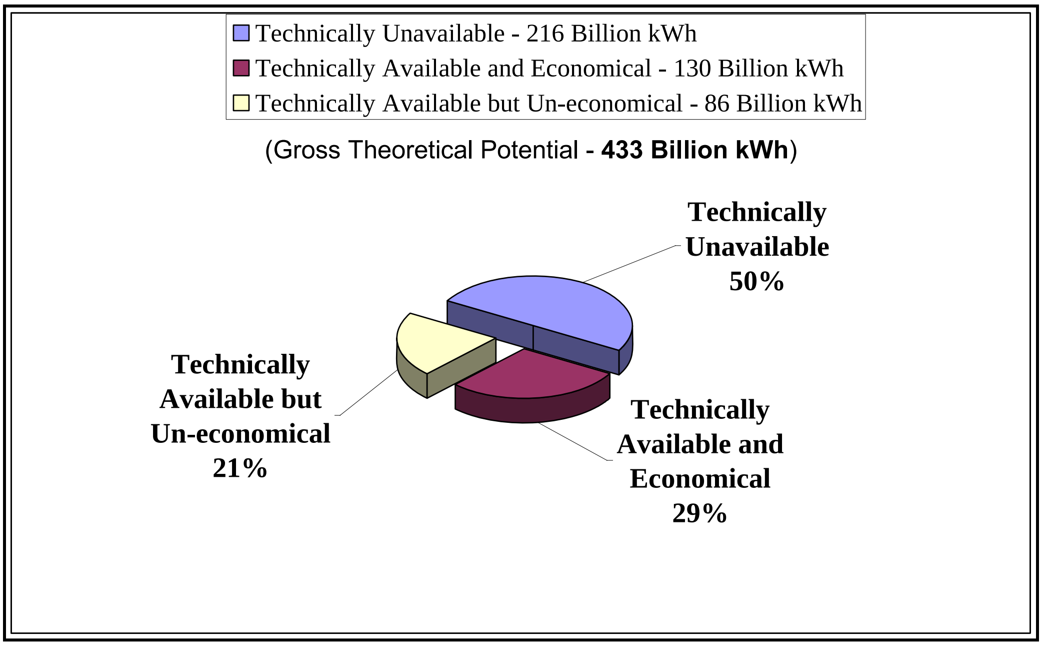

Figure 2.6. Hydroelectric Potential of Turkey (Eroğlu, 2007)

According to Adıgüzel et al. (2002), 40% of the total water is non-usable for energy generation since they are fully developed for different sectors like irrigation, water supply and flood control. As a result, technically available hydroelectric potential should be decreased to 183 billion kWh. The difference between economically feasible and technically available is

57 billion kWh. A report submitted by State Hydraulic Works states that 57 billion kWh is technically utilizable and two third of the technically exploitable energy should be considerable as economical. Half of this estimation is taken for small hydropower potential. In the light of the very rough calculations given in the study, Turkey's small hydropower potential is estimated to be approximately 19,000 GWh (Özgöbek, 2001).

Figure 2.7 presents the unexploited small hydropower potentials (< 10 MW) of European Union countries and Turkey. Remaining small hydropower potential of European Union countries is 27,150 GWh/year (Marketing Working Group of the TNSHP, 2004). Turkey, alone, has unexploited small hydropower potential which is equal to approximately 70% of the total number in 27 member countries of European Union.

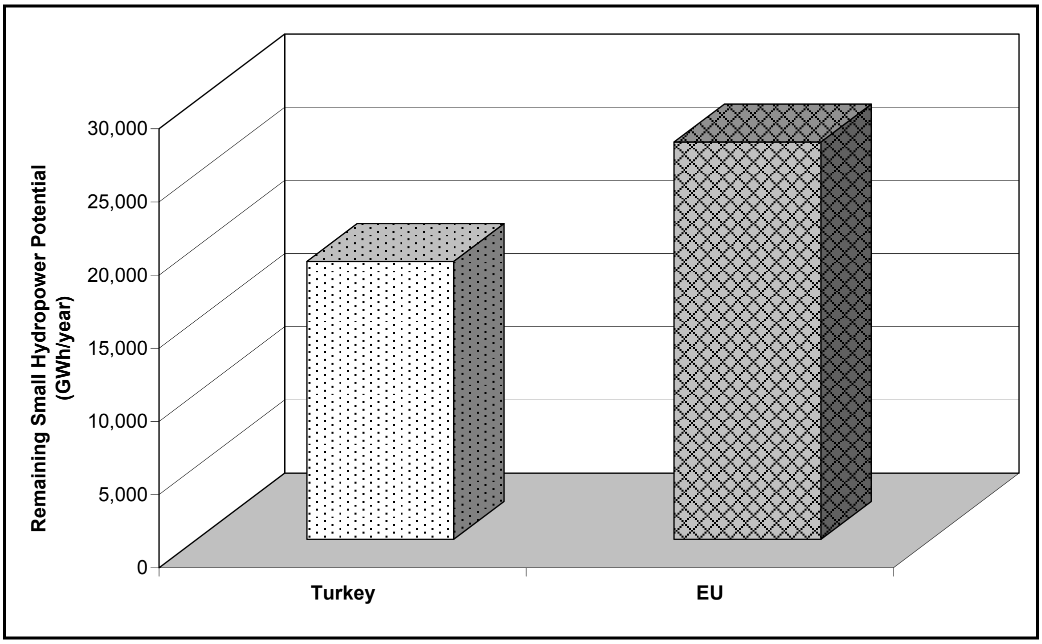

Figure 2.7. Remaining Small Hydropower Potential in Turkey and EU Countries (2004)
(Resource: Marketing Working Group of the TNSHP, 2004)

CHAPTER 3

ELECTRICITY DEMAND

Modern life is getting more and more dependant on electricity. Increase in the demand for electricity is directly proportional to the increase in industrialization and urbanization. Also mankind's desire for prosperity makes them dependent to technology and electric energy. Development of countries could be compared by using different measures. Energy consumption is one of the economic indicators of development (Wikipedia, 2008a). Lowest energy consumption takes place in the least developed countries, on the other side developed countries like Canada has the highest energy consumption per person (Wikipedia, 2008b).

Turkish economy has undergone a transformation from agricultural to industrial especially after 1982 (Ediger et al., 2006). As a fast developing country and candidate for European Union, Turkey's need for electricity has been increasing rapidly. Although Turkey's primary energy generation is from natural gas (Table 3.1), its reserves and production is domestically very low. If Turkey does not evaluate its own potentials and resources, dependency to the others for buying electricity would be unavoidable.

Table 3.1. Installed Energy Capacity and Annual Electric Generation of Turkey (Eroğlu, 2007)

SOURCE	INSTALLED CAPACITY (MW)	GENERATION CAPACITY (10^9 kWh /year)	ACTUAL GENERATION (10^9 kWh /year)	RATIO OF USAGE (%)
COAL	10,076	67.7	44	65

Table 3.1. Continued

FUELOIL	3,110	20.5	8.5	41
NATURAL GAS	13,484	102.3	66.5	65
HYDROELECTRIC	12,941	46.5	42	90
TOTAL (*)	**39,611**	**237**	**161**	**68**
*** Geothermal Energy and Wind Energy is included in total values.**				

According to the Activity Report for year 2006 of Ministry of Energy and Natural Resources of Turkey, long term electricity generation planning studies, in order to meet the future electricity demands with a proper arrangement and suitable to Turkey's energy policies, shows that in high demand scenario 56,500 MW and in low demand scenario 40,500 MW of new investment is needed by 2020 other than the energy development projects have already been developed and have been under construction. As of today Turkey's installed capacity is about 39,500 MW. In the planning stage, complete usage of Turkey's own resources is the primary objective. Also nuclear power plant with installed capacity of 5,000 MW is envisaged to operate starting from 2012 (MENR, 2007b).

The electricity network is interconnected in Europe. Import and export of electricity is usually an economic choice but not due to shortages. Figure 3.1, which was prepared according to Eurostat 2005 values, shows that France is the most important electricity exporting country in Europe with 52,300 GWh (Goerten et al., 2007). The highest import values are given for Italy with 49,200 GWh. Turkey has transformed into an energy exporting country since 2003 (Table 3.2).

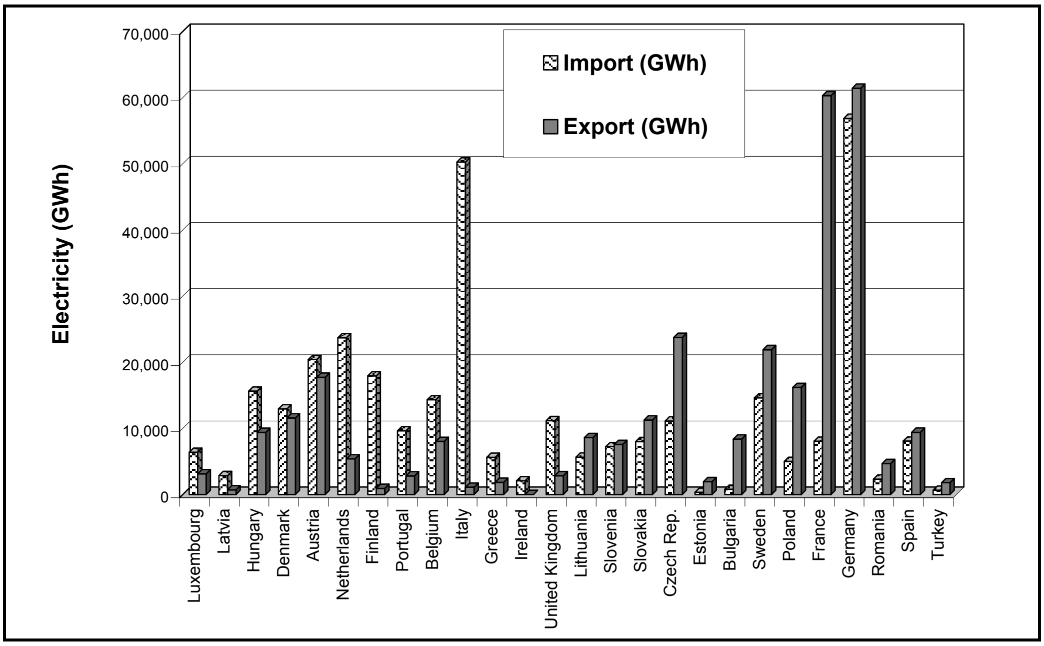

Figure 3.1. Imports and Exports of Electricity in European Countries in 2005 (Source: Goerten et al., 2007)

As given in Table 3.2, there is a rapid increase in consumption per capita. According to OECD, Turkey is one of the countries with the largest increase in energy demand (Ereke, 2007).

Table 3.2. Yearly Electric Energy Gross Production – Import – Export – Gross Consumption of Turkey (TEİAŞ, 2007)

YEAR	GROSS PRODUCTION (GWh)	IMPORT (GWh)	EXPORT (GWh)	GROSS CONSUMPTION (GWh)	ANNUAL AVARAGE INCREASE (%)	GROSS CONSUMPTION PER CAPITA (kWh/capita)	ANNUAL AVARAGE INCREASE (%)
1995	86,247.4	0	695.9	85,551.5	-	1,411	
1996	94,861.7	270.1	343.1	94,788.7	10.8	1,540	9.1
1997	103,295.8	2,492.3	271	105,517.1	11.3	1,678	9.0
1998	111,022.4	3,298.5	298.2	114,022.7	8.1	1,797	7.1
1999	116,439.9	2,330.3	285.3	118,484.9	3.9	1,840	2.4

Table 3.2. Continued

2000	124,921.6	3,791.3	437.3	128,275.6	8.3	1,891	2.8
2001	122,724.7	4,579.4	432.8	126,871.3	-1.1	1,851	-2.1
2002	129,399.5	3,588.2	435.1	132,552.6	4.5	1,904	2.9
2003	140,580.5	1,158.0	587.6	141,150.9	6.5	1,996	4.8
2004	150,698.3	463.5	1,144.3	150,017.5	6.3	2,090	4.7
2005	161,956.2	635.9	1,798.1	160,794.0	7.2	2,231	6.7

Turkey's annual increase in the demand for electricity is forecasted as 6 – 8 % by State Hydraulic Works (Table 3.3). Similarly Ministry of Energy and Natural Resources of Turkey forecasts an average annual increase of 7 – 8 % in electricity demand given in Activity Report of Year 2006. Also in the same report, balancing studies for "supply and demand" in electricity shows that development of new installed capacity will be needed after 2009 (MENR, 2007b).

Table 3.3. Increase in the Demand for Electric Energy up to Year 2030 (Eroğlu, 2007)

COUNTRIES	ANNUAL INCREASE (%)
World Average	2.4
Developed Countries Average	< 2.0
Developing Countries Average	4.1
TURKEY	6 – 8

Turkey aims to make improvements in electricity market, especially generation from renewable sources, in order to accelerate construction of on-going projects and extract new investments to local energy sector. However, policies in infrastructure projects like water and energy have some complexities (Altınbilek, 2005). Therefore, policy makers in Turkey should follow a certain policy in energy sector to increase common welfare of Turkish nation. Realization of the value of Turkey's own resources and potential should be the main objective while constituting energy policies.

3.1. Political Aspects of Small Hydropower in the World

Representatives from allover the world emphasize the importance of hydropower, as a sustainable source of energy, in human life in Stockholm in 1972, in Rio de Janeiro in 1992 and in Johannesburg in 2002 (Altınbilek, 2008). Important milestone in the promotion of renewable sources of energy is the Kyoto Protocol in 1997. The importance of energy generation from renewable sources of energy has also been enhanced by the European Union. This importance has been emphasized by issuing of the White Paper: "Energy for the Future: Renewable Sources of Energy" in 1997, and the Directive 2001/77/EC, "Promotion of Electricity Produced from Renewable Energy Sources" in 2001.

Objective of the White Paper is to attain minimum 12% energy penetration from renewable energy sources in the European Union by 2010. An additional installed capacity of 4,500 MW of small hydro plants by 2010 is a realistic contribution which could be achieved given a more favorable regulatory environment, since these small projects, if correctly planned, can have much lower environmental impact (European Commission, 1997). The goal of achieving more electricity from renewable sources would create a more sustainable energy system and reduce CO_2 levels. Progress of each branch of renewable energy sources are quoted in the White Paper, where large hydropower schemes are considered as competitive and do not need any further assistance. However, small hydropower development should be further increased according to the paper (European Commission, 1997).

The specific goal of the Directive 2001/77/EC is to reach 12% use of electricity from renewable in the European Union by the year 2010. The directive gives member states a reason to be interested in small hydropower since it is the best proven renewable-energy technology. The directive proposes some measures to encourage renewable sources. First, it sets national targets for consumption of electricity from renewable sources of energy. Second, national support schemes and, if necessary, a harmonized support system should be made. Third, administrative procedures for authorization and to get licenses should be simplified. Fourth one is the guaranteed access to transmission and distribution of electricity from renewable energy sources (European Parliament, 2001).

The Directive gives a reason to consider small hydropower potential in European countries. “Of special interest for Europe, from both the economic and environmental points of view, is exploiting the high potential for upgrading and refurbishing existing plants” (Lins et al., 2004).

Representatives of governments, representatives of private sector, United Nations agencies, international organizations and academia have met at the United Nations Symposium on Hydropower and Sustainable Development in Beijing China on October 27 – 29, 2004. Beijing Declaration on Hydropower and Sustainable Development, adopted at the end of symposium, states strategic importance of hydropower for sustainable development by promoting environmentally friendly, socially responsible and economically viable hydropower development. Beijing Declaration recalls Johannesburg Plan of Implementation in 2001 which calls significant increase in the global share of energy from renewable energy sources including hydropower. Beijing Declaration also recalls Political Declaration adopted at the Bonn International Conference for Renewable Energies in June 2004 which states renewable energies, including hydropower, can contribute to sustainable development by decreasing greenhouse gas emissions (United Nations Division for Sustainable Development, 2007).

3.2. Political Aspects to Small Hydropower in Turkey

Possible energy shortages in near future and dependency to generation of electricity from imported goods like fossil fuels might be minimized by the participation of private sector. Unlike the slow moving wheels and long bureaucracy of governmental organizations, private companies are aiming to complete energy projects as soon as possible to minimize turn back time of investments. Table 3.4 summarizes the historical overview of the privatization of energy market in Turkey.

Table 3.4. Privatization of Electricity Market in Turkey – Acts and Regulations

NO	YEAR	PUBLICATION	DESCRIPTION
1	1984	ACT NO: 3096	Forms a Built-Operate-Transfer (BOT) model for local and foreign private companies to generate, transmit, distribute and trade electricity (TBMM, 1984).
2	1999	ACT NO: 4446	Defines legal foundation of "Privatization" in the Constitution (TBMM, 1999).
3	2001	ACT NO: 4628	Aims to form a stable, transparent and competitive electricity market to generate sufficient, sustainable and cheaper electricity (TBMM, 2001)
4	2003	REGULATION	Aims to increase involvement of private sector in the electricity market. (MENR, 2003)
5	2004	REGULATION	Transfers six on-going HPP developments to private sector (MENR, 2004)
6	2005	ACT NO: 5346	Aims to increase electricity generation from renewable sources (TBMM, 2005)

Opening of Turkish energy market to private investors has been initiated with the Act No 3096. It was prepared and published in the Official Newspaper number 18610 on December 19th, 1984. Local and foreign private enterprises, other than Turkish Electricity Administration, had given the opportunity to generate, transmit, distribute and trade electricity (TBMM, 1984).

Different applications of privatization have been carried out in the Republic of Turkey since 1984. However, there had been no articles in the Constitution that specifically regulates “privatization”. In the practical application, international arbitration as the place of dispute resolution had been denied by State Council until 1999. Decision of State Council had an adverse effect in Built – Operate – Transfer (BOT) type projects for foreign investors to enter Turkish market (TBMM, 2008). To put an end to these difficulties and complications in the execution, “privatization” has been defined under the Article 47 of the Constitution by the publication of Act No 4446 in Official Newspaper number 23786 on August 14th, 1999 (TBMM, 1999). Also international arbitration opportunity has been given to foreign investors with the same act. According to Kılıç et al. (2007), amendments like Act No 4446 are planned to accelerate infrastructure projects, like power plants, by procuring easier financing and consent.

Regulating and organizing energy market with a politically independent agency is a common practice in many countries. Moreover, such agency is requested by European Union in the participation process of Turkey. Consequently, Energy Market Regulatory Authority (EMRA) has been established with the publication of Act No 4628 in Official Newspaper number 24335 on March 3rd, 2001. Restructuring of energy market in Turkey has started with the foundation of the Energy Market Regulatory Authority (Balat, 2007). The EMRA published Energy Market Licensing Regulation and the Electricity Market Tariffs Regulation in August 2002 (Kılıç et al., 2007).

After 2003, Ministry of Energy and Natural Resources of Turkey and authorities of energy in the Republic of Turkey have been paying more attention to the energy market by implementing new laws and regulations in order to avoid energy shortages.

"Regulation about Procedures and Principles for Contract Agreements in Water Usage Rights for Production in Electricity Market" was published on Official Newspaper number 25150 on June 26th, 2003 (MENR, 2003). This regulation is one of the most important milestones for generation and distribution of electricity in Turkey. Contractual matter of water usage rights have been edited with the publication on June 2003. Aim of this regulation should be summarized as to meet growing demand of electricity in Turkey by the role of private sector which is more competitive and faster than governmental organizations.

A change has been made in the Contract Agreements in Water Usage Rights Regulation on May 25th, 2004. With this change, 6 on-going Hydro Electric Power Plant construction projects were transferred to private sector (Eroğlu, 2007).

"Act about Usage of Renewable Energy Sources for Electric Energy Production Purposes" was published on Official Newspaper number 25819 on May 18th, 2005. As stated in the Clause 1 of the Act (TBMM, 2005); aim of this act is to generalize the use of renewable energy sources for electricity generation, to bring in these sources dependably, economically and with high quality to economy, to increase variety of sources, to decrease greenhouse gas emissions, to evaluate wastes, to protect environment and to develop the production sector needed to implement these aims.

According to the Activity Report for year 2006 of the Ministry of Energy and Natural Resources of Turkey (MENR, 2007b), "Act about Renewable Energy Sources for Electric Energy Production Purposes" gives private sector opportunity to generate electricity from renewable sources. It also gives investors feasibility opportunities in wind power, run-off river hydropower, and small-scale reservoir hydropower projects. Also with the change in the act, more attractive investment privileges have been aimed for the private sector. In this context, purchase guarantee of energy generated from renewable energy sources is extended. Guaranteed purchase period is increased from 7 years to 10 years. Also the guaranteed buy-back rate is increased to 5 – 5.5 Euro cent/kWh (MENR, 2007b).

New acts and regulations in Turkey's energy sector also provide private companies the opportunity to develop their own energy projects. Companies are encouraged to investigate and make studies on different locations, on different drainage basins, and on different branches of rivers to develop potential energy generation projects. The process of initial investigations is followed by the preliminary feasibility study. According to the results of pre-feasibility studies, economically feasible and profitable projects are selected. Further studies would continue to develop feasibility of an energy project and to submit it to authorities for approval.

According to the numbers given by General Directorate of Electrical Power Resources Survey and Development Administration (EIE, 2007), there are 142 operating and 41 on – going hydropower plants in Turkey with total installed capacities 12,788 MW and 4,397 MW, respectively. Also there are 589 hydropower schemes that are planned to be constructed (Table 3.5).

Table 3.5. Hydropower Schemes at the Planning Stage (EIE, 2007)

Classification	Number of Plants	Total Installed Capacity (MW)	Total Dependable Energy (GWh/year)	Annual Mean Energy (GWh/year)
Small Hydro (< 50MW)	492	5,701	10,379	23,464

Table 3.5. Continued

Large Hydro (> 50MW)	97	13,658	26,956	45,709
TOTAL	**589**	**19,359**	**37,335**	**69,173**

According to the report published in World Atlas and Industry Guide 2007, there are 76 small scale hydro plants operating in Turkey. However, under the new energy market regulations, the private sector applied for 694 small hydropower projects (The International Journal on Hydropower & Dams, 2007b). These projects are exploited by private sector in addition to the schemes exploited by EIE that are given in Table 3.5. 589 projects are at planning stage by EIE as of February 2007 (EIE, 2007). Excluding the competition between Turkish companies to gather licenses from EMRA, foreign investors are highly interested in Turkish energy market. According to Ereke (2007), foreign energy companies from Italy, China, United States of America, Germany, Austria, United Arab Emirates and Azerbaijan had entered to Turkish market by establishing partnerships with Turkish companies. The result of these studies justifies that MENR's initial objective in Turkish energy sector had been achieved. Completion of constructions and operating these plants is the next step for a promising future.

According to Altınbilek (2007), annual performance of State Hydraulic Works (DSİ) in the last 50 years is approximately 280 MW. Considering the completion times, expectation from the private sector is 4 – 5 times larger than DSİ per year. Altınbilek listed some of the problems that might arise due to increased demand in the market. The first problem is the financing power of private sector to complete hydropower developments. It is impossible for private sector to put all investment money from its own resources; therefore, private sector should raise adequate credits. The second problem stated by Altınbilek (2007), is the background of companies which applied for licenses from Electricity Market Regulatory Authority. Some companies acting in different industries applied for licenses in order to enter into the electricity market. Their capacity and know-how in hydropower projects is a big question mark. The third problem stated by Altınbilek (2007) is to find enough number of engineering, consultancy, and project development firms and subcontractors that have satisfactory know-how in hydropower projects. Number of design offices that can develop hydropower projects is not sufficient to meet current demand. Small hydropower schemes involve building of energy tunnels. Similar to the problem in the number of design offices, number of subcontracting companies which have expertise in tunnel works is another problem. The last problem is the long delivery times of electromechanical equipment manufacturers. Similarly, delivery times of machinery and equipment that are used in tunnel works are very long. According to the common practice in Turkey, diameters of tunnels in small hydropower schemes are between 3.0 and 4.0 meters which require smaller (mining) type of machinery (drilling rigs, underground loaders, dumper trucks, concrete mixer trucks, etc.). Availability of machinery especially for small diameter energy tunnels is another difficulty in addition to the shortage of subcontractors in tunnel works.

CHAPTER 4

RETSCREEN CLEAN ENERGY PROJECT ANALYSIS SOFTWARE – SMALL HYDRO PROJECT MODEL

4.1. Computer Software Programs in Small Hydropower

Development of a small hydropower project is not a quite simple task, as previously described in Chapter 2. It requires some expertise in engineering. Some computer software programs have been developed to overcome this problem. Mainly, these programs are used simply for initial estimations of energy output of a hydropower scheme. They should give an idea about the economy of a small hydropower development without spending relatively much time and money.

Software programs use two main approaches to estimate energy output that are the flow duration curve method and simulated stream flow method. No clear advantage has been generally apparent for either method (TNSHP, 2004).

Some of the computer based software programs and their main features are listed Table 4.1. From the software programs listed below, only IMP and RETScreen Software can be applied internationally. Both IMP and RETScreen can be used to evaluate energy production. However, RETScreen has costing, risk, emission reductions and economical evaluation features more than IMP. Also RETScreen software is available free of charge for download at RETScreen International web site.

Table 4.1. Evaluation of Assessment methodologies and Software (IEA, 2007)

ASSESSMENT TOOL		FEATURES				
Product	**Applicable Countries**	**Hydrology**	**Power & Energy**	**Costing**	**Economic Evaluation**	**Pre-liminary Design**
ASCE Small Hydro	USA	X				
HES	USA	X				
Hydra	Europe	X	X			
IMP	International	X	X			
PEACH	France	X		X		X
PROPHETE	France	X	X		X	
Remote Small Hydro	Canada	X	X		X	
RETScreen	International	X	X	X	X	

The RETScreen International Clean Energy Project Analysis Software is a unique decision support tool developed with the contribution of numerous experts from government, industry, and academia. The software also includes product, cost and climate databases, and a detailed online user manual (RETScreen 2007).

4.2. Overview

RETScreen International is managed under the Natural Resources Canada that is one of the largest science based departments in the Government of Canada. Natural Resources Canada is specialized in the use of natural resources and sustainability (Natural Resources Canada, 2008). RETScreen had been developed by Natural Resources Canada's CANMET Energy Technology Centre in Varannes, Quebec in collaboration with several partners. The National Aeronautics and Space

Administration's Langley Research Center and the Renewable Energy and Energy Efficiency Partnership are two main partners (Natural Resources Canada, 2008).

The aim of RETScreen International Clean Energy Decision Support Centre is to build the capacity of planners, decision – makers and industry to implement renewable energy and energy efficiency projects. This objective was achieved by developing decision making tools (e.g. RETScreen Software). RETScreen Software has been developed with the objective to reduce the cost of pre-feasibility studies; to help people make better decisions; and to analyze the technical and financial viability of possible projects (RETScreen, 2007).

The online manual of Small Hydro Project Model covers all information required to run the model. It comes with the software and both can be downloaded free from RETScreen International's internet homepage (www.RETScreen.net). Therefore it would not be included in this study. Instead, working methodology of the software will be introduced.

4.3. Flow Duration Curve Method for Power Potential Calculation

Two different methods; flow duration curve method and sequential streamflow routing method, can be used for computing power output of hydropower projects. Flow duration method gives better results for run-of-river projects. However, sequential streamflow routing method was developed primarily for storage projects (Yanmaz, 2006).

RETScreen Software has been developed based on the flow duration curve method. Procedure of flow duration curve method given by Yanmaz (2006) to determine energy is as follows:

1. Firstly, flow duration curve is developed.
2. Variations of tailwater elevation with discharge are reflected by developing a head versus discharge curve.

3. Plant size is selected by considering maximum and minimum head and minimum single unit discharge. Therefore, maximum discharge that can pass through turbine is determined.

4. Flow duration curve should be modified to include only the usable flow which is limited by the selected turbine.

5. Power duration curve is developed by using the modified flow duration curve and power equation.

6. The average annual energy can be calculated by computing the area under the power duration curve and multiplying by number of hours in a year.

4.3.1. Evaluating Streamflow – Flow Duration Curves

According to the definition given by Searcy (1963), “flow duration curve is a cumulative frequency curve that shows the percent of time, specified discharge were equaled or exceeded in a given period”. Magnitudes of daily, weekly or monthly flows are used to prepare a flow duration curve. They are arranged according to the time they were equaled or exceeded. The curve may be used as a probability curve to evaluate reflection of stream flows in future.

In normal practice at least 30 years of flow record is necessary for hydropower development projects. Finding records for such long period is not always possible. Flow duration curves prepared from records of shorter period are unreliable for predicting the future pattern of flow (Searcy, 1963). If less than 30 years of flow data is available, nearby or similar stations with longer periods of records should be used by correlation.

4.3.2. Gross Head

The gross head is the elevation difference between upstream water level and turbine. This value is used to calculate potential power output.

4.3.3. Maximum Tailwater Effect

After developing the head versus discharge curve, maximum tailwater effect which is the maximum reduction in available gross head that will occur during times of high flows in the river is calculated. The tailwater effect can be significant for low-head sites. On the other side, the head can be considered constant in medium and high head schemes because variations in the upper or lower surface levels are small compared with the head (RETScreen, 2004).

4.3.4. Design Flow

Design flow is defined as the flow which is available for 80 – 100 days in a year, in other words equaled or exceeded %20 - %30 of time, for run-of-river type small hydropower plants (Başeşme, 2003).

4.3.5. Various Efficiencies and Losses

In the power equation, various efficiencies and losses, gross head and design flow are used to calculate the potential power capacity and energy generation of the plant.

4.3.5.1. Maximum Hydraulic Losses

Hydraulic losses are the losses due to friction and due to intakes. In the RETScreen Software, the user enters a value that represents the estimated maximum hydraulic losses (%). For preliminary studies a value of 5% is appropriate for most hydro plants to run the model. Value changes between 2% and 7% for plants with very short water passages and for low-head hydro plants with long water passages respectively (RETScreen, 2004).

4.3.5.2. Generator Efficiency

Generator efficiency is a rate defined for the losses in generator output.

4.3.5.3. Transformer Losses

"A transformer is generally required to match the voltage of the generator with that of the transmission line or distribution system to which it is connected" (RETScreen, 2004).

Estimated transformer loss at plant capacity in percentage is entered into RETScreen software. Transformer efficiency is generally 0.99, therefore, a value of 1% is appropriate as an estimate of transformer losses (RETScreen, 2004).

4.3.5.4. Parasitic electricity Losses

Power plants might use some of the energy generated for auxiliary equipment, lighting, heating, etc. Parasitic electricity losses are typically minimal for small hydro plants. A range from 1% to 3% for parasitic electricity losses could be evaluated but RETScreen International suggests a value of 2% for most small hydro plants (RETScreen, 2004).

4.3.5.5. Annual Downtime Losses

While routine and emergency maintenance of the plant is being carried out, the small hydro plant would have to be shut down. An estimation of time for shut downs is entered to run the software program. "This value is one of the factors used to calculate the available annual energy production of the small hydro plant" (RETScreen, 2004).

CHAPTER 5

CASE STUDIES

Two small hydropower development projects were studied in the scope of this thesis. Feasibility of both projects was prepared by a private Turkish engineering and consultancy company. As per these feasibility reports, water usage contract was signed with the State Hydraulic Works and licenses of both projects were granted from Energy Market Regulatory Authority. The numbers and information given in the feasibility studies were used to run RETScreen Small Hydro Project Model. The information used in the study may be evaluated as disclosure of confidentiality and violation of rights because both projects have been under construction. Therefore project names and company names were not given in the study. Without their exact identity, these feasibility reports are carried out such that they reflect common practice of the industry in Turkey.

5.1. Case Study 1

5.1.1. Background Information for Project 1

The Project 1 is located at Karaman province in the Republic of Turkey. Main characteristics of Project 1, taken from the feasibility report, were given in Table 5.1.

Table 5.1. Main Characteristics of Project 1 (from Feasibility Report)

NO	DESCRIPTIONS	
1	Drainage Basin (km^2)	1,720.00

Table 5.1. Continued

2	Mean Flow (m^3/s)	24.92
3	Top Elevation (m)	692.50
4	Maximum Water Level (m)	691.65
5	Minimum Water Level (m)	687.40
6	Tailwater Level (m)	600.78
7	Diversion Tunnel Type	Pressure Tunnel (Horseshoe)
8	Diversion Tunnel Length (m)	5,498.00
9	Diversion Tunnel Slope	0.004
10	Penstock Length (m)	140.00
11	Penstock Diameter (m)	2.60
12	Turbine Type	Vertical Shaft Francis
13	Number of Turbines	2
14	Gross Head (m)	88.52
15	Net Head (m)	76.12
16	Design Flow (m^3/s)	21.00
17	Installed Capacity (MW)	14.00
18	Dependable Power (MW)	5.025
19	Dependable Energy (GWh)	44,022
20	Secondary Energy (GWh)	41,459
21	Total Energy (GWh)	85,481
22	Investment Cost (USD)	40,228,317
23	Construction Period (Year)	2
24	Exchange Rate (USD/YTL)	1.42

Project 1 which is the subject of Case Study 1 is a run-of-river type small hydropower project development. In the scope of Project 1 there are one fish passage, 5,498 meters of power tunnel in horseshoe cross-section, 140 meters of single penstock and a powerhouse building that contains two Francis turbines with vertical shaft (Figure 5.1).

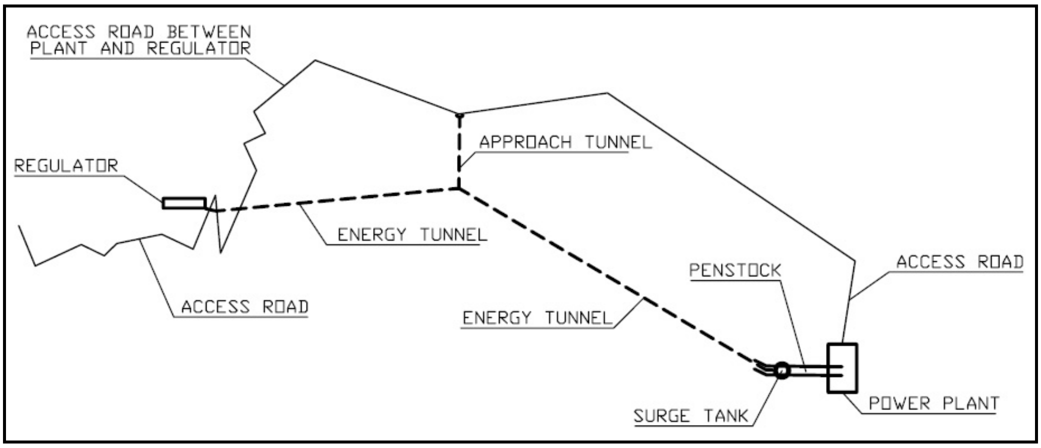

Figure 5.1. General Plan of Project 1 (Source: Feasibility Report)

5.1.2. Data Required To Run RETScreen Software for Project 1

All values and data required to run software were taken directly from feasibility report except the ones explained in paragraphs below.

Maximum tailwater effect was taken as zero. This assumption is based on the fact that Project 1 is a high head scheme.

"Maximum hydraulic losses" were calculated according to the data given in the feasibility report. The total amount of hydraulic losses is the difference between net head (88.52 m) and gross head (76.12 m), which is 12.40 meters for Project 1. Value of "maximum hydraulic losses", which will be entered into the software program, is in percentages. The percent of total hydraulic losses to the gross head equals to 14%.

"Parasitic electricity losses" and "annual down time losses" were assumed as zero.

Cost ratios are the most important parameters in modifying "formula costing method" of RETScreen computer software program in order to best fit Turkish practice. Values in Table 5.2 were taken from study of Korkmaz, (2007). Calculations of items 2, 3 and 5 were given by Korkmaz (2007) in his study. Nevertheless, item 1 and item 4 were assumed as 1.00 in the study. "Equipment manufacture cost coefficient" is used for adjusting the cost of imported components; therefore, the assumption made in the study is acceptable. However, assuming "Local vs. Canadian equipment costs ratio" as 1.00 is not reflecting reality. Unit prices of main construction materials in Canada should be compared with their prices in Turkey. However, decreasing the "Local vs. Canadian equipment costs ratio" increases the prices of equipment which is irrational. Therefore, the same assumptions given in Table 5.2 were used throughout this study.

Table 5.2. Ratios between Turkish and Canadian Costs (Korkmaz, 2007)

NO	DESCRIPTION	RATIO
1	Local vs. Canadian Equipment Costs Ratio	1.00
2	Local vs. Canadian Fuel Costs Ratio	2.08
3	Local vs. Canadian Labor Costs Ratio	0.23
4	Equipment Manufacture Cost Coefficient	1.00
5	Exchange Rate ($/CAD)	0.88

Maximum hydraulic loss is the sum of tunnel head loss, penstock head loss, canal head loss and intake and miscellaneous losses. Value entered into the "Intake and miscellaneous losses" cell, which is at cost analysis worksheet, is only for information and has no direct effect on energy or cost calculations.

Total head loss in the diversion system was given by Equation 5.1 in the feasibility report.

$$H_f = 0.0263Q^2 \quad \textbf{(5.1)}$$

Total head loss in the diversion system was calculated as 11.60 meters by using Equation 5.1. Difference between the total hydraulic losses, 12.40 meters, and diversion system losses, 11.60 meters, is the intake and miscellaneous losses which is 0.80 meters. Consequently, "intake and miscellaneous losses" is 0.90% of the gross head.

Head loss in the penstock can be calculated by using the Hazen – Williams equation (Mott, 2006), which is:

$$h_f = \frac{10.6}{C^{1.85}} \frac{L}{D^{4.87}} Q^{1.85} \quad \textbf{(5.2)}$$

where;

h_f is friction loss in meters

C is Hazen – Williams coefficient of roughness

L is pipe length in meters

D is pipe diameter in meters

Q is flow rate in m^3/s

The Hazen – Williams coefficient (C) is 148 for steel pipes (Aydın et al., 2001). Penstock length is 140 meters, diameter is 2.40 meters and design flow is 21 m^3/s. Friction loss was calculated as 0.56 meters by using the Equation 5.2.

$$h_f = \frac{10.6}{(148)^{1.85}} \frac{140}{(2.40)^{4.87}} (21)^{1.85} = 0.56 \text{ meters}$$

Finally, head loss in tunnel is 11.04 meters. Tunnel head loss and penstock head loss are 12.47% and 0.63% of gross head respectively.

"Difficulty of terrain" for road construction was assumed as 3.0 which is hilly terrain with rock outcrops according to the user manual.

Soil classifications in the tunnel section are given in the feasibility report as 25% good, 25% medium and 50% bad. All tunnel length requires lining according to feasibility report therefore "percent length of tunnel that is lined" is 100.

A value between 1 and 2 must be entered to RETScreen software for "difficulty of terrain" of transmission line. Turkish Electricity Transmission Company (TEİAŞ) divides Turkey into 5 regions and Karaman is in Region III (TEİAŞ, 2006). There is no particular information in the feasibility report that points out particular difficulties of terrain. Therefore it was assumed as 1.50.

Common practice in Turkey is taking miscellaneous costs approximately 10% of reconnaissance cost except land rights. Therefore, adjustment factor for miscellaneous cost in RETScreen software was chosen as 0.50 in order to get closer results to Turkish practice.

Data required to be entered in the "Financial Summary" worksheet was taken directly from the study of Korkmaz, (2007).

Cost of operation and maintenance was assumed to be 0.2% of investment cost. Annual wage of operation and maintenance personnel was assumed to be 52,800 USD as stated in feasibility report.

Periodic cost of a power plant during its lifetime, which is 50 years in common practice, is renewal costs of electromechanical equipment other than annual costs. The renewal cost is 50% of electromechanical equipment cost in 35^{th} year.

Data required to run RETScreen software for Project 1 was given in Table 5.3 for "Energy Model", "Hydrology and Load", "Equipment Data", "Cost Analysis" and "Financial Summary" worksheets.

Table 5.3. Data Required by RETScreen Software (Project 1)

NO	DESCRIPTION		SOURCE
A. ENERGY MODEL			
1	Gross Head (m)	88.52	Feasibility Report
2	Maximum Tailwater Effect (m)	0	Assumption
3	Design Flow (m^3/s)	21.00	Feasibility Report
4	Maximum Hydraulic Losses (%)	14	Calculated
5	Generator Efficiency (%)	97	Feasibility Report
6	Transformer Losses (%)	1	Feasibility Report
7	Parasitic Electricity Losses (%)	0	Assumption
8	Annual Downtime Losses (%)	0	Assumption
B. HYDROLOGY & LOAD			
1	Residual Flow (m^3/s)	0.118	Feasibility Report
2	Percent time firm flow available (%)	95	Feasibility Report
3	Grid Type	Central Grid	Feasibility Report
C. EQUIPMENT DATA			
1	Turbine Type	Francis	Feasibility Report
2	Number of Turbines	2	Feasibility Report
3	Turbine Manufacture / Design Coefficient	4.50	Software Default
4	Efficiency Adjustment (%)	- 1.10	Calculated

Table 5.3. Continued

D. COST ANALYSIS			
1	Local vs. Canadian Equipment Costs Ratio	1.00	Calculated
2	Local vs. Canadian Fuel Costs Ratio	2.08	Calculated
3	Local vs. Canadian Labor Costs Ratio	0.23	Calculated
4	Equipment Manufacture Cost Coefficient	1.00	Calculated
5	Exchange Rate ($/CAD)	0.88	Calculated
6	Cold Climate (yes/no)	No	Feasibility Report
7	Existing Dam (yes/no)	No	Feasibility Report
8	New Dam Crest Length (m)	24.50	Feasibility Report
9	Rock at Dam Site? (yes/no)	Yes	Feasibility Report
10	Intake and Miscellaneous Losses (%)	0.90	Calculated
11	Access Road Required (yes/no)	Yes	Feasibility Report
12	Length (km)	11.30	Feasibility Report
13	Tote road only (yes/no)	No	Feasibility Report
14	Difficulty of Terrain	3.0	Feasibility Report
15	Tunnel Required? (yes/no)	Yes	Feasibility Report
16	Tunnel Length (m)	5,498	Feasibility Report

Table 5.3. Continued			
17	Allowable Tunnel Head Loss Factor (%)	12.47	Calculated
18	Percent Length of Tunnel that is Lined (%)	100	Feasibility Report
19	Tunnel Excavation Method	Mechanized	Assumption
20	Canal Required (yes/no)	No	Feasibility Report
21	Penstock Required (yes/no)	Yes	Feasibility Report
22	Penstock Length (m)	140	Feasibility Report
23	Number of Identical Penstocks	1	Feasibility Report
24	Allowable Penstock Head Loss Factor (%)	0.63	Calculated
25	Distance to Borrow Pits (km)	5	Feasibility Report
26	Transmission Line Length (km)	35	Feasibility Report
27	Difficulty of Terrain	1.50	Assumption
28	Voltage (kV)	33.00	Feasibility Report
29	Interest Rate (%)	9.50	Feasibility Report
30	Expropriation costs (USD)	411,919	Feasibility Report
31	Miscellaneous Adjustment Factor	0.50	Assumption
E. FINANCIAL SUMMARY			
1	Avoided cost of energy ($/kWh)	0.0750	Feasibility Report

Table 5.3. Continued

2	RE Production Credit ($/kWh)	-	Feasibility Report
3	Debt Ratio (%)	0	Feasibility Report
4	Income Tax Analysis (Yes/No)	Yes	(Korkmaz, 2007)
5	Effective Income Tax Rate (%)	20	(Korkmaz, 2007)
6	Loss Carry forward?	Yes	(Korkmaz, 2007)
7	Depreciation Method	Straight-line	(Korkmaz, 2007)
8	Depreciation Tax Basis (%)	93.5	(Korkmaz, 2007)
9	Depreciation Period	50	(Korkmaz, 2007)
10	Tax Holiday Available? (Yes/No)	No	(Korkmaz, 2007)
11	Avoided Cost of Capacity ($/kW-yr)	-	(Korkmaz, 2007)
12	Energy Cost Escalation Rate (%)	0	(Korkmaz, 2007)
13	Inflation (%)	5.0	(Korkmaz, 2007)
14	Discount Rate (%)	9.5	Feasibility Report
15	Project Life (yr)	50	Feasibility Report

5.2. Case Study 2

5.2.1. Background Information for Project 2

The Project 2 is also located at Karaman province in the Republic of Turkey. Main characteristics of Project 2, taken from the feasibility report, were given in Table 5.4.

Table 5.4. Main Characteristics of Project 2 (from Feasibility Report)

NO	DESCRIPTIONS	
1	Drainage Basin (km^2)	2,600.00
2	Mean Flow (m^3/s)	28.63
3	Top Elevation (m)	504.50
4	Maximum Water Level (m)	503.80
5	Minimum Water Level (m)	497.00
6	Diversion Tunnel Type	Pressure Tunnel (Horseshoe)
7	Diversion Tunnel Length (m)	3,594
8	Diversion Tunnel Slope	0.006
9	Penstock Length (m)	122
10	Penstock Diameter (m)	3.20
11	Turbine Type	Vertical Shaft Francis
12	Number of Turbines	2
13	Gross Head (m)	88.58
14	Net Head (m)	76.182
15	Design Flow (m^3/s)	35.00
16	Installed Capacity (MW)	25.00
17	Dependable Energy (GWh)	40,900
18	Secondary Energy (GWh)	74,178
19	Total Energy (GWh)	115,078
20	Investment Cost (USD)	39,086,483
21	Construction Period (Year)	2
22	Exchange Rate (USD/YTL)	1.42

Project 2 is also run-of-river type small hydropower project development like Project 1. There are 3,594 meters of power tunnel in horseshoe cross-section, 122 meters of single penstock and a powerhouse building which contains two vertical shaft Francis turbines in the scope of Project 2 (Figure 5.2).

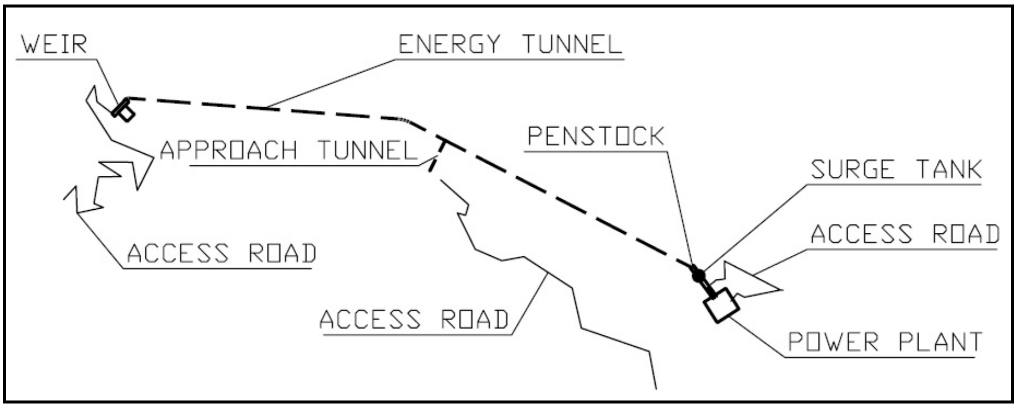

Figure 5.2. General Plan of Project 2 (Source: Feasibility Report)

5.2.2. Data Required To Run RETScreen Software for Project 2

All values and data required to run software were taken directly from feasibility report except the ones explained in paragraphs below. Moreover, if no explanation was given below, same assumptions with Project 1 were made for Project 2.

"Maximum hydraulic losses" were calculated as 12.398 meters by subtracting net head (76.182 m) from gross head (88.58 m) given in the feasibility report. The percent of total hydraulic losses to the gross head was calculated as 14% for Project 2.

Total head loss in the diversion system was given by Equation 5.3 in the feasibility report.

$$H_f = 0.0077Q^2 \quad \textbf{(5.3)}$$

Total head loss in the diversion system was calculated as 9.433 meters by using the Equation 5.3. Difference between the total hydraulic losses (12.398 m) and diversion system losses (9.433 m) is the intake and miscellaneous losses which is 2.965 meters. Consequently, “intake and miscellaneous losses” is 3.35% of the gross head.

The Hazen – Williams coefficient (C) is 148 for steel pipes (Aydın et al., 2001). Penstock length is 122 meters, diameter is 3.20 meters and design flow is 35 m^3/s. Friction loss of the penstock was calculated as 0.311 meters by using Equation 5.2. Subtracting penstock losses (0.311 m) from diversion system losses (9.433 m) gives tunnel head loss which is 9.122 meters. Tunnel head loss and penstock head loss are 10.30% and 0.35% of the gross head, respectively.

Table 5.5 gives the data required by RETScreen software in order to perform the pre-feasibility study of Project 2.

Table 5.5. Data Required by RETScreen Software (Project 2)

NO	DESCRIPTION		FROM
A. ENERGY MODEL			
1	Gross Head (m)	88.58	Feasibility Report
2	Maximum Tailwater Effect (m)	0	Assumption
3	Design Flow (m^3/s)	35.00	Feasibility Report
4	Maximum Hydraulic Losses (%)	14	Calculated
5	Generator Efficiency (%)	97	Feasibility Report
6	Transformer Losses (%)	1	Feasibility Report

Table 5.5. Continued

7	Parasitic Electricity Losses (%)	0	Assumption
8	Annual Downtime Losses (%)	0	Assumption
B. HYDROLOGY & LOAD			
1	Residual Flow (m^3/s)	0.15	Feasibility Report
2	Percent time firm flow available (%)	95	Feasibility Report
3	Grid Type	Central Grid	Feasibility Report
C. EQUIPMENT DATA			
1	Turbine Type	Francis	Feasibility Report
2	Number of Turbines	2	Feasibility Report
3	Turbine Manufacture / Design Coefficient	4.50	Software
4	Efficiency Adjustment (%)	-1.40	Calculated
D. COST ANALYSIS			
1	Local vs. Canadian Equipment Costs Ratio	1.00	Calculated
2	Local vs. Canadian Fuel Costs Ratio	2.08	Calculated
3	Local vs. Canadian Labor Costs Ratio	0.23	Calculated
4	Equipment Manufacture Cost Coefficient	1.00	Calculated
5	Exchange Rate ($/CAD)	0.88	Calculated

Table 5.5. Continued

6	Cold Climate (yes/no)	No	Feasibility Report
7	Existing Dam (yes/no)	No	Feasibility Report
8	New Dam Crest Length (m)	13.50	Feasibility Report
9	Rock at Dam Site? (yes/no)	Yes	Feasibility Report
10	Intake and Miscellaneous Losses (%)	3.35	Calculated
11	Access Road Required (yes/no)	Yes	Feasibility Report
12	Length (km)	1.20	Feasibility Report
13	Tote road only (yes/no)	No	Feasibility Report
14	Difficulty of Terrain	5.00	Assumption
15	Tunnel Required? (yes/no)	Yes	Feasibility Report
16	Tunnel Length (m)	3.594	Feasibility Report
17	Allowable Tunnel Head Loss Factor (%)	10.30	Calculated
18	Percent Length of Tunnel that is Lined (%)	85	Feasibility Report
19	Tunnel Excavation Method	Mechanized	Assumption
20	Canal Required (yes/no)	No	Feasibility Report
21	Penstock Required (yes/no)	Yes	Feasibility Report
22	Penstock Length (m)	122	Feasibility Report

Table 5.5. Continued

23	Number of Identical Penstocks	1	Feasibility Report
24	Allowable Penstock Head Loss Factor (%)	0.35	Calculated
25	Distance to Borrow Pits (km)	5	Feasibility Report
26	Transmission Line Length (km)	30	Feasibility Report
27	Difficulty of Terrain	1.00	Assumption
28	Voltage (kV)	154.00	Feasibility Report
29	Interest Rate (%)	9.50	Feasibility Report
30	Expropriation costs (USD)	1,000,000	Feasibility Report
31	Miscellaneous Adjustment Factor	0.50	Assumption
E. FINANCIAL SUMMARY			
1	Avoided cost of energy ($/kWh)	0.0750	Feasibility Report
2	RE Production Credit ($/kWh)	-	Feasibility Report
3	Debt Ratio (%)	0	Feasibility Report
4	Income Tax Analysis (Yes/No)	Yes	(Korkmaz, 2007)
5	Effective Income Tax Rate (%)	20	(Korkmaz, 2007)
6	Loss Carry forward?	Yes	(Korkmaz, 2007)
7	Depreciation Method	Straight-line	(Korkmaz, 2007)
8	Depreciation Tax Basis (%)	93.5	(Korkmaz, 2007)

Table 5.5. Continued

9	Depreciation Period	50	(Korkmaz, 2007)
10	Tax Holiday Available? (Yes/No)	No	(Korkmaz, 2007)
11	Avoided Cost of Capacity ($/kW-yr)	-	(Korkmaz, 2007)
12	Energy Cost Escalation Rate (%)	0	(Korkmaz, 2007)
13	Inflation (%)	5.0	(Korkmaz, 2007)
14	Discount Rate (%)	9.5	Feasibility Report
15	Project Life (yr)	50	Feasibility Report

5.3. Comparison of Costs

The results of RETScreen Small Hydro Project Model for Project 1 and Project 2 were given at Appendix A and Appendix B, respectively. Moreover, comparisons of costs between the ones calculated by the software and given in the feasibility report were tabulated in Table 5.6 and Table 5.7.

Table 5.6. Comparison of Costs for Project 1

NO	DESCRIPTION	FEASIBILTY REPORT (USD)	RETSCREEN SOFTWARE (USD)
1	Land Rights	411,919	411,919
2	Energy Equipment	4,800,000	8,725,073
3	Access Road	1,175,595	1,183,586
4	Transmission Line	1,602,113	974,718

Table 5.6. Continued

5	Substation and Transformer	774,590	375,396
6	Penstock	591,615	458,173
7	Tunnel	15,613,148	28,485,379
8	Other Works	8,495,746	7,201,039
9	TOTAL Reconnaissance Cost	33,464,726	47,815,283
10	Miscellaneous	3,106,472	4,403,415
11	TOTAL Plant Cost	36,571,198	52,218,698
12	Feasibility – Development – Engineering	3,657,120	4,571,303
13	**TOTAL Investment Cost**	**40,228,318**	**56,790,001**

Table 5.7. Comparison of Results for Project 2

NO	DESCRIPTION	FEASIBILTY REPORT (USD)	RETSCREEN SOFTWARE (USD)
1	Land Rights	1,000,000	1,000,000
2	Energy Equipment	8,710,000	13,322,717
3	Access Road	786,977	437,125
4	Transmission Line	963,958	3,355,109
5	Substation and Transformer	1,249,319	943,330
6	Penstock	653,963	598,597
7	Tunnel	13,151,961	22,818,620
8	Other Works	6,182,610	10,972,428
9	TOTAL Reconnaissance Cost	32,698,788	53,447,926

Table 5.7. Continued

10	Miscellaneous	2,834,378	5,299,698
11	TOTAL Plant Cost	35,533,166	58,747,624
12	Feasibility – Development – Engineering	3,553,317	5,256,955
13	**TOTAL Investment Cost**	**39,086,483**	**64,004,579**

After one by one comparison of every cost item in tables, the largest differences were found in the tunnel, transmission line and energy equipment costs.

5.3.1. Tunnel Works

The major difference in the comparison was found in the cost of tunnel. Reason for difference in tunnel costs was examined by checking estimations of RETScreen Software. Tunnel diameters in feasibility report and RETScreen Software are different in both projects. For Project 1, diameter was calculated as 4.80 meters by the RETScreen Small Hydro Project Model. However, it is given as 3.80 meters in the feasibility report. Similarly diameter calculated by the RETScreen Small Hydro Project Model for Project 2 is larger than feasibility report. Although it is given as 3.80 meters in feasibility report, RETScreen calculation is 5.50 meters for Project 2.

In order to compare tunnel costs more accurately, tunnel diameter must be decreased to the values in feasibility report. There is no option in the software that allows users to modify tunnel diameter. Moreover, the formula, which calculates the tunnel diameter, is not given by RETScreen. Tunnel length, "percent length of tunnel that is lined" and "allowable tunnel headloss factor" are the input data for tunnels that are entered into the RETScreen software. Headloss due to friction in closed conduits is inversely proportional to diameter and surface roughness. Changes in the “percent length of tunnel that is lined” cell do not change the value of tunnel diameter. However, increasing the percentage of lining decreases roughness, therefore tunnel diameter should be increased.

There is only one approach to update tunnel diameter which is by adjusting the input data. Tunnel length is a solid fact taken directly from the feasibility report. Moreover, “percent length of tunnel that is lined” and tunnel length have direct effect on the cost of tunnel. On the other side, tunnel headloss is not and may be modified. Annual energy production is calculated from the data which is entered into the “maximum hydraulic losses” cell in “Energy Model” worksheet. However, data entered into the “allowable tunnel headloss factor” cell has no effect on energy generation and plant capacity calculations. When the tunnel headloss factor was increased above the percentage in maximum hydraulic losses, RETScreen software only gave a warning message that tells the user to increase the percentage in maximum hydraulic losses cell in Energy Model (Figure 5.3). Consequently, tunnel diameter was decreased manually by increasing “allowable tunnel headloss factor” in this study.

Tunnel required?	yes/no	Yes	
Length	m	5.498	
Allowable tunnel headloss factor	%	43,0%	Increase Maximum hydraulic losses in Energy Model by 30.5%
Percent length of tunnel that is lined	%	100%	15% to 100%
Tunnel excavation method	-	Mechanised	
Tunnel diameter	m	3,8	
Canal required?	yes/no	No	
Penstock required?	yes/no	Yes	
Length	m	140,0	
Number of identical penstocks	penstock	1	
Allowable penstock headloss factor	%	0,6%	Increase Maximum hydraulic losses in Energy Model by 30.5%
Pipe diameter	m	2,59	
Average pipe wall thickness	mm	9,4	
Distance to borrow pits	km	5,0	

Figure 5.3. Warning Message

In Project 1, “tunnel headloss factor” is increased from 12.47% to 43% in RETScreen software in order to decrease tunnel diameter from 4.80 meters to 3.80 meters. Consequently, cost of tunnel works was decreased from 28,485,379 USD to 18,933,849 USD. Besides that, feasibility, development, engineering and miscellaneous costs were decreased.

Hence, total investment cost was decreased to 45,608,068 USD for Project 1 (Appendix C). In Project 2, tunnel head loss factor is increased to 70% in order to decrease tunnel diameter to 3.80 meters, which decreases the cost of tunnel works from 22,818,620 USD to 12,124,044 USD (Appendix D). Investment cost of Project 2 was decreased to 51,398,022 USD. Updated tunnel diameters lead to more accurate results in costs. Therefore, an adjustment factor should be added for the tunnel diameter calculations. In conclusion, tunnel diameter costing gives accurate results for Turkey if tunnel diameter is decreased manually.

5.3.2. Transmission Line

Another big difference in cost items is the cost of transmission lines. In Project 1, voltage of transmission line is 33kV. Difference of costs in transmission line in Project 1 might be acceptable for pre-feasibility works. However, difference in Project 2, in which voltage of transmission line is 154kV, is huge. Estimated unit prices for high – voltage energy systems in 2006 published by Turkish Electricity Transmission Company were used for comparison (TEİAŞ, 2006). According to estimated unit prices for Region III (TEİAŞ, 2006), cost of transmission line with 154 kV system changes between 93,276 YTL/km and 225,871 YTL/km depending on the diameter and number of conductors used. Mean value for the cost of 154 kV transmission line per kilometer might be taken 110,000 USD (1 USD = 1.42 YTL). As a result, the cost of 30 km transmission line in Project 2 should be 3,300,000 USD. In conclusion, cost of transmission line calculated by RETScreen Software gives more realistic results than feasibility report.

5.3.3. Electromechanical Equipment

Budget proposals for both projects were taken from different electromechanical equipment manufacturers around the world. Proposals include design, engineering, installation, commissioning, start – up, testing and all related services for the works and electromechanical equipment. In other words, proposals are in turn key basis. 2 sets of vertical shaft Francis turbines have been selected for Project 1 and Project 2 with installed capacities 14 MW and 25 MW respectively.

Runner diameters of the turbines calculated by the manufacturers and estimated by RETScreen computer software were compared in Table 5.8. Estimations of the software are approximately 15% – 20% larger than the actual diameters. Estimation of runner diameter might be used to give an idea about the scale of civil works. It can be used especially in dimensioning powerhouse building.

Table 5.8. Comparison of Runner Diameters

NO	COMPANY	RUNNER DIAMETER (mm)	
		PROJECT 1	PROJECT 2
1	SPAIN	1,140.00	1,383.00
2	CZECH REP.	1,100.00	1,500.00
3	CHINA (2)	1,130.00	1,520.00
4	MEAN (manufacturers)	1,123.33	1,467.67
5	RETSCREEN SOFTWARE	1,400.00	1,700.00

Costs of electromechanical equipment, given in the feasibility report which was prepared in 2006, are 4,800,000 USD and 8,710,000 USD for Project 1 and Project 2 respectively. On the other side, RETScreen software calculated 8,725,073 USD and 13,322,717 USD for energy equipments of Project 1 and Project 2 respectively. The proposals that were taken from several electromechanical companies in the fourth quarter of 2007 were given in Figure 5.4 and Figure 5.5. The lowest prices were given by Chinese companies.

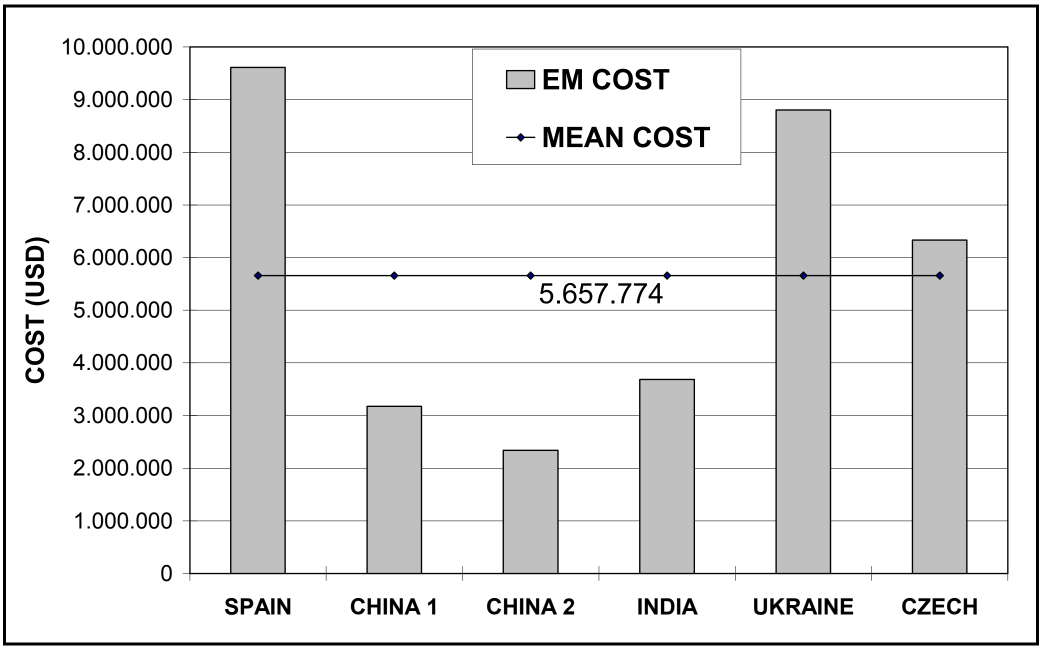

Figure 5.4. Actual Electromechanical Equipment Costs for Project 1

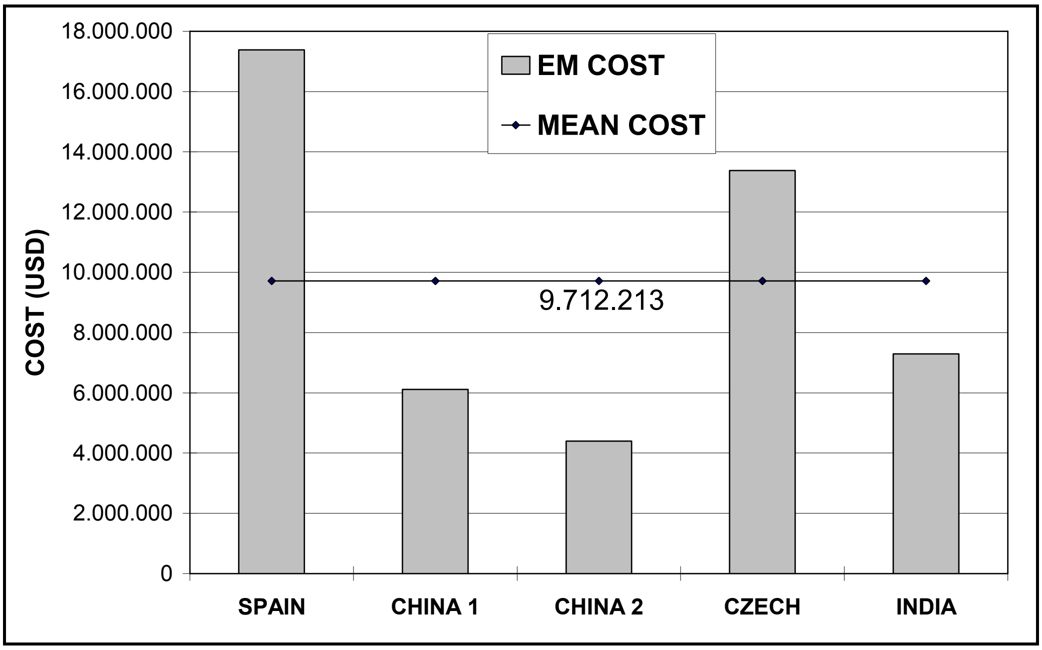

Figure 5.5. Actual Electromechanical Equipment Costs for Project 2

In RETScreen software, cost of energy equipment is given by using Equation 5.4 and Equation 5.5 (RETScreen International, 2004).

$$\text{Cost of Generator and Control} = 0.82\, n^{0.96} C_g (MW/H_g{}^{0.28})^{0.29} 10^6 \quad \textbf{(5.4)}$$

$$\text{Cost of Francis Turbine} = 0.17\, n^{0.96} J_t K_t d^{1.47} [(13 + 0.01 H_g)^{0.3} + 3] 10^6 \quad \textbf{(5.5)}$$

where;

n is the number of turbines

C_g is the lower cost generation factor

MW is the total capacity in megawatts

H_g is the gross head in meters

J_t is the vertical axis turbine factor

K_t is the small horizontal axis turbine factor

d is the runner diameter in meters

Cost of electromechanical equipment in the feasibility report was calculated from the power of turbine. For example, cost of electromechanical equipment in Project 1 is calculated from the equation which is a constant cost for switchgear 600,000 USD plus 300 USD per kilowatt. However, cost of energy equipments is calculated from Equation 5.4 and Equation 5.5 by RETScreen Small Hydro Project Model (RETScreen, 2007). Using runner diameter as a factor in turbine cost calculations instead of capacity gives more rational results.

Prices of European manufacturers double and even triple the prices of Chinese manufacturers in actual case (Figure 5.4 and Figure 5.5). Electromechanical equipment costs of RETScreen Software are closer to the prices in European market. However, cost estimations in feasibility report limit the number of choices to only Chinese manufacturers. Also RETScreen Small Hydro Project Model has an adjustment factor, equipment manufacture cost coefficient, for foreign components of work which includes penstock, electromechanical equipment and engineering. Chinese alternative might be adopted into the pre-feasibility study by using either “Equipment Manufacture Cost Coefficient” or “Energy Equipment Adjustment Factor” option in “Cost Analysis” worksheet.

In the study of Korkmaz, (2007), few other limitations of RETScreen software in Turkish practice were pointed out. The first limitation is that RETScreen software does not capable of making reservoir operation studies. Therefore, it should not be used for reservoir type projects. The second one is that identical turbines should be selected for each project. User is not allowed to choose turbines with different capacities. The third one is that the diameter of penstock calculated by RETScreen software cannot be adjusted which is similar to the case in tunnel diameter.

CHAPTER 6

ELECTRICITY GENERATION FROM MULTIPURPOSE DAMS

6.1. Background Information

There are several dams in Turkey used for domestic, industrial and irrigation water supply or flood control but not for energy generation. Porsuk Dam (Figure 6.1) is a 36 years old multipurpose dam which has been used for irrigation, flood control and domestic water supply in Eskişehir province of Turkey since 1972. Height of the dam from thalweg elevation is 49.70 meters (DSİ, 2008). Small hydroelectric plants can be developed at existing dams which requires minor civil works. Cordova Dam, which is used for fish hatchery and located at Ontario, Canada, is an example for generating electricity by refurbishing the existing dam (Natural Resources Canada, 2008).

Figure 6.1. View from Porsuk Dam (DSİ, 2008)

Potential of Porsuk Dam will be reevaluated for electricity generation in the scope of this study. In literature similar study had been carried out for Porsuk Dam by Bakış et al in 2005. Installed capacity of Porsuk Dam was calculated as 3.90 MW by installing 3 Francis turbines at the end of a single 230 meters long penstock (Bakış et al., 2005). According to the proceeding study of Bakış about Porsuk basin in 2006, construction of two concrete faced rockfill dams in the valley of Porsuk River was proposed for the full evaluation of basin's potential. Porsuk Dam and planned two dams have installed capacity of 9.80 MW in the second study (Bakış, 2007). RETScreen software can further be used as a decision and support tool in the evaluation of existing dams like Porsuk. In the evaluation of Porsuk Dam, no pressure tunnel was planned for diverting water. Therefore, although RETScreen software has some limitations in Turkish applications, they are in the acceptable range for the case of Porsuk Dam.

6.2. Hydrology

Monthly average flow rates released from Porsuk Dam were taken from the study of Bakış and Bilgin and tabulated in Table 6.1 (Bakış et al., 2005). Flow duration curve of run-of-river type hydropower schemes should be developed from daily flow records. However, due the availability of 32 years of monthly flow record between 1972 and 2003, they were used to prepare flow duration curve (Figure 6.2).

Table 6.1. Annual Flow (m^3/s) Released From Porsuk Dam Between 1972 and 2003 (Bakış et al., 2005)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total	Mean
1972	6,91	0,08	6,72	16,63	9,84	5,60	0,79	7,69	9,57	10,23	11,46	9,14	**94,66**	**7,89**
1973	6,50	5,36	2,82	2,80	0,00	0,65	3,56	11,31	12,73	13,63	12,17	9,72	**81,25**	**6,77**
1974	6,46	3,05	0,37	0,93	0,17	1,69	5,13	6,91	14,12	14,64	13,33	13,00	**79,80**	**6,65**
1975	10,16	7,48	6,01	0,13	0,12	0,67	7,37	7,39	16,63	22,74	21,09	16,94	**116,73**	**9,73**
1976	8,40	6,52	0,24	0,38	0,50	3,13	3,09	13,14	12,11	16,17	16,17	14,85	**94,70**	**7,89**
1977	10,83	3,40	0,24	0,28	0,27	5,26	7,79	13,48	17,44	16,73	17,32	25,89	**118,93**	**9,91**
1978	8,96	2,82	0,10	0,15	0,14	2,49	3,01	14,22	18,98	18,03	12,99	12,77	**94,66**	**7,89**
1979	12,06	11,27	14,60	10,84	14,92	11,28	16,44	18,74	13,97	17,06	21,80	22,84	**185,82**	**15,49**
1980	29,05	11,30	7,32	13,70	10,21	7,47	3,18	15,61	17,01	16,91	18,00	25,77	**175,53**	**14,63**
1981	20,35	4,86	4,82	1,15	0,21	2,77	18,02	15,20	19,41	24,98	20,61	30,48	**162,86**	**13,57**
1982	24,87	20,45	4,82	3,07	3,03	2,74	5,32	10,60	12,23	16,65	16,50	13,46	**133,74**	**11,15**

Table 6.1. Continued

1983	6,12	6,29	1,24	1,24	1,20	3,41	9,61	14,34	14,47	14,49	12,58	9,88	**94,87**	**7,91**
1984	3,88	2,19	0,20	0,17	0,12	1,13	7,37	27,14	17,48	19,97	20,57	18,02	**118,24**	**9,85**
1985	11,84	10,22	6,31	6,17	7,90	9,97	7,18	15,12	15,43	15,31	13,10	11,42	**129,97**	**10,83**
1986	5,38	3,94	1,58	0,63	0,44	2,45	11,27	10,79	10,61	9,56	7,43	6,94	**71,02**	**5,92**
1987	3,53	2,70	1,00	0,05	0,05	0,07	1,69	6,20	9,38	10,45	10,86	10,34	**56,32**	**4,69**
1988	7,68	4,50	0,66	0,05	0,04	0,52	3,17	9,35	10,09	10,28	9,89	10,71	**66,94**	**5,58**
1989	5,30	0,22	0,02	0,01	0,01	3,09	8,83	8,77	6,40	7,54	6,05	3,29	**49,53**	**4,13**
1990	2,70	1,16	0,01	0,35	0,35	0,69	3,67	7,02	10,42	8,77	8,14	0,02	**43,30**	**3,61**
1991	0,01	0,02	0,01	0,03	0,03	0,03	0,31	8,92	8,10	9,11	8,10	4,82	**39,49**	**3,29**
1992	1,59	1,13	0,54	0,37	0,22	0,02	0,76	10,45	8,64	9,00	8,29	4,82	**45,83**	**3,82**
1993	1,15	0,34	0,21	0,24	0,08	0,02	4,17	6,72	10,03	9,26	7,84	6,29	**46,35**	**3,86**
1994	0,57	0,33	0,11	0,08	0,07	0,10	5,79	7,28	8,02	8,89	5,56	2,79	**39,59**	**3,30**
1995	0,59	0,13	0,06	0,03	0,02	0,01	0,60	9,52	10,26	8,14	8,33	4,17	**41,86**	**3,49**
1996	0,56	0,66	0,66	0,63	0,07	0,05	2,28	10,75	8,99	9,56	8,36	4,09	**46,66**	**3,89**
1997	0,77	1,04	1,00	0,83	1,04	2,04	2,03	9,15	7,52	8,81	6,27	5,90	**46,40**	**3,87**
1998	4,93	0,66	0,65	0,21	0,16	0,92	2,83	3,17	5,71	9,30	10,75	6,02	**45,31**	**3,78**
1999	5,49	1,17	1,05	0,45	0,02	0,01	1,46	10,08	9,22	8,70	8,55	10,42	**56,62**	**4,72**
2000	10,98	4,05	2,21	3,16	1,86	0,57	3,31	20,83	12,58	11,24	12,32	11,73	**94,84**	**7,90**
2001	2,74	1,94	2,10	2,17	1,02	2,69	1,17	10,19	13,19	9,86	8,74	5,67	**61,48**	**5,12**
2002	2,83	2,11	0,44	0,46	0,58	0,47	29,90	33,60	21,22	11,39	11,39	7,79	**122,18**	**10,18**
2003	6,76	16,36	14,78	10,96	4,00	3,99	8,41	22,10	17,82	16,54	15,34	12,69	**149,75**	**12,48**
Total	**229,95**	**137,75**	**82,90**	**78,35**	**58,69**	**76,00**	**189,51**	**395,78**	**399,78**	**413,94**	**389,90**	**352,68**		
Mean	**7,19**	**4,30**	**2,59**	**2,45**	**1,83**	**2,38**	**5,92**	**12,37**	**12,49**	**12,94**	**12,18**	**11,02**		

Firm flow, the flow available at least 95% of time, is 0.05 m^3/s according to the flow duration curve (Figure 6.2).

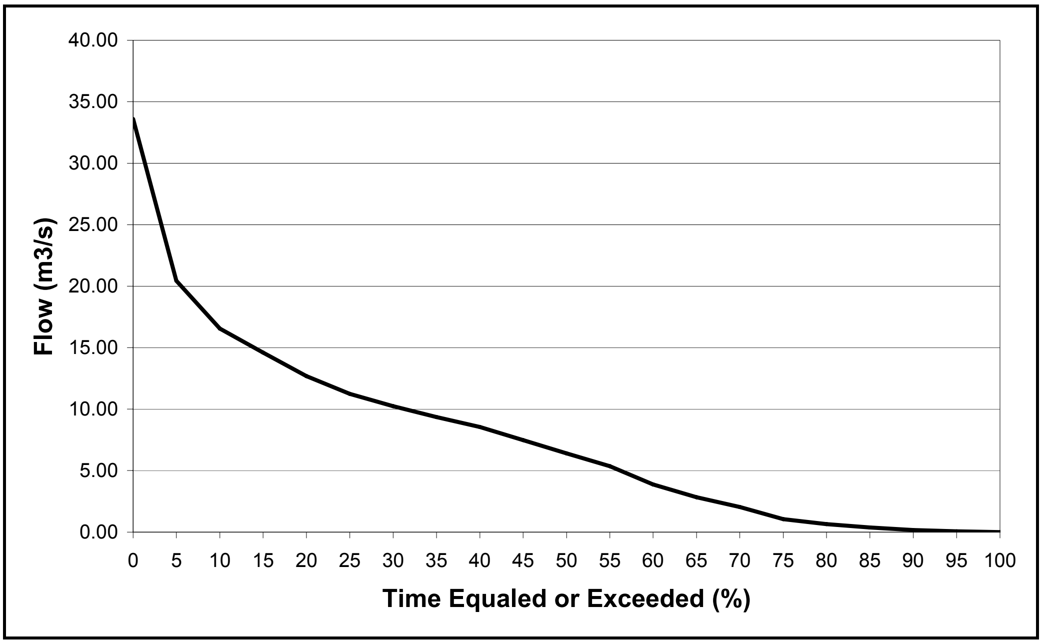

Figure 6.2. Flow Duration Curve of Porsuk Dam

Flow duration curve, as a probability curve to forecast future flows, can be used for Porsuk Dam due to lack of information about the operational studies of the dam. Further studies may involve operational studies which lead to more deterministic models to describe flow released from Porsuk Dam. According to the flow duration curve method, design flow is generally defined as the flow available at 20% - 30% of time. Study for defining installed capacity of the plant was carried out by taking the flows available at 20%, 25% and 30% of time.

6.3. Gross Head

Monthly average gross heads at the reservoir has been changing between 39.12 meters and 43.00 meters (Bakış et al., 2005). Gross head was estimated by taking the mean value of monthly average heads at the reservoir of Porsuk dam, which is 40.61 meters.

6.4. Penstock

Single penstock, 230 meters long and 2.30 meters in diameter, was proposed in the former study (Bakış et al., 2005). Head loss in 230 meters long penstock was calculated by examining different diameters from 1.90 meters to 2.60 and design flows (Q_{20}, Q_{25} and Q_{30}) from Hazen-Williams Equation (Equation 5.2). Results were tabulated in Table 6.2. Although increasing the penstock diameter decreases head losses, it also increases the cost of penstock.

Table 6.2. Head loss (m) in Penstock for Different Diameters and Flows

Diameter (m)	**Design Flow**		
	Q_{20}=12.69 m^3/s	**Q_{25}=11.24 m^3/s**	**Q_{30}=10.23 m^3/s**
1.90	1.137	0.909	0.763
2.00	0.886	*0.708*	*0.595*

Table 6.2. Continued

2.10	*0.699*	0.558	0.469
2.20	0.557	0.445	0.374
2.30	0.449	0.358	0.301
2.40	0.365	0.291	0.245
2.50	0.299	0.239	0.201
2.60	0.247	0.197	0.166

Economic appraisal of hydropower projects can be made by net present value method, benefit – cost ratio method or internal rate of return method. Although the benefit-cost ratio method could be used for economic appraisal, it does not give the amount of net benefit. In other words a project with largest ratio does not always yield the largest benefit. On the other side, net present value (NPV) is useful for comparing different projects (Jiandong, 1997). After comparing net present values of alternative penstock diameters, optimum diameter was calculated as 2.10 meters for Q_{20} (Figure 6.3). However, optimum diameter was calculated as 2.00 meters for Q_{25} and Q_{30}.

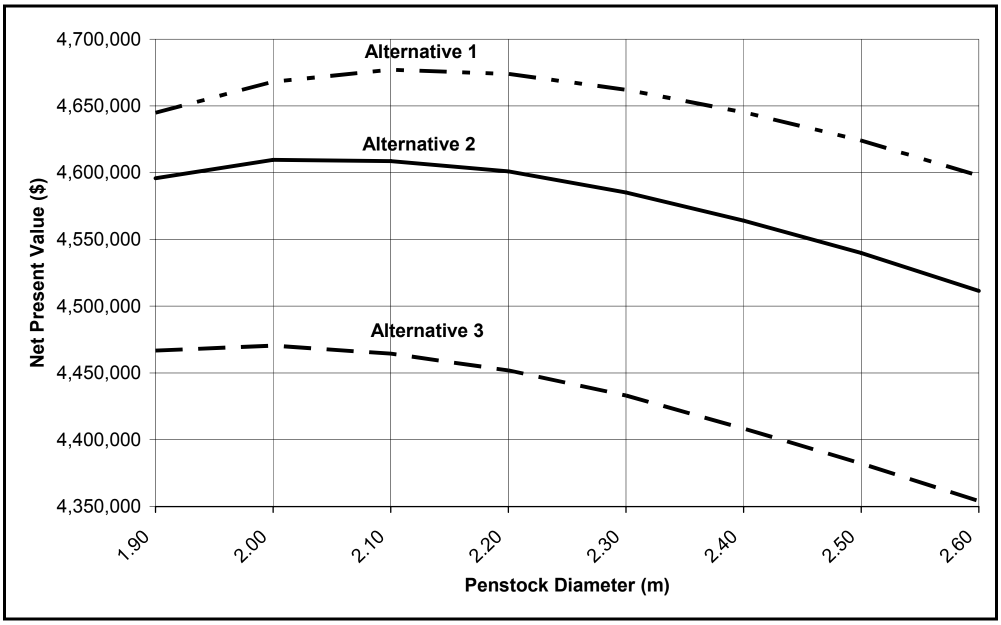

Figure 6.3. Optimization of Penstock Diameters

6.5. Energy Equipment

Turbine peak efficiency, generator efficiency and transformer efficiency were assumed 0.92, 0.97 and 0.99 respectively.

3 sets Francis turbines were selected for energy generation in the former study (Bakış et al., 2005). Usable flow range of turbines would increase with the increase in turbine number. Hence, 3 sets of turbines would generate more energy than 2 sets. Cost of electromechanical equipment in feasibility reports is calculated from capacity in kilowatts and does not consider number of turbines in common practice. However, initial investment cost would increase according to the number of turbine sets because number of vanes, generators, etc. would increase. Therefore, an optimization study between cost of equipment and benefit of energy generation should be carried out. Consequently, 2 Francis type turbines were selected for Porsuk Dam (Figure 6.4 and Figure 6.5).

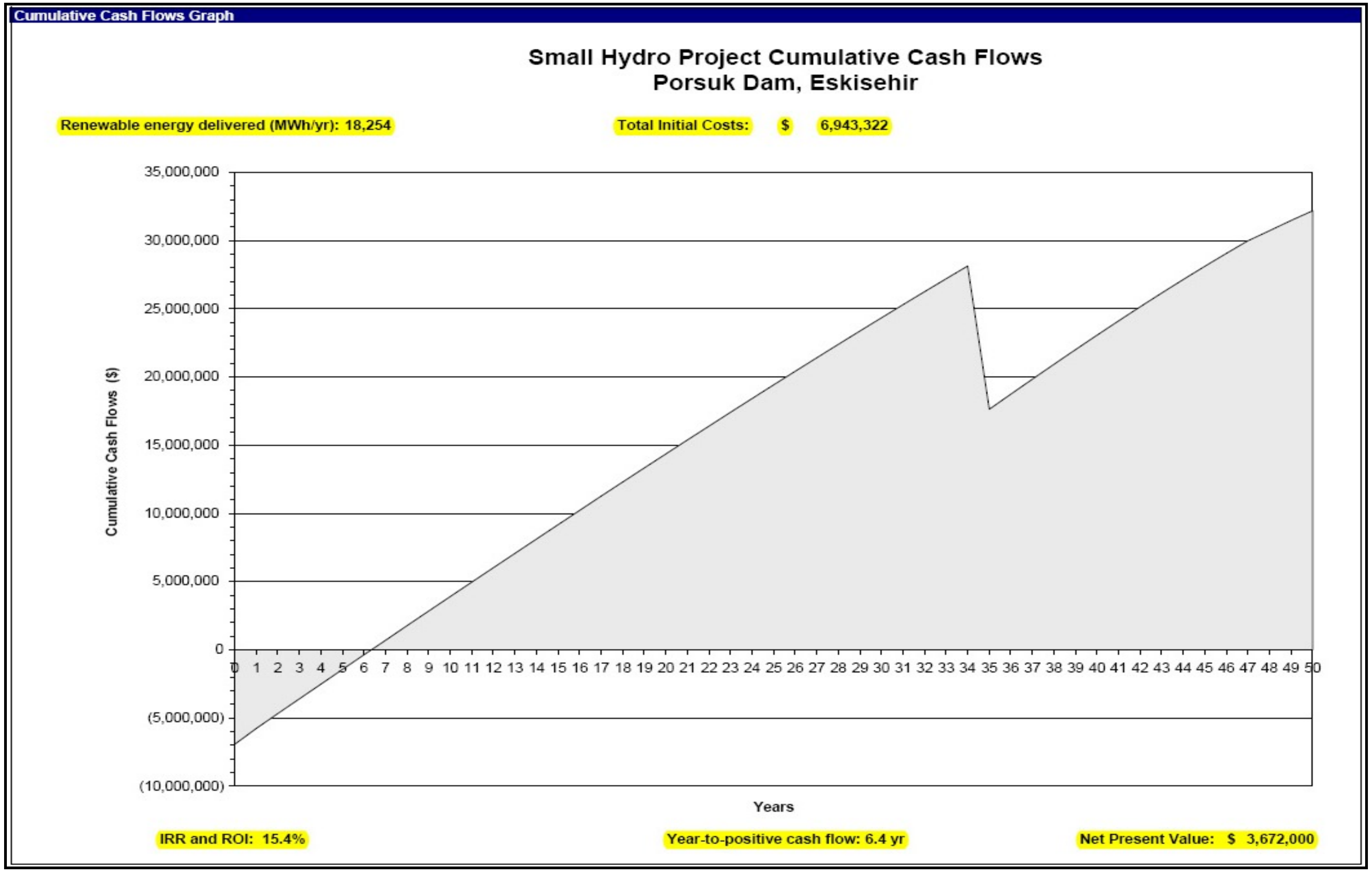

Figure 6.4. Alternative with 3 Francis Turbines

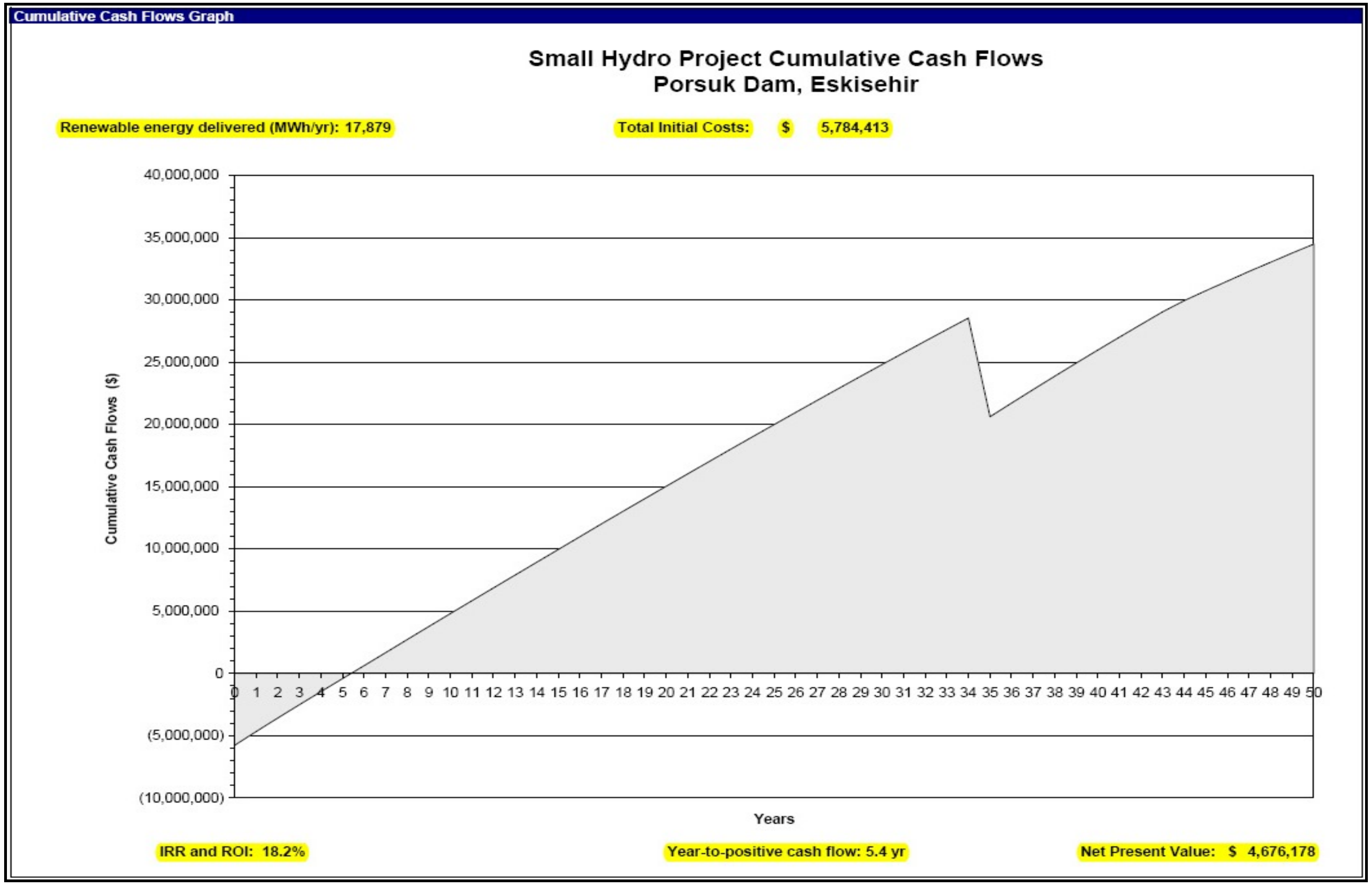

Figure 6.5. Alternative with 2 Francis Turbines

6.6. Operation and Maintenance Costs

Annual cost of maintenance was assumed as 0.20% of investment cost. Also, 30,000 USD was assumed for annual wages of operation personnel.

6.7. Outcomes of the Study

Installed capacity and energy generation has been calculated for different design flows by RETScreen Small Hydro Project Model (Appendix E, Appendix F, and Appendix G). Selling price of electricity was taken as 7.50 Dollar cent/kWh and discount rate was taken as 9.50% in financial analysis. The results were tabulated in Table 6.3.

Table 6.3. Information Chart of Porsuk Dam

No	Description	Alternative 1	Alternative 2	Alternative 3
1	Penstock Length (m)	230	230	230
2	Penstock Diameter (m)	2.10	2.00	2.00
3	Turbine Type	Francis	Francis	Francis
4	Number of Turbines	2	2	2
5	Gross Head (m)	40.61	40.61	40.61
6	Net Head (m)	39.51	39.65	39.61
7	Design Flow (m^3/s)	12.69	11.24	10.23
8	Installed Capacity (MW)	4.15	3.68	3.35
9	Dependable Energy (GWh)	0	0	0
10	Secondary Energy (GWh)	17.879	16.972	16.220
11	Total Energy (GWh)	17.879	16.972	16.220
12	Investment Cost (USD)	5,784,413	5,304,545	4,989,039

Table 6.3. Continued

13	Annual O&M Cost(USD)	41,569	40,609	39,978
14	Positive Cash – Flow (yr)	5.4	5.2	5.2
15	Benefit / Cost Ratio	1.81	1.87	1.90
16	Net Present Value (USD)	4,676,178	4,609,684	4,470,492

Investment cost increases from alternative 1 to alternative 3, in Porsuk case which is directly proportional to installed capacity. Nonetheless, alternative 1 would generate more annual electricity than other two alternatives. The benefit – cost ratio of all three alternatives, given in Table 6.3., are larger than 1 therefore all of them are economically feasible. Alternative 3, which was designed according to the flow available at 20% of time, is less risky than alternative 1. In other words, sensitivity of alternative 3 to the operational studies at the dam and to the availability of water is relatively smaller. However, the best alternative should be decided after economical analysis and should be selected as alternative 1 by comparing their net present values.

6.8. Discussion of Results

Refurbishment of Porsuk Dam for energy generation is an economically acceptable investment. Alternative 1 will reach to positive cash flow in less than 6 years. Guaranteed purchase time of energy from renewable sources is 10 years in Turkey. As an advantage, year to positive cash-flow less than 10 years decreases the economical risk of alternative 1.

On the other side, energy generation from Porsuk Dam has an important disadvantage. Since firm flow is almost equal to zero, firm capacity and firm benefit of the plant is zero (Table 6.4). Therefore, proposed plant would only generate secondary energy. In Turkey, this could be a common disadvantage when refurbishing multipurpose dams. Moreover, some of them may only generate electricity during spring months when excessive water comes from the melting of snow.

Table 6.4. Annual Benefits of Porsuk Dam According to DSİ Criteria

ITEM	QUANTITY	UNIT BENEFIT	TOTAL BENEFIT
Firm Energy	0	0.060 $/kWh	0
Secondary Energy	17,879,000kWh	0.033 $/kWh	590,007 USD
Peak Power (DSİ Criteria)	4,150 kW	85.00 $/kW	352,750 USD
		TOTAL BENEFIT	**942,757 USD**

Electricity generation from a multipurpose dam serving only for irrigation and/or domestic water supply has another important disadvantage in economical evaluation which is the money paid to the State Hydraulic Works for the energy contribution credit. If a dam has not been built, there would not be any water stored in the reservoir to gain head. Therefore, a payment is collected by State Hydraulic Works.

In spite of some disadvantages, refurbishment of existing dams should be on the agenda while making long term plans of Turkey. Also adaptation of incentive measures like eliminating energy contribution credit should turn a threat into an opportunity for energy generation projects from multipurpose dams.

CHAPTER 7

CONCLUSIONS

Increasing threat of climate change made countries search every means to reduce greenhouse gas emissions. As a result, promotion of clean energy technologies has increased over the past decades. Hydropower energy as a sustainable development is the most important type of renewable energy.

RETScreen Small Hydro Project Model is a decision-making tool which could be applied internationally. Software program follows the flow duration curve method to calculate power generation from hydropower projects. Hence RETScreen software gives more accurate results for small hydropower projects especially run-of-river type.

Two case studies from Turkey were selected to test the accuracy of RETScreen software in Turkish practice. The data given in feasibility reports were entered into RETScreen software. Costs given by the software were compared with the costs given in feasibility report. The following conclusion can be written as a result of case studies.

Firstly, cost of tunnel works in feasibility reports are less than the costs calculated by the software. Such difference is due to the inequality of the given and calculated diameter of tunnels. Tunnel diameter calculated by the software was decreased artificially to the value in feasibility report by increasing the tunnel headloss factor in the software. Consequently, decrease in tunnel diameter results decrease in tunnel costs. An adjustment factor for tunnel diameter should be implemented into the software program.

Secondly, RETScreen software calculates the cost of 154 kV transmission line higher than the feasibility report in case study 2. Estimated unit costs supplied by TEİAŞ for 2006 were used to determine which calculation is more reliable. Consequently, result of RETScreen software is found to be more accurate.

Thirdly, another huge difference comes from the cost of energy equipment. Actual situation of electromechanical equipment market in the last quarter of 2007 was used in the comparison. European market prices are 2 – 3 times higher than Chinese market prices. RETScreen software better reflects the market situation of Europe. On the other side, China has the fastest developing industry and a long term past experience in small hydro power. By using adjustment factor for energy equipments Chinese effect may be implicated into costs. Less investment costs yields to more economical results.

Further the RETScreen software can be used to examine upgrading of existing dams. Most of the hydropower potential has been already exploited in the developed countries. Therefore, renovation and refurbishment of existing dams is getting more important. Especially possibility of generating electricity from irrigation and water supply dams has been investigated widely in Europe and Canada. Similarly, economical small hydropower potential of Turkey can be re-evaluated by upgrading existing dams. For example, Porsuk Dam can generate 17.879 GWh of electricity by making an investment of 5.78 million USD. The project pays off initial investment in 5.4 years. Example of Porsuk dam given in the study justifies the opportunity of electricity generation by making small investment.

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APPENDIX A

RESULTS OF RETSCREEN SOFTWARE FOR PROJECT 1

RETScreen® Energy Model - Small Hydro Project

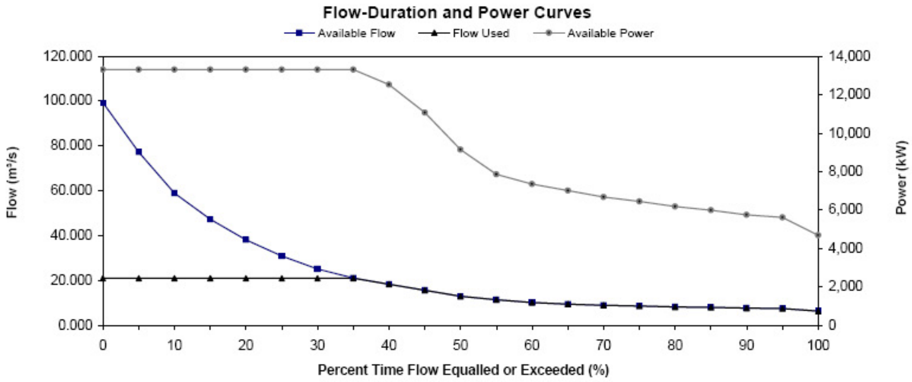
Training & Support

Units: Metric

Site Conditions		Estimate		Notes/Range
Project name		Project 1		See Online Manual
Project location		Karaman		
Latitude of project location	°N			-90.00 to 90.00
Longitude of project location	°E			-180.00 to 180.00
Gross head	m	88.52		
Maximum tailwater effect	m	0.00		
Residual flow	m³/s	0.12	➡	Complete Hydrology & Load sheet
Firm flow	m³/s	7.51		

System Characteristics		Estimate		Notes/Range
Grid type	-	Central-grid		
Design flow	m³/s	21.000		
Turbine type	-	Francis	➡	Complete Equipment Data sheet
Number of turbines	turbine	2		
Turbine peak efficiency	%	92.0%		
Turbine efficiency at design flow	%	88.3%		
Maximum hydraulic losses	%	14%		2% to 7%
Generator efficiency	%	97%		93% to 97%
Transformer losses	%	1%		1% to 2%
Parasitic electricity losses	%	0%		1% to 3%
Annual downtime losses	%	0%		2% to 7%

Annual Energy Production		Estimate	Notes/Range
Small hydro plant capacity	kW	13,297	
	MW	13.297	
Small hydro plant firm capacity	kW	**5,620**	
Available flow adjustment factor	-	1.00	
Small hydro plant capacity factor	%	73%	40% to 95%
Renewable energy delivered	MWh	**84,841**	
	GJ	305,427	



Complete Cost Analysis sheet

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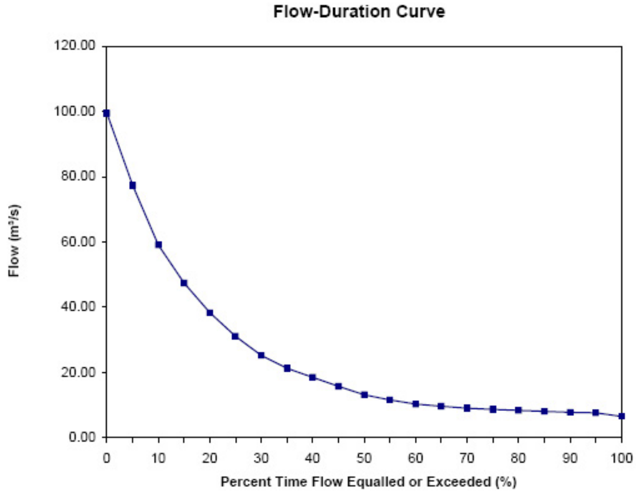
Figure A.1. “Energy Model” Worksheet of Project 1

RETScreen® Hydrology Analysis and Load Calculation - Small Hydro Project

Hydrology Analysis		Estimate	Notes/Range
Project type		Run-of-river	
Hydrology method		User-defined	
Hydrology Parameters			
Residual flow	m^3/s	0.118	
Percent time firm flow available	%	95%	90% to 100%
Firm flow	m^3/s	7.51	

Flow-Duration Curve Data

Time (%)	Flow (m^3/s)
0%	99.36
5%	77.30
10%	59.07
15%	47.40
20%	38.30
25%	31.09
30%	25.24
35%	21.30
40%	18.50
45%	15.80
50%	13.15
55%	11.60
60%	10.37
65%	9.64
70%	9.09
75%	8.74
80%	8.37
85%	8.11
90%	7.80
95%	7.63
100%	6.55



Load Characteristics	Estimate	Notes/Range
Grid type	Central-grid	

Return to Energy Model sheet

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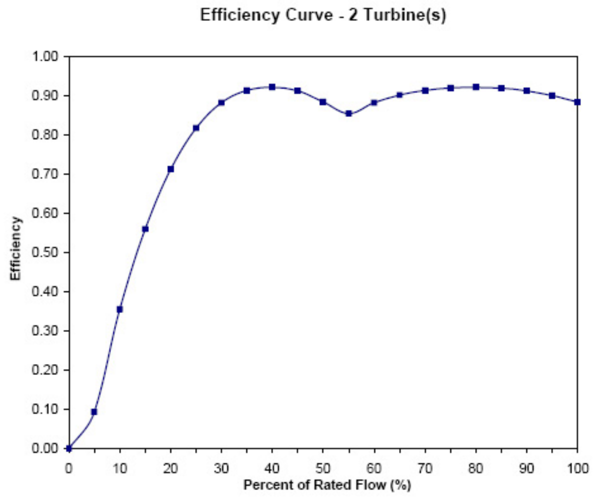
Figure A.2. “Hydrology Analysis and Load Calculation” Worksheet of Project 1

RETScreen® Equipment Data - Small Hydro Project

Small Hydro Turbine Characteristics		Estimate	Notes/Range
Gross head	m	88.52	
Design flow	m³/s	21.000	
Turbine type	-	Francis	See Product Database
Turbine efficiency curve data source	-	Standard	
Number of turbines	turbine	2	
Small hydro turbine manufacturer			
Small hydro turbine model			
Turbine manufacture/design coefficient	-	2.3	2.8 to 6.1; Default = 4.5
Efficiency adjustment	%	0%	-5% to 5%
Turbine peak efficiency	%	92.0%	
Flow at peak efficiency	m³/s	16.9	
Turbine efficiency at design flow	%	88.3%	

Turbine Efficiency Curve Data

Flow (%)	Turbine efficiency	Turbines running #	Combined turbine efficiency
0%	0.00	0	0.00
5%	0.00	1	0.09
10%	0.09	1	0.35
15%	0.23	1	0.56
20%	0.35	1	0.71
25%	0.46	1	0.82
30%	0.56	1	0.88
35%	0.64	1	0.91
40%	0.71	1	0.92
45%	0.77	1	0.91
50%	0.82	1	0.88
55%	0.85	2	0.85
60%	0.88	2	0.88
65%	0.90	2	0.90
70%	0.91	2	0.91
75%	0.92	2	0.92
80%	0.92	2	0.92
85%	0.92	2	0.92
90%	0.91	2	0.91
95%	0.90	2	0.90
100%	0.88	2	0.88



Return to
Energy Model sheet

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Figure A.3. "Equipment Data" Worksheet of Project 1

RETScreen® Cost Analysis - Small Hydro Project

Costing method: Formula | Currency: $ | Cost references: None

Formula Costing Method			Notes/Range
Input Parameters			
Project country		Turkey	
Local vs. Canadian equipment costs ratio	-	1.00	
Local vs. Canadian fuel costs ratio	-	2.08	
Local vs. Canadian labour costs ratio	-	0.23	
Equipment manufacture cost coefficient	-	1.00	0.50 to 1.00
Exchange rate	$/CAD	0.88	
Cold climate?	yes/no	No	
Number of turbines	turbine	2	
Flow per turbine	m³/s	10.5	
Approx. turbine runner diameter (per unit)	m	1.4	
Project classification:			
Suggested classification	-	Small	
Selected classification	-	Small	
Existing dam?	yes/no	No	
New dam crest length	m	24.5	
Rock at dam site?	yes/no	Yes	
Maximum hydraulic losses	%	14%	
Intake and miscellaneous losses	%	1%	1% to 5%
Access road required?	yes/no	Yes	
Length	km	11.3	
Tote road only?	yes/no	No	
Difficulty of terrain	-	3.0	1.0 to 6.0
Tunnel required?	yes/no	Yes	
Length	m	5,498	
Allowable tunnel headloss factor	%	12.5%	4.0% to 7.0%
Percent length of tunnel that is lined	%	100%	15% to 100%
Tunnel excavation method	-	Mechanised	
Tunnel diameter	m	4.8	
Canal required?	yes/no	No	
Penstock required?	yes/no	Yes	
Length	m	140.0	
Number of identical penstocks	penstock	1	
Allowable penstock headloss factor	%	0.6%	1.0% to 4.0%
Pipe diameter	m	2.59	
Average pipe wall thickness	mm	9.4	
Distance to borrow pits	km	5.0	
Transmission line			
Length	km	35.0	
Difficulty of terrain	-	1.5	1.0 to 2.0
Voltage	kV	33.0	
Interest rate	%	9.5%	

Initial Costs (Formula Method)		Cost (local currency)	Adjustment Factor	Amount (local currency)	Relative Costs
Feasibility Study		$ 1,885,101	1.00	$ 1,885,101	3.3%
Development		$ 1,926,522	1.00	$ 1,926,522	3.4%
Land rights				$ 411,919	0.7%
Development Sub-total:				$ 2,338,441	4.1%
Engineering		$ 759,681	1.00	$ 759,681	1.3%
Energy Equipment		$ 7,947,563	1.00	$ 7,947,563	14.0%
Balance of Plant					
Access road		$ 1,183,586	1.00	$ 1,183,586	2.1%
Transmission line		$ 974,718	1.00	$ 974,718	1.7%
Substation and transformer		$ 341,944	1.00	$ 341,944	0.6%
Penstock		$ 393,941	1.00	$ 393,941	0.7%
Canal		$ -	1.00	$ -	0.0%
Tunnel		$ 28,485,379	1.00	$ 28,485,379	50.2%
Civil works (other)		$ 8,076,233	1.00	$ 8,076,233	14.2%
Balance of Plant Sub-total:		$ 39,455,801		$ 39,455,801	69.5%
Miscellaneous		$ 8,806,831	0.50	$ 4,403,415	7.8%
GHG baseline study and MP	Cost	$ -		$ -	0.0%
GHG validation and registration	Cost	$ -		$ -	0.0%
Miscellaneous Sub-total:				$ 4,403,415	7.8%
Initial Costs - Total (Formula Method)		$ 60,781,498		$ 56,790,002	100.0%

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Land lease	project	1	$ -	$ -		-	-
Property taxes	%	0.0%	$ 56,790,002	$ -		-	-
Water rental	kW	13,297	$ -	$ -		-	-
Insurance premium	%	0.00%	$ 56,790,002	$ -		-	-
Transmission line maintenance	%	0.0%	$ 1,316,662	$ -		-	-
Spare parts	%	0.20%	$ 56,790,002	$ 113,580		-	-
O&M labour	p-yr	1.00	$ 52,800	$ 52,800		-	-
GHG monitoring and verification	project	0	$ -	$ -		-	-
Travel and accommodation	p-trip	0	$ 1,000	$ -		-	-
General and administrative	%	0%	$ 166,380	$ -		-	-
	Cost			$ -		-	-
Contingencies	%	0%	$ 166,380	$ -		-	-
Annual Costs - Total				$ 166,380	100.0%		

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
Electromechanical Equipment	Cost	35 yr	$ 3,973,782	$ 3,973,782	-	-
				$ -	-	-
				$ -	-	-
End of project life	Credit	-	$ -	$ -		

Go to GHG Analysis sheet

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Figure A.4. "Cost Analysis" Worksheet of Project 1

RETScreen® Financial Summary - Small Hydro Project

Annual Energy Balance

Project name		Project 1
Project location		Karaman
Renewable energy delivered	MWh	84,841
Excess RE available	MWh	-
Firm RE capacity	kW	5,620
Grid type		Central-grid

Financial Parameters

Avoided cost of energy	$/kWh	0.0750	Debt ratio	%	0.0%
RE production credit	$/kWh	-			
			Income tax analysis?	yes/no	Yes
			Effective income tax rate	%	20.0%
			Loss carryforward?	-	Yes
			Depreciation method	-	Straight-line
Avoided cost of capacity	$/kW-yr	-	Depreciation tax basis	%	93.5%
Energy cost escalation rate	%	0.0%			
Inflation	%	5.0%	Depreciation period	yr	50
Discount rate	%	9.5%	Tax holiday available?	yes/no	No
Project life	yr	50			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	3.3%	$	1,885,101	O&M	$	166,380
Development	4.1%	$	2,338,441			
Engineering	1.3%	$	759,681			
Energy equipment	14.0%	$	7,947,563	**Annual Costs and Debt - Total**	**$**	**166,380**
Balance of plant	69.5%	$	39,455,801			
Miscellaneous	7.8%	$	4,403,415	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**$**	**56,790,002**	Energy savings/income	$	6,363,055
				Capacity savings/income	$	-
Incentives/Grants		$	-			
				Annual Savings - Total	**$**	**6,363,055**
Periodic Costs (Credits)						
Electromechanical Equipment		$	3,973,782	Schedule yr # 35		
		$	-			
		$	-			
End of project life - Credit		$	-			

Financial Feasibility

			Calculate energy production cost?	yes/no	No
Pre-tax IRR and ROI	%	10.5%			
After-tax IRR and ROI	%	8.7%			
Simple Payback	yr	9.2			
Year-to-positive cash flow	yr	10.9	Project equity	$	56,790,002
Net Present Value - NPV	$	(4,379,818)			
Annual Life Cycle Savings	$	(420,562)			
Benefit-Cost (B-C) ratio	-	0.92			

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09.01.2008; Project1_2008.01.07.xls

Figure A.5. Data Sheet of "Financial Summary" (Project 1)

Yearly Cash Flows

Year #	Pre-tax $	After-tax $	Cumulative $
0	(56,790,002)	(56,790,002)	(56,790,002)
1	6,188,356	5,901,349	(50,888,653)
2	6,179,621	5,156,091	(45,732,561)
3	6,170,449	5,148,754	(40,583,807)
4	6,160,819	5,141,060	(35,442,758)
5	6,150,707	5,132,960	(30,309,797)
6	6,140,090	5,124,466	(25,185,331)
7	6,128,941	5,115,548	(20,069,783)
8	6,117,236	5,106,183	(14,963,600)
9	6,104,945	5,096,350	(9,867,250)
10	6,092,039	5,086,026	(4,781,223)
11	6,078,489	5,075,185	293,962
12	6,064,260	5,063,803	5,357,765
13	6,049,321	5,051,851	10,409,616
14	6,033,634	5,039,302	15,448,917
15	6,017,163	5,026,125	20,475,042
16	5,999,868	5,012,289	25,487,331
17	5,981,709	4,997,762	30,485,093
18	5,962,642	4,982,508	35,467,601
19	5,942,621	4,966,491	40,434,092
20	5,921,599	4,949,674	45,383,766
21	5,899,526	4,932,016	50,315,782
22	5,876,350	4,913,475	55,229,256
23	5,852,015	4,894,006	60,123,263
24	5,826,463	4,873,565	64,996,827
25	5,799,633	4,852,101	69,848,928
26	5,771,462	4,829,564	74,678,493
27	5,741,882	4,805,900	79,484,393
28	5,710,824	4,781,054	84,265,447
29	5,678,212	4,754,964	89,020,411
30	5,643,970	4,727,571	93,747,982
31	5,608,016	4,698,807	98,446,789
32	5,570,264	4,668,606	103,115,395
33	5,530,624	4,636,894	107,752,289
34	5,489,003	4,603,597	112,355,885
35	(16,474,141)	(16,474,141)	95,881,745
36	5,399,412	5,399,412	101,281,157
37	5,351,230	5,351,230	106,632,387
38	5,300,639	5,300,639	111,933,027
39	5,247,518	5,247,518	117,180,545
40	5,191,741	4,462,829	121,643,374
41	5,133,176	4,318,935	125,962,309
42	5,071,682	4,269,740	130,232,049
43	5,007,113	4,218,085	134,450,134
44	4,939,316	4,163,848	138,613,982
45	4,868,129	4,106,898	142,720,880
46	4,793,383	4,047,101	146,767,981
47	4,714,899	3,984,314	150,752,295
48	4,632,492	3,918,388	154,670,683
49	4,545,963	3,849,165	158,519,848
50	4,455,109	3,776,482	162,296,330

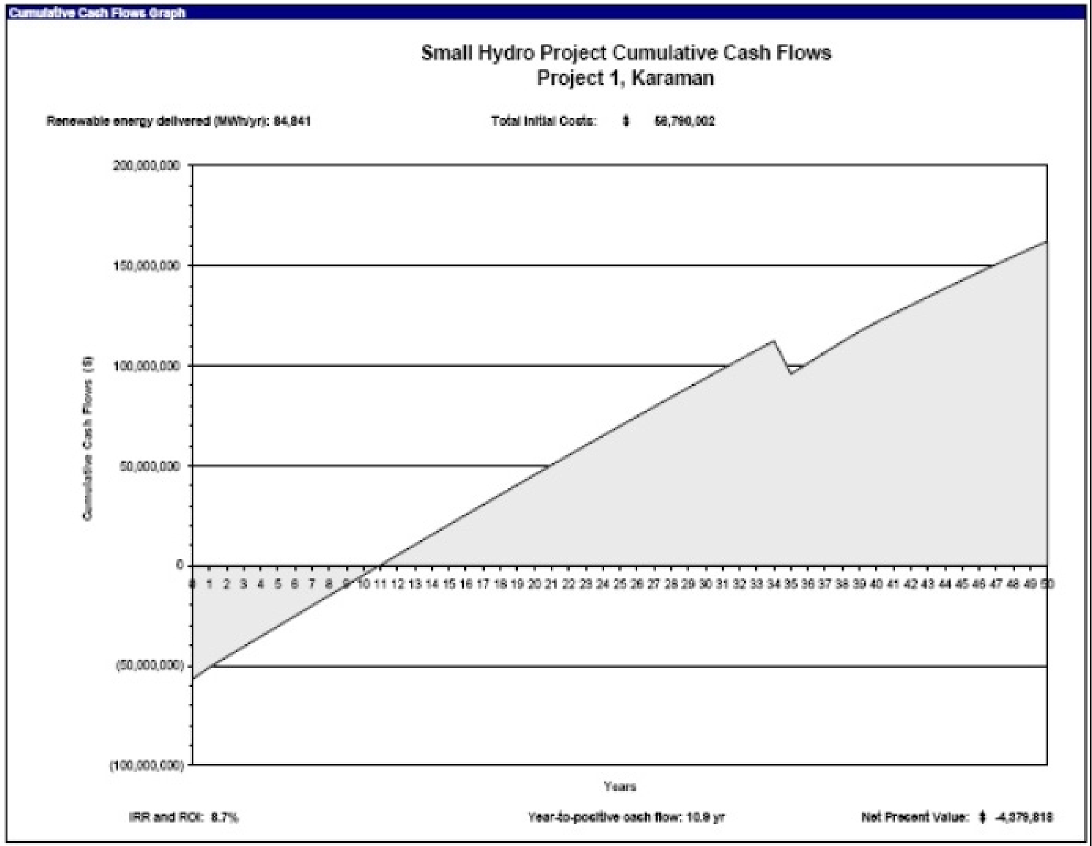


Figure A.6. Cash Flow of Project 1

APPENDIX B

RESULTS OF RETSCREEN SOFTWARE FOR PROJECT 2

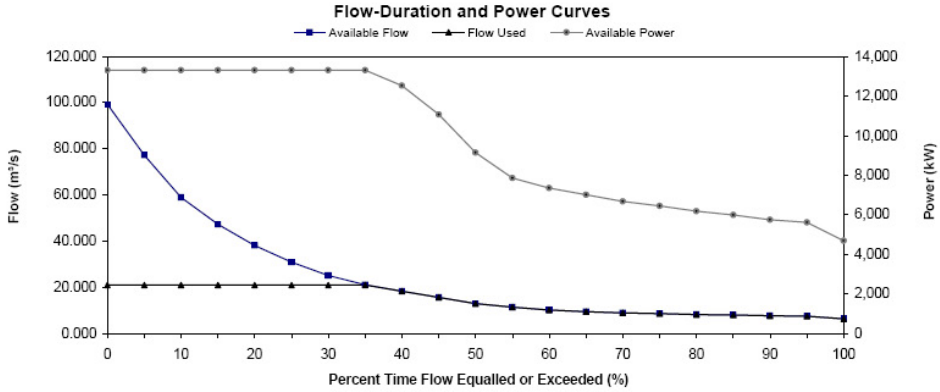
RETScreen® Energy Model - Small Hydro Project — Training & Support

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		Project 1	See Online Manual
Project location		Karaman	
Latitude of project location	°N		-90.00 to 90.00
Longitude of project location	°E		-180.00 to 180.00
Gross head	m	88.52	
Maximum tailwater effect	m	0.00	
Residual flow	m³/s	0.12	Complete Hydrology & Load sheet
Firm flow	m³/s	7.51	

System Characteristics		Estimate	Notes/Range
Grid type	-	Central-grid	
Design flow	m³/s	21.000	
Turbine type	-	Francis	Complete Equipment Data sheet
Number of turbines	turbine	2	
Turbine peak efficiency	%	92.0%	
Turbine efficiency at design flow	%	88.3%	
Maximum hydraulic losses	%	14%	2% to 7%
Generator efficiency	%	97%	93% to 97%
Transformer losses	%	1%	1% to 2%
Parasitic electricity losses	%	0%	1% to 3%
Annual downtime losses	%	0%	2% to 7%

Annual Energy Production		Estimate	Notes/Range
Small hydro plant capacity	kW	13,297	
	MW	13.297	
Small hydro plant firm capacity	kW	**5,620**	
Available flow adjustment factor	-	1.00	
Small hydro plant capacity factor	%	73%	40% to 95%
Renewable energy delivered	MWh	**84,841**	
	GJ	305,427	



Complete Cost Analysis sheet

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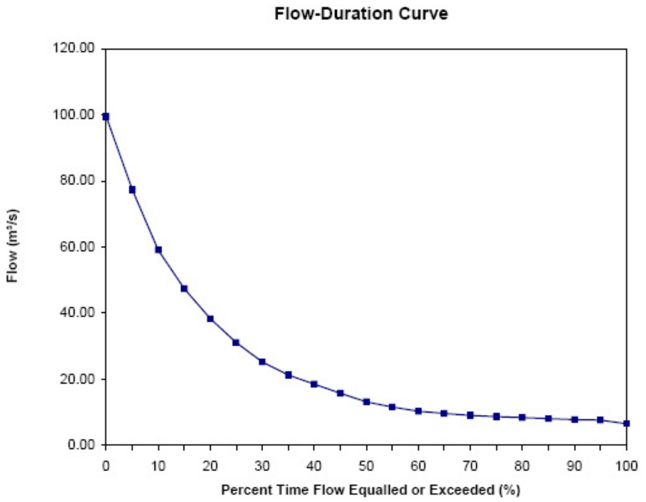
Figure B.1. "Energy Model" Worksheet of Project 2

RETScreen® Hydrology Analysis and Load Calculation - Small Hydro Project

Hydrology Analysis		Estimate	Notes/Range
Project type		Run-of-river	
Hydrology method		User-defined	
Hydrology Parameters			
Residual flow	m³/s	0.118	
Percent time firm flow available	%	95%	90% to 100%
Firm flow	m³/s	7.51	

Flow-Duration Curve Data

Time (%)	Flow (m³/s)
0%	99.36
5%	77.30
10%	59.07
15%	47.40
20%	38.30
25%	31.09
30%	25.24
35%	21.30
40%	18.50
45%	15.80
50%	13.15
55%	11.60
60%	10.37
65%	9.64
70%	9.09
75%	8.74
80%	8.37
85%	8.11
90%	7.80
95%	7.63
100%	6.55



Load Characteristics	Estimate	Notes/Range
Grid type	Central-grid	

Return to Energy Model sheet

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Figure B.2. "Hydrology Analysis and Load Calculation" Worksheet of Project 2

RETScreen® Equipment Data - Small Hydro Project

Small Hydro Turbine Characteristics		Estimate	Notes/Range
Gross head	m	88.52	
Design flow	m³/s	21.000	
Turbine type	-	Francis	See Product Database
Turbine efficiency curve data source	-	Standard	
Number of turbines	turbine	2	
Small hydro turbine manufacturer			
Small hydro turbine model			
Turbine manufacture/design coefficient	-	2.3	2.8 to 6.1; Default = 4.5
Efficiency adjustment	%	0%	-5% to 5%
Turbine peak efficiency	%	92.0%	
Flow at peak efficiency	m³/s	16.9	
Turbine efficiency at design flow	%	88.3%	

Turbine Efficiency Curve Data

Flow (%)	Turbine efficiency	Turbines running #	Combined turbine efficiency
0%	0.00	0	0.00
5%	0.00	1	0.09
10%	0.09	1	0.35
15%	0.23	1	0.56
20%	0.35	1	0.71
25%	0.46	1	0.82
30%	0.56	1	0.88
35%	0.64	1	0.91
40%	0.71	1	0.92
45%	0.77	1	0.91
50%	0.82	1	0.88
55%	0.85	2	0.85
60%	0.88	2	0.88
65%	0.90	2	0.90
70%	0.91	2	0.91
75%	0.92	2	0.92
80%	0.92	2	0.92
85%	0.92	2	0.92
90%	0.91	2	0.91
95%	0.90	2	0.90
100%	0.88	2	0.88

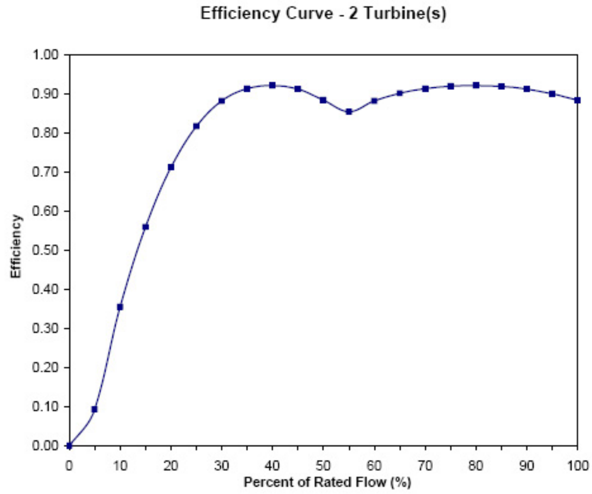

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Figure B.3. "Equipment Data" Worksheet of Project 2

RETScreen® Cost Analysis - Small Hydro Project

Costing method: Formula   Currency: $ Cost references: None

Formula Costing Method			Notes/Range
Input Parameters			
Project country		Turkey	
Local vs. Canadian equipment costs ratio	-	1.00	
Local vs. Canadian fuel costs ratio	-	2.08	
Local vs. Canadian labour costs ratio	-	0.23	
Equipment manufacture cost coefficient	-	1.00	0.50 to 1.00
Exchange rate	$/CAD	0.88	
Cold climate?	yes/no	No	
Number of turbines	turbine	2	
Flow per turbine	m³/s	10.5	
Approx. turbine runner diameter (per unit)	m	1.4	
Project classification:			
Suggested classification	-	Small	
Selected classification	-	Small	
Existing dam?	yes/no	No	
New dam crest length	m	24.5	
Rock at dam site?	yes/no	Yes	
Maximum hydraulic losses	%	14%	
Intake and miscellaneous losses	%	1%	1% to 5%
Access road required?	yes/no	Yes	
Length	km	11.3	
Tote road only?	yes/no	No	
Difficulty of terrain	-	3.0	1.0 to 6.0
Tunnel required?	yes/no	Yes	
Length	m	5,498	
Allowable tunnel headloss factor	%	12.5%	4.0% to 7.0%
Percent length of tunnel that is lined	%	100%	15% to 100%
Tunnel excavation method	-	Mechanised	
Tunnel diameter	m	4.8	
Canal required?	yes/no	No	
Penstock required?	yes/no	Yes	
Length	m	140.0	
Number of identical penstocks	penstock	1	
Allowable penstock headloss factor	%	0.6%	1.0% to 4.0%
Pipe diameter	m	2.59	
Average pipe wall thickness	mm	9.4	
Distance to borrow pits	km	5.0	
Transmission line			
Length	km	35.0	
Difficulty of terrain	-	1.5	1.0 to 2.0
Voltage	kV	33.0	
Interest rate	%	9.5%	

Initial Costs (Formula Method)	Cost (local currency)	Adjustment Factor	Amount (local currency)	Relative Costs
Feasibility Study	$ 1,885,101	1.00	$ 1,885,101	3.3%
Development	$ 1,926,522	1.00	$ 1,926,522	3.4%
Land rights			$ 411,919	0.7%
Development Sub-total:			$ 2,338,441	4.1%
Engineering	$ 759,681	1.00	$ 759,681	1.3%
Energy Equipment	$ 7,947,563	1.00	$ 7,947,563	14.0%
Balance of Plant				
Access road	$ 1,183,586	1.00	$ 1,183,586	2.1%
Transmission line	$ 974,718	1.00	$ 974,718	1.7%
Substation and transformer	$ 341,944	1.00	$ 341,944	0.6%
Penstock	$ 393,941	1.00	$ 393,941	0.7%
Canal	$ -	1.00	$ -	0.0%
Tunnel	$ 28,485,379	1.00	$ 28,485,379	50.2%
Civil works (other)	$ 8,076,233	1.00	$ 8,076,233	14.2%
Balance of Plant Sub-total:	$ 39,455,801		$ 39,455,801	69.5%
Miscellaneous	$ 8,806,831	0.50	$ 4,403,415	7.8%
GHG baseline study and MP — Cost	$ -		$ -	0.0%
GHG validation and registration — Cost	$ -		$ -	0.0%
Miscellaneous Sub-total:			$ 4,403,415	7.8%
Initial Costs - Total (Formula Method)	$ 60,781,498		$ 56,790,002	100.0%

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Land lease	project	1	$ -	$ -		-	-
Property taxes	%	0.0%	$ 56,790,002	$ -		-	-
Water rental	kW	13,297	$ -	$ -		-	-
Insurance premium	%	0.00%	$ 56,790,002	$ -		-	-
Transmission line maintenance	%	0.0%	$ 1,316,662	$ -		-	-
Spare parts	%	0.20%	$ 56,790,002	$ 113,580		-	-
O&M labour	p-yr	1.00	$ 52,800	$ 52,800		-	-
GHG monitoring and verification	project	0	$ -	$ -		-	-
Travel and accommodation	p-trip	0	$ 1,000	$ -		-	-
General and administrative	%	0%	$ 166,380	$ -		-	-
	Cost			$ -		-	-
Contingencies	%	0%	$ 166,380	$ -		-	-
Annual Costs - Total				$ 166,380	100.0%		

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
Electromechanical Equipment	Cost	35 yr	$ 3,973,782	$ 3,973,782	-	-
				$ -	-	-
				$ -	-	-
End of project life	Credit	-	$ -	$ -		

Go to GHG Analysis sheet

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Figure B.4. "Cost Analysis" Worksheet of Project 2

RETScreen® Financial Summary - Small Hydro Project

Annual Energy Balance

Project name		Project 1
Project location		Karaman
Renewable energy delivered	MWh	84,841
Excess RE available	MWh	-
Firm RE capacity	kW	5,620
Grid type		Central-grid

Financial Parameters

Avoided cost of energy	$/kWh	0.0750	Debt ratio	%	0.0%
RE production credit	$/kWh	-			
			Income tax analysis?	yes/no	Yes
			Effective income tax rate	%	20.0%
			Loss carryforward?	-	Yes
			Depreciation method	-	Straight-line
Avoided cost of capacity	$/kW-yr	-	Depreciation tax basis	%	93.5%
Energy cost escalation rate	%	0.0%			
Inflation	%	5.0%	Depreciation period	yr	50
Discount rate	%	9.5%	Tax holiday available?	yes/no	No
Project life	yr	50			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	3.3%	$	1,885,101	O&M	$	166,380
Development	4.1%	$	2,338,441			
Engineering	1.3%	$	759,681			
Energy equipment	14.0%	$	7,947,563	**Annual Costs and Debt - Total**	**$**	**166,380**
Balance of plant	69.5%	$	39,455,801			
Miscellaneous	7.8%	$	4,403,415	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**$**	**56,790,002**	Energy savings/income	$	6,363,055
				Capacity savings/income	$	-
Incentives/Grants		$	-			
				Annual Savings - Total	**$**	**6,363,055**
Periodic Costs (Credits)						
Electromechanical Equipment		$	3,973,782	Schedule yr # 35		
		$	-			
		$	-			
End of project life - Credit		$	-			

Financial Feasibility

			Calculate energy production cost?	yes/no	No
Pre-tax IRR and ROI	%	10.5%			
After-tax IRR and ROI	%	8.7%			
Simple Payback	yr	9.2			
Year-to-positive cash flow	yr	10.9	Project equity	$	56,790,002
Net Present Value - NPV	$	(4,379,818)			
Annual Life Cycle Savings	$	(420,562)			
Benefit-Cost (B-C) ratio	-	0.92			

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Figure B.5. Data Sheet of "Financial Summary" (Project 2)

Yearly Cash Flows

Year #	Pre-tax $	After-tax $	Cumulative $
0	(56,790,002)	(56,790,002)	(56,790,002)
1	6,188,356	5,901,349	(50,888,653)
2	6,179,621	5,156,091	(45,732,561)
3	6,170,449	5,148,754	(40,583,807)
4	6,160,819	5,141,050	(35,442,758)
5	6,150,707	5,132,960	(30,309,797)
6	6,140,090	5,124,466	(25,185,331)
7	6,128,941	5,115,548	(20,069,783)
8	6,117,236	5,106,183	(14,963,600)
9	6,104,945	5,096,360	(9,867,250)
10	6,092,039	5,086,026	(4,781,223)
11	6,078,489	5,075,185	293,962
12	6,064,260	5,063,803	5,357,765
13	6,049,321	5,051,851	10,409,616
14	6,033,634	5,039,302	15,448,917
15	6,017,163	5,026,125	20,475,042
16	5,999,868	5,012,289	25,487,331
17	5,981,709	4,997,762	30,485,093
18	5,962,642	4,982,508	35,467,601
19	5,942,621	4,966,491	40,434,092
20	5,921,599	4,949,674	45,383,766
21	5,899,526	4,932,016	50,315,782
22	5,876,350	4,913,475	55,229,256
23	5,852,015	4,894,006	60,123,263
24	5,826,463	4,873,565	64,996,827
25	5,799,633	4,852,101	69,848,928
26	5,771,462	4,829,564	74,678,493
27	5,741,882	4,805,900	79,484,393
28	5,710,824	4,781,054	84,265,447
29	5,678,212	4,754,964	89,020,411
30	5,643,970	4,727,571	93,747,982
31	5,608,016	4,698,807	98,446,789
32	5,570,264	4,668,606	103,115,395
33	5,530,624	4,636,894	107,752,289
34	5,489,003	4,603,597	112,355,885
35	(16,474,141)	(16,474,141)	95,881,745
36	5,399,412	5,399,412	101,281,157
37	5,351,230	5,351,230	106,632,387
38	5,300,639	5,300,639	111,933,027
39	5,247,518	5,247,518	117,180,545
40	5,191,741	4,462,829	121,643,374
41	5,133,176	4,318,935	125,962,309
42	5,071,682	4,269,740	130,232,049
43	5,007,113	4,218,085	134,450,134
44	4,939,316	4,163,848	138,613,982
45	4,868,129	4,106,898	142,720,880
46	4,793,383	4,047,101	146,767,981
47	4,714,899	3,984,314	150,752,295
48	4,632,492	3,918,388	154,670,683
49	4,545,963	3,849,165	158,519,848
50	4,455,109	3,776,482	162,296,330

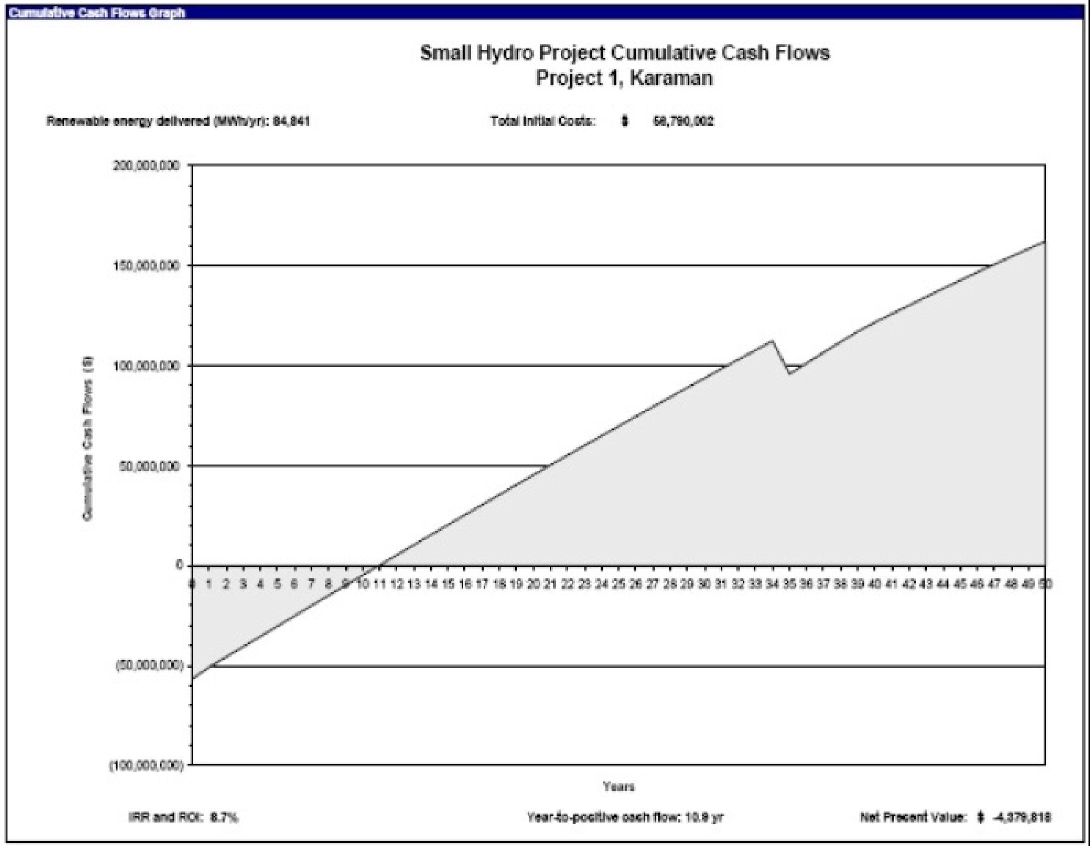

Figure B.6. Cash Flow of Project 2

APPENDIX C

EFFECT OF TUNNEL DIAMETER IN COST FOR PROJECT 1

RETScreen® Cost Analysis - Small Hydro Project

Costing method: Formula | Currency: $ | Cost references: None

Formula Costing Method	Unit	Value	Notes/Range
Input Parameters			
Project country		Turkey	
Local vs. Canadian equipment costs ratio	-	1.00	
Local vs. Canadian fuel costs ratio	-	2.08	
Local vs. Canadian labour costs ratio	-	0.23	
Equipment manufacture cost coefficient	-	1.00	0.50 to 1.00
Exchange rate	$/CAD	0.88	
Cold climate?	yes/no	No	
Number of turbines	turbine	2	
Flow per turbine	m³/s	10.5	
Approx. turbine runner diameter (per unit)	m	1.4	
Project classification:			
Suggested classification	-	Small	
Selected classification	-	Small	
Existing dam?	yes/no	No	
New dam crest length	m	24.5	
Rock at dam site?	yes/no	Yes	
Maximum hydraulic losses	%	14%	
Intake and miscellaneous losses	%	1%	1% to 5%
Access road required?	yes/no	Yes	
Length	km	11.3	
Tote road only?	yes/no	No	
Difficulty of terrain	-	3.0	1.0 to 6.0
Tunnel required?	yes/no	Yes	
Length	m	5,498	
Allowable tunnel headloss factor	%	43.0%	Increase Maximum hydraulic losses in Energy Model by 30.5%
Percent length of tunnel that is lined	%	100%	15% to 100%
Tunnel excavation method	-	Mechanised	
Tunnel diameter	m	3.8	
Canal required?	yes/no	No	
Penstock required?	yes/no	Yes	
Length	m	140.0	
Number of identical penstocks	penstock	1	
Allowable penstock headloss factor	%	0.6%	Increase Maximum hydraulic losses in Energy Model by 30.5%
Pipe diameter	m	2.59	
Average pipe wall thickness	mm	9.4	
Distance to borrow pits	km	5.0	
Transmission line			
Length	km	35.0	
Difficulty of terrain	-	1.5	1.0 to 2.0
Voltage	kV	33.0	
Interest rate	%	9.5%	

Initial Costs (Formula Method)	Cost (local currency)	Adjustment Factor	Amount (local currency)	Relative Costs
Feasibility Study	$ 1,510,548	1.00	$ 1,510,548	3.3%
Development	$ 1,544,038	1.00	$ 1,544,038	3.4%
Land rights			$ 411,919	0.9%
Development Sub-total:			$ 1,955,957	4.3%
Engineering	$ 759,681	1.00	$ 759,681	1.7%
Energy Equipment	$ 7,947,563	1.00	$ 7,947,563	17.4%
Balance of Plant				
Access road	$ 1,183,586	1.00	$ 1,183,586	2.6%
Transmission line	$ 974,718	1.00	$ 974,718	2.1%
Substation and transformer	$ 341,944	1.00	$ 341,944	0.7%
Penstock	$ 393,941	1.00	$ 393,941	0.9%
Canal	$ -	1.00	$ -	0.0%
Tunnel	$ 18,933,849	1.00	$ 18,933,849	41.5%
Civil works (other)	$ 8,076,233	1.00	$ 8,076,233	17.7%
Balance of Plant Sub-total:	$ 29,904,272		$ 29,904,272	65.6%
Miscellaneous	$ 7,060,094	0.50	$ 3,530,047	7.7%
GHG baseline study and MP — Cost	$ -		$ -	0.0%
GHG validation and registration — Cost	$ -		$ -	0.0%
Miscellaneous Sub-total:			$ 3,530,047	7.7%
Initial Costs - Total (Formula Method)	$ 48,726,196		$ 45,608,068	100.0%

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Land lease	project	1	$ -	$ -		-	-
Property taxes	%	0.0%	$ 45,608,068	$ -		-	-
Water rental	kW	13,297	$ -	$ -		-	-
Insurance premium	%	0.00%	$ 45,608,068	$ -		-	-
Transmission line maintenance	%	0.0%	$ 1,316,662	$ -		-	-
Spare parts	%	0.20%	$ 45,608,068	$ 91,216		-	-
O&M labour	p-yr	1.00	$ 52,800	$ 52,800		-	-
GHG monitoring and verification	project	0	$ -	$ -		-	-
Travel and accommodation	p-trip	0	$ 1,000	$ -		-	-
General and administrative	%	0%	$ 144,016	$ -		-	-
	Cost			$ -		-	-
Contingencies	%	0%	$ 144,016	$ -		-	-
Annual Costs - Total				$ 144,016	100.0%		

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
Electromechanical Equipment	Cost	35 yr	$ 3,973,782	$ 3,973,782	-	-
				$ -	-	-
				$ -	-	-
End of project life	Credit	-	$ -	$ -		Go to GHG Analysis sheet

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Figure C.1. Effect of Tunnel Diameter to Investment Costs (Project 1)

APPENDIX D

EFFECT OF TUNNEL DIAMETER IN COST FOR PROJECT 2

RETScreen® Cost Analysis - Small Hydro Project

Costing method: Formula | Currency: $ | Cost references: None

Formula Costing Method	Unit	Value	Notes/Range
Input Parameters			
Project country		Turkey	
Local vs. Canadian equipment costs ratio	-	1.00	
Local vs. Canadian fuel costs ratio	-	2.08	
Local vs. Canadian labour costs ratio	-	0.23	
Equipment manufacture cost coefficient	-	1.00	0.50 to 1.00
Exchange rate	$/CAD	0.88	
Cold climate?	yes/no	No	
Number of turbines	turbine	2	
Flow per turbine	m³/s	17.5	
Approx. turbine runner diameter (per unit)	m	1.7	
Project classification:			
Suggested classification	-	Small	
Selected classification	-	Small	
Existing dam?	yes/no	No	
New dam crest length	m	13.5	
Rock at dam site?	yes/no	Yes	
Maximum hydraulic losses	%	14%	
Intake and miscellaneous losses	%	3%	1% to 5%
Access road required?	yes/no	Yes	
Length	km	1.2	
Tote road only?	yes/no	No	
Difficulty of terrain	-	5.0	1.0 to 6.0
Tunnel required?	yes/no	Yes	
Length	m	3,594	
Allowable tunnel headloss factor	%	70.0%	Increase Maximum hydraulic losses in Energy Model by 59.7%
Percent length of tunnel that is lined	%	85%	15% to 100%
Tunnel excavation method	-	Mechanised	
Tunnel diameter	m	3.8	
Canal required?	yes/no	No	
Penstock required?	yes/no	Yes	
Length	m	122.0	
Number of identical penstocks	penstock	1	
Allowable penstock headloss factor	%	0.4%	Increase Maximum hydraulic losses in Energy Model by 59.7%
Pipe diameter	m	3.42	
Average pipe wall thickness	mm	11.1	
Distance to borrow pits	km	5.0	
Transmission line			
Length	km	30.0	
Difficulty of terrain	-	1.0	1.0 to 2.0
Voltage	kV	154.0	
Interest rate	%	9.5%	

Initial Costs (Formula Method)	Cost (local currency)	Adjustment Factor	Amount (local currency)	Relative Costs
Feasibility Study	$ 1,693,859	1.00	$ 1,693,859	3.3%
Development	$ 1,710,603	1.00	$ 1,710,603	3.3%
Land rights			$ 1,000,000	1.9%
Development Sub-total:			$ 2,710,603	5.3%
Engineering	$ 1,001,157	1.00	$ 1,001,157	1.9%
Energy Equipment	$ 12,135,501	1.00	$ 12,135,501	23.6%
Balance of Plant				
Access road	$ 437,125	1.00	$ 437,125	0.9%
Transmission line	$ 3,355,109	1.00	$ 3,355,109	6.5%
Substation and transformer	$ 859,268	1.00	$ 859,268	1.7%
Penstock	$ 514,679	1.00	$ 514,679	1.0%
Canal	$ -	1.00	$ -	0.0%
Tunnel	$ 12,124,044	1.00	$ 12,124,044	23.6%
Civil works (other)	$ 12,327,624	1.00	$ 12,327,624	24.0%
Balance of Plant Sub-total:	$ 29,617,849		$ 29,617,849	57.6%
Miscellaneous	$ 8,478,106	0.50	$ 4,239,053	8.2%
GHG baseline study and MP — Cost	$ -		$ -	0.0%
GHG validation and registration — Cost	$ -		$ -	0.0%
Miscellaneous Sub-total:			$ 4,239,053	8.2%
Initial Costs - Total (Formula Method)	$ 54,637,075		$ 51,398,022	100.0%

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Land lease	project	1	$ -	$ -		-	-
Property taxes	%	0.0%	$ 51,398,022	$ -		-	-
Water rental	kW	22,159	$ -	$ -		-	-
Insurance premium	%	0.00%	$ 51,398,022	$ -		-	-
Transmission line maintenance	%	0.0%	$ 4,214,377	$ -		-	-
Spare parts	%	0.20%	$ 51,398,022	$ 102,796		-	-
O&M labour	p-yr	1.00	$ 52,800	$ 52,800		-	-
GHG monitoring and verification	project	0	$ -	$ -		-	-
Travel and accommodation	p-trip	0	$ 1,000	$ -		-	-
General and administrative	%	0%	$ 155,596	$ -		-	-
Other - O&M	Cost	0	$ -	$ -		-	-
Contingencies	%	0%	$ 155,596	$ -		-	-
Annual Costs - Total				$ 155,596	100.0%		

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
Electromechanical Equipment	Cost	35 yr	$ 6,067,751	$ 6,067,751	-	-
				$ -	-	-
				$ -	-	-
End of project life	Credit	-	$ 1,500,000	$ (1,500,000)		Go to GHG Analysis sheet

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Figure D.1. Effect of Tunnel Diameter to Investment Costs (Project 2)

APPENDIX E

RESULTS OF RETSCREEN SOFTWARE FOR PORSUK DAM

(Q_d = Q_{20})

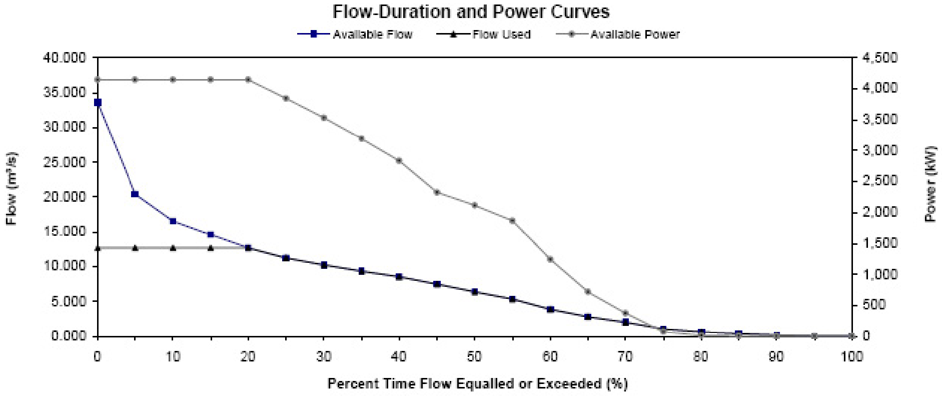
RETScreen® Energy Model - Small Hydro Project — Training & Support

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		Porsuk Dam	See Online Manual
Project location		Eskisehir	
Latitude of project location	°N	38°45 & 39°59	-90.00 to 90.00
Longitude of project location	°E	29°39 & 32°01	-180.00 to 180.00
Gross head	m	40.61	
Maximum tailwater effect	m	0.00	
Residual flow	m³/s	0.00	Complete Hydrology & Load sheet
Firm flow	m³/s	0.05	

System Characteristics		Estimate	Notes/Range
Grid type	-	Central-grid	
Design flow	m³/s	12.690	
Turbine type	-	Francis	Complete Equipment Data sheet
Number of turbines	turbine	2	
Turbine peak efficiency	%	92.0%	
Turbine efficiency at design flow	%	87.9%	
Maximum hydraulic losses	%	3%	2% to 7%
Generator efficiency	%	97%	93% to 97%
Transformer losses	%	1%	1% to 2%
Parasitic electricity losses	%	0%	1% to 3%
Annual downtime losses	%	0%	2% to 7%

Annual Energy Production		Estimate	Notes/Range
Small hydro plant capacity	kW	4,149	
	MW	4.149	
Small hydro plant firm capacity	kW	0	
Available flow adjustment factor	-	1.00	
Small hydro plant capacity factor	%	49%	40% to 95%
Renewable energy delivered	MWh	17,879	
	GWh	17.879	



Complete Cost Analysis sheet

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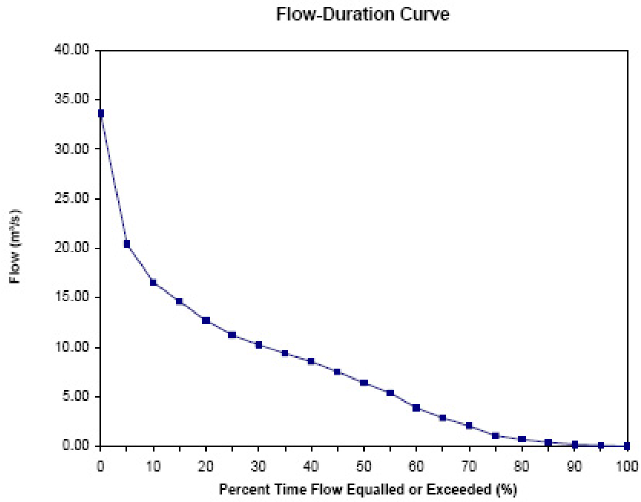
Figure E.1. "Energy Model" Worksheet of Porsuk Dam (Q_d = Q_{20})

RETScreen® Hydrology Analysis and Load Calculation - Small Hydro Project

Hydrology Analysis		Estimate	Notes/Range
Project type		Run-of-river	
Hydrology method		User-defined	
Hydrology Parameters			
Residual flow	m³/s	0	
Percent time firm flow available	%	95%	90% to 100%
Firm flow	m³/s	0.05	

Flow-Duration Curve Data

Time (%)	Flow (m³/s)
0%	33.60
5%	20.45
10%	16.55
15%	14.60
20%	12.69
25%	11.24
30%	10.23
35%	9.35
40%	8.55
45%	7.48
50%	6.40
55%	5.36
60%	3.88
65%	2.83
70%	2.04
75%	1.05
80%	0.65
85%	0.37
90%	0.16
95%	0.05
100%	0.00



Load Characteristics	Estimate	Notes/Range
Grid type	Central-grid	

Return to Energy Model sheet

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Figure E.2. "Hydrology Analysis and Load Calculation" Worksheet of Porsuk Dam ($Q_d = Q_{20}$)

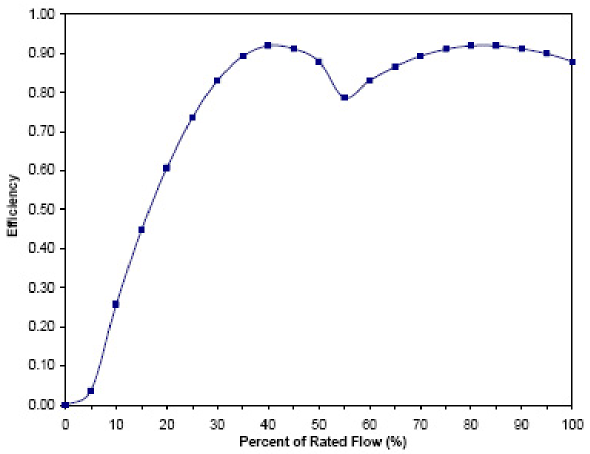
RETScreen® Equipment Data - Small Hydro Project

Small Hydro Turbine Characteristics		Estimate	Notes/Range
Gross head	m	40.61	
Design flow	m³/s	12.690	
Turbine type	-	Francis	See Product Database
Turbine efficiency curve data source	-	Standard	
Number of turbines	turbine	2	
Small hydro turbine manufacturer			
Small hydro turbine model			
Turbine manufacture/design coefficient	-	4.5	2.8 to 6.1; Default = 4.5
Efficiency adjustment	%	1%	-5% to 5%
Turbine peak efficiency	%	92.0%	
Flow at peak efficiency	m³/s	10.4	
Turbine efficiency at design flow	%	87.9%	

Turbine Efficiency Curve Data

Flow (%)	Turbine efficiency	Turbines running #	Combined turbine efficiency
0%	0.01	0	0.00
5%	0.01	1	0.04
10%	0.04	1	0.26
15%	0.15	1	0.45
20%	0.26	1	0.61
25%	0.36	1	0.73
30%	0.45	1	0.83
35%	0.53	1	0.89
40%	0.61	1	0.92
45%	0.67	1	0.91
50%	0.73	1	0.88
55%	0.79	2	0.79
60%	0.83	2	0.83
65%	0.87	2	0.87
70%	0.89	2	0.89
75%	0.91	2	0.91
80%	0.92	2	0.92
85%	0.92	2	0.92
90%	0.91	2	0.91
95%	0.90	2	0.90
100%	0.88	2	0.88

Efficiency Curve - 2 Turbine(s)



Return to Energy Model sheet

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Figure E.3. "Equipment Data" Worksheet of Porsuk Dam (Q_d = Q_{20})

RETScreen® Cost Analysis - Small Hydro Project

Costing method: Formula | Currency: $ | Cost references: None

Formula Costing Method			Notes/Range
Input Parameters			
Project country		TURKEY	
Local vs. Canadian equipment costs ratio	-	1.00	
Local vs. Canadian fuel costs ratio	-	2.08	
Local vs. Canadian labour costs ratio	-	0.23	
Equipment manufacture cost coefficient	-	1.00	0.50 to 1.00
Exchange rate	$/CAD	0.88	
Cold climate?	yes/no	No	
Number of turbines	turbine	2	
Flow per turbine	m³/s	6.3	
Approx. turbine runner diameter (per unit)	m	1.1	
Project classification:			
Suggested classification	-	Mini	
Selected classification	-	Mini	
Existing dam?	yes/no	Yes	
Rock at dam site?	yes/no	Yes	
Maximum hydraulic losses	%	3%	
Intake and miscellaneous losses	%	1%	1% to 5%
Access road required?	yes/no	No	
Tunnel required?	yes/no	No	
Canal required?	yes/no	No	
Penstock required?	yes/no	Yes	
Length	m	230.0	
Number of identical penstocks	penstock	1	
Allowable penstock headloss factor	%	1.7%	1.0% to 4.0%
Pipe diameter	m	2.25	
Average pipe wall thickness	mm	8.9	
Distance to borrow pits	km	5.0	
Transmission line			
Length	km	15.0	
Difficulty of terrain	-	1.0	1.0 to 2.0
Voltage	kV	33.0	
Interest rate	%	9.5%	

Initial Costs (Formula Method)		Cost (local currency)	Adjustment Factor	Amount (local currency)	Relative Costs
Feasibility Study		$ 216,800	0.00	$ -	0.0%
Development		$ 223,850	0.00	$ -	0.0%
Land rights				$ -	0.0%
Development Sub-total:				$ -	0.0%
Engineering		$ 280,253	0.00	$ -	0.0%
Energy Equipment		$ 3,278,436	1.00	$ 3,278,436	56.7%
Balance of Plant					
Access road		$ -	1.00	$ -	0.0%
Transmission line		$ 290,829	1.00	$ 290,829	5.0%
Substation and transformer		$ 102,231	1.00	$ 102,231	1.8%
Penstock		$ 510,273	1.00	$ 510,273	8.8%
Canal		$ -	1.00	$ -	0.0%
Tunnel		$ -	1.00	$ -	0.0%
Civil works (other)		$ 1,127,183	1.00	$ 1,127,183	19.5%
Balance of Plant Sub-total:		$ 2,030,515		$ 2,030,515	35.1%
Miscellaneous		$ 950,923	0.50	$ 475,461	8.2%
GHG baseline study and MP	Cost	$ -		$ -	0.0%
GHG validation and registration	Cost	$ -		$ -	0.0%
Miscellaneous Sub-total:				$ 475,461	8.2%
Initial Costs - Total (Formula Method)		$ 6,980,777		$ 5,784,413	100.0%

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Land lease	project	1	$ -	$ -		-	-
Property taxes	%	0.0%	$ 5,784,413	$ -		-	-
Water rental	kW	4,149	$ -	$ -		-	-
Insurance premium	%	0.00%	$ 5,784,413	$ -		-	-
Transmission line maintenance	%	0.0%	$ 393,060	$ -		-	-
Spare parts	%	0.20%	$ 5,784,413	$ 11,569		-	-
O&M labour	p-yr	1.00	$ 30,000	$ 30,000		-	-
GHG monitoring and verification	project	0	$ -	$ -		-	-
Travel and accommodation	p-trip	0	$ 1,000	$ -		-	-
General and administrative	%	0%	$ 41,569	$ -		-	-
Other - O&M	Cost	0	$ -	$ -		-	-
Contingencies	%	0%	$ 41,569	$ -		-	-
Annual Costs - Total				$ 41,569	100.0%		

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
Turbine overhaul	Cost	35 yr	$ 1,639,218	$ 1,639,218	-	-
				$ -	-	-
				$ -	-	-
End of project life	Credit	-		$ -		

Go to GHG Analysis sheet

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Figure E.4. "Cost Analysis" Worksheet of Porsuk Dam ($Q_d = Q_{20}$)

RETScreen® Financial Summary - Small Hydro Project

Annual Energy Balance

Project name		Porsuk Dam
Project location		Eskisehir
Renewable energy delivered	MWh	17,879
Excess RE available	MWh	-
Firm RE capacity	kW	0
Grid type		Central-grid

Financial Parameters

Avoided cost of energy	$/kWh	0.0750	Debt ratio	%	0.0%
RE production credit	$/kWh	-			
			Income tax analysis?	yes/no	Yes
			Effective income tax rate	%	20.0%
			Loss carryforward?	-	Yes
			Depreciation method	-	Straight-line
Avoided cost of capacity	$/kW-yr	-	Depreciation tax basis	%	93.5%
Energy cost escalation rate	%	0.0%			
Inflation	%	5.0%	Depreciation period	yr	50
Discount rate	%	9.5%	Tax holiday available?	yes/no	No
Project life	yr	50			

Project Costs and Savings

Initial Costs			
Feasibility study	0.0%	$	-
Development	0.0%	$	-
Engineering	0.0%	$	-
Energy equipment	56.7%	$	3,278,436
Balance of plant	35.1%	$	2,030,515
Miscellaneous	8.2%	$	475,461
Initial Costs - Total	100.0%	**$**	**5,784,413**
Incentives/Grants		$	-
Periodic Costs (Credits)			
Turbine overhaul		$	1,639,218
		$	-
		$	-
End of project life - Credit		$	-

Annual Costs and Debt		
O&M	$	41,569
Annual Costs and Debt - Total	**$**	**41,569**
Annual Savings or Income		
Energy savings/income	$	1,340,956
Capacity savings/income	$	-
Annual Savings - Total	**$**	**1,340,956**
Schedule yr # 35		

Financial Feasibility

			Calculate energy production cost?	yes/no	No
Pre-tax IRR and ROI	%	22.2%			
After-tax IRR and ROI	%	18.2%			
Simple Payback	yr	4.5			
Year-to-positive cash flow	yr	5.4	Project equity	$	5,784,413
Net Present Value - NPV	$	4,676,178			
Annual Life Cycle Savings	$	449,041			
Benefit-Cost (B-C) ratio	-	1.81			

Figure E.5. Data Sheet of "Financial Summary" Porsuk Dam ($Q_d = Q_{20}$)

Year #	Pre-tax $	After-tax $	Cumulative $
0	(5,784,413)	(5,784,413)	(5,784,413)
1	1,297,309	1,134,678	(4,649,735)
2	1,295,126	1,057,735	(3,592,000)
3	1,292,835	1,055,901	(2,536,098)
4	1,290,429	1,053,977	(1,482,122)
5	1,287,902	1,051,956	(430,166)
6	1,285,250	1,049,833	619,667
7	1,282,464	1,047,605	1,667,272
8	1,279,540	1,045,265	2,712,538
9	1,276,469	1,042,809	3,755,347
10	1,273,245	1,040,229	4,795,576
11	1,269,859	1,037,521	5,833,097
12	1,266,304	1,034,677	6,867,774
13	1,262,572	1,031,691	7,899,465
14	1,258,652	1,028,556	8,928,021
15	1,254,537	1,025,263	9,953,284
16	1,250,216	1,021,807	10,975,091
17	1,245,679	1,018,177	11,993,268
18	1,240,915	1,014,366	13,007,634
19	1,235,913	1,010,364	14,017,999
20	1,230,661	1,006,163	15,024,161
21	1,225,147	1,001,751	16,025,912
22	1,219,356	997,119	17,023,031
23	1,213,276	992,255	18,015,286
24	1,206,892	987,147	19,002,433
25	1,200,189	981,785	19,984,218
26	1,193,151	976,154	20,960,372
27	1,185,760	970,242	21,930,614
28	1,178,001	964,034	22,894,649
29	1,169,853	957,516	23,852,165
30	1,161,298	950,672	24,802,837
31	1,152,315	943,486	25,746,322
32	1,142,883	935,940	26,682,262
33	1,132,979	928,017	27,610,279
34	1,122,580	919,698	28,529,977
35	(7,930,290)	(7,930,290)	20,599,687
36	1,100,197	1,100,197	21,699,884
37	1,088,159	1,088,159	22,788,043
38	1,075,519	1,075,519	23,863,562
39	1,062,247	1,062,247	24,925,809
40	1,048,312	1,048,312	25,974,121
41	1,033,680	1,033,680	27,007,800
42	1,018,316	1,018,316	28,026,116
43	1,002,184	1,002,184	29,028,300
44	985,245	904,869	29,933,168
45	967,460	795,601	30,728,770
46	948,785	780,662	31,509,431
47	929,176	764,975	32,274,406
48	908,587	748,504	33,022,909
49	886,969	731,209	33,754,118
50	864,269	713,049	34,467,168

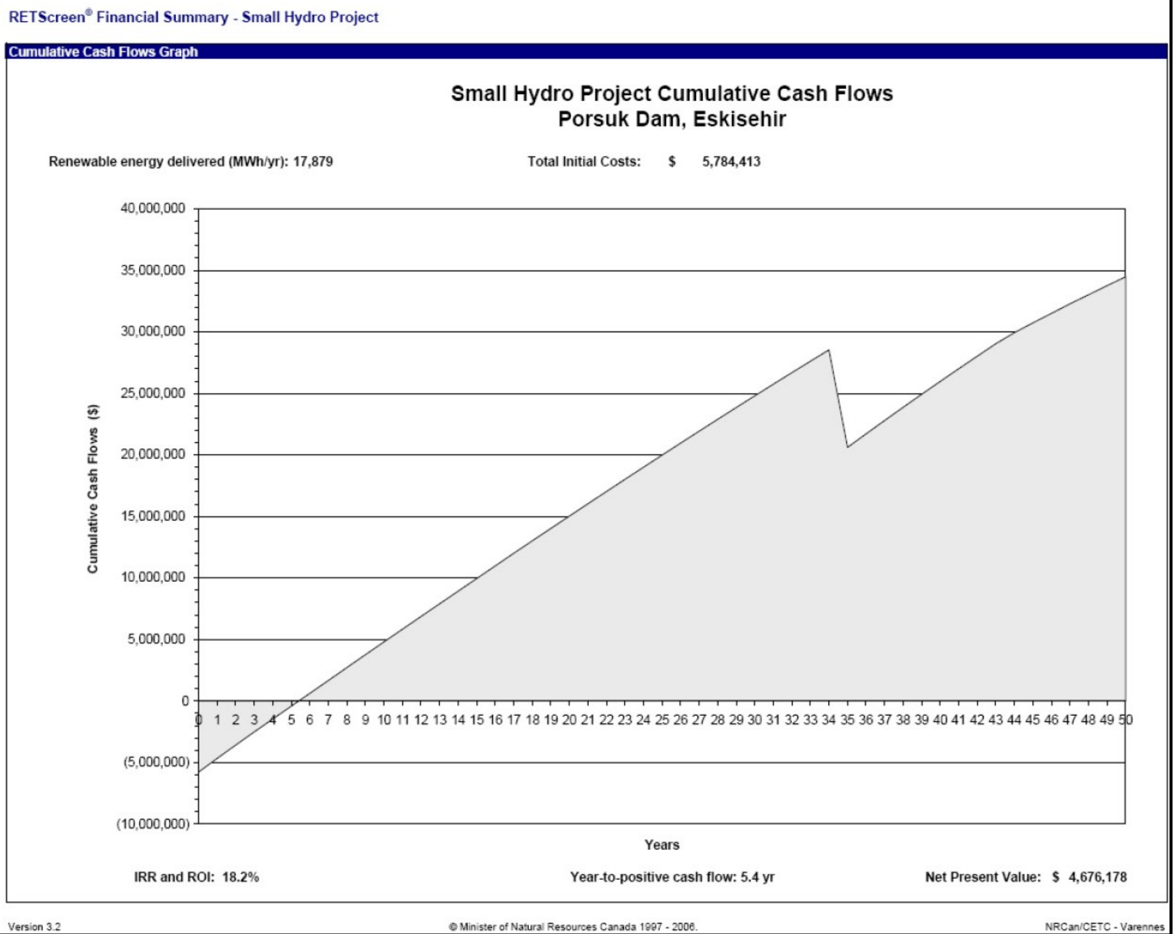


Figure E.6. Cash Flow of Porsuk Dam ($Q_d = Q_{20}$)

APPENDIX F

RESULTS OF RETSCREEN SOFTWARE FOR PORSUK DAM ($Qd = Q_{25}$)

RETScreen® Energy Model - Small Hydro Project

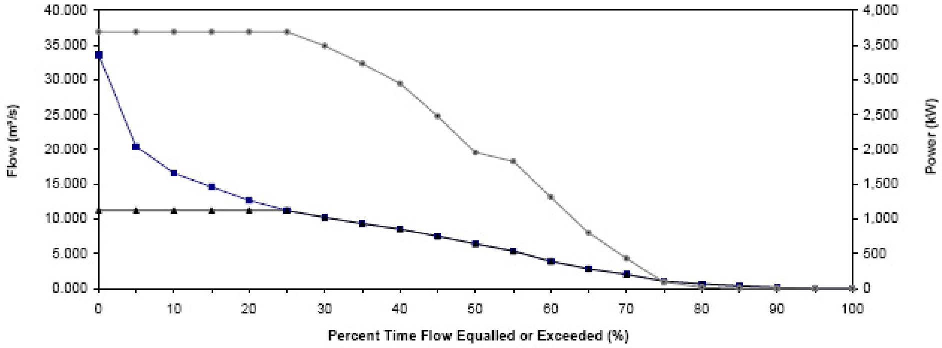
Training & Support

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		Porsuk Dam	See Online Manual
Project location		Eskisehir	
Latitude of project location	°N	38°45 & 39°59	-90.00 to 90.00
Longitude of project location	°E	29°39 & 32°01	-180.00 to 180.00
Gross head	m	40.61	
Maximum tailwater effect	m	0.00	
Residual flow	m³/s	0.00	Complete Hydrology & Load sheet
Firm flow	m³/s	0.05	

System Characteristics		Estimate	Notes/Range
Grid type	-	Central-grid	
Design flow	m³/s	11.240	
Turbine type	-	Francis	Complete Equipment Data sheet
Number of turbines	turbine	2	
Turbine peak efficiency	%	92.1%	
Turbine efficiency at design flow	%	87.9%	
Maximum hydraulic losses	%	2%	2% to 7%
Generator efficiency	%	97%	93% to 97%
Transformer losses	%	1%	1% to 2%
Parasitic electricity losses	%	0%	1% to 3%
Annual downtime losses	%	0%	2% to 7%

Annual Energy Production		Estimate	Notes/Range
Small hydro plant capacity	kW	3,690	
	MW	3.690	
Small hydro plant firm capacity	kW	0	
Available flow adjustment factor	-	1.00	
Small hydro plant capacity factor	%	53%	40% to 95%
Renewable energy delivered	MWh	**17,027**	
	GWh	17.027	



Complete Cost Analysis sheet

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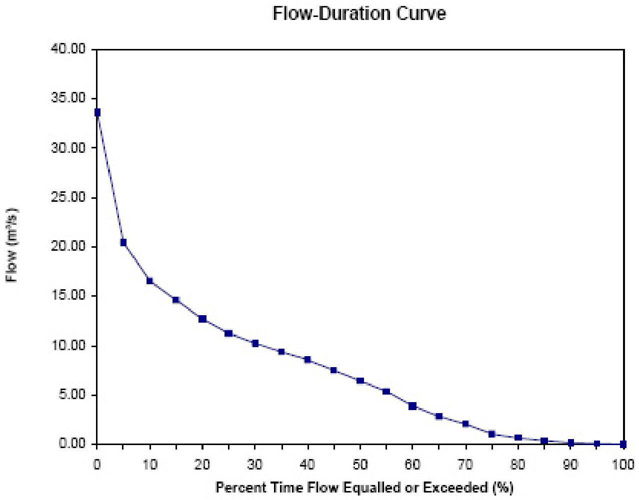
Figure F.1. “Energy Model” Worksheet of Porsuk Dam ($Q_d = Q_{25}$)

RETScreen® Hydrology Analysis and Load Calculation - Small Hydro Project

Hydrology Analysis		Estimate	Notes/Range
Project type		Run-of-river	
Hydrology method		User-defined	
Hydrology Parameters			
Residual flow	m³/s	0	
Percent time firm flow available	%	95%	90% to 100%
Firm flow	m³/s	0.05	

Flow-Duration Curve Data

Time (%)	Flow (m³/s)
0%	33.60
5%	20.45
10%	16.55
15%	14.60
20%	12.69
25%	11.24
30%	10.23
35%	9.35
40%	8.55
45%	7.48
50%	6.40
55%	5.36
60%	3.88
65%	2.83
70%	2.04
75%	1.05
80%	0.65
85%	0.37
90%	0.16
95%	0.05
100%	0.00



Load Characteristics	Estimate	Notes/Range
Grid type	Central-grid	

Return to Energy Model sheet

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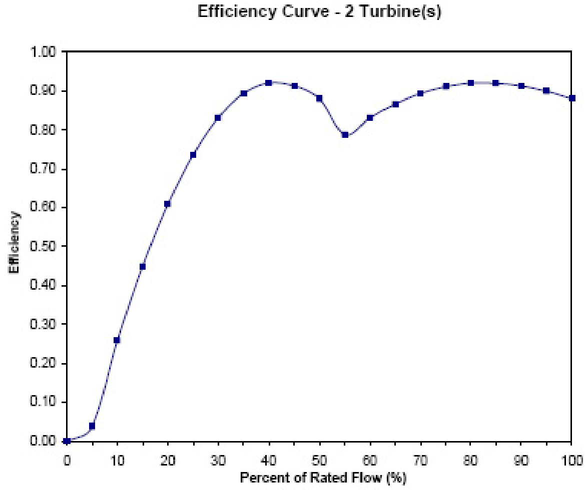
Figure F.2. “Hydrology Analysis and Load Calculation” Worksheet of Porsuk Dam ($Q_d = Q_{25}$)

RETScreen® Equipment Data - Small Hydro Project

Small Hydro Turbine Characteristics		Estimate	Notes/Range
Gross head	m	40.61	
Design flow	m³/s	11.240	
Turbine type	-	Francis	See Product Database
Turbine efficiency curve data source	-	Standard	
Number of turbines	turbine	2	
Small hydro turbine manufacturer			
Small hydro turbine model			
Turbine manufacture/design coefficient	-	4.5	2.8 to 6.1; Default = 4.5
Efficiency adjustment	%	1%	-5% to 5%
Turbine peak efficiency	%	92.1%	
Flow at peak efficiency	m³/s	9.2	
Turbine efficiency at design flow	%	87.9%	

Turbine Efficiency Curve Data

Flow (%)	Turbine efficiency	Turbines running #	Combined turbine efficiency
0%	0.01	0	0.00
5%	0.01	1	0.04
10%	0.04	1	0.26
15%	0.15	1	0.45
20%	0.26	1	0.61
25%	0.36	1	0.74
30%	0.45	1	0.83
35%	0.53	1	0.89
40%	0.61	1	0.92
45%	0.68	1	0.91
50%	0.74	1	0.88
55%	0.79	2	0.79
60%	0.83	2	0.83
65%	0.87	2	0.87
70%	0.89	2	0.89
75%	0.91	2	0.91
80%	0.92	2	0.92
85%	0.92	2	0.92
90%	0.91	2	0.91
95%	0.90	2	0.90
100%	0.88	2	0.88



Return to Energy Model sheet

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Figure F.3. "Equipment Data" Worksheet of Porsuk Dam ($Q_d = Q_{25}$)

RETScreen® Cost Analysis - Small Hydro Project

Costing method: Formula | Currency: $ | Cost references: None

Formula Costing Method			Notes/Range
Input Parameters			
Project country		TURKEY	
Local vs. Canadian equipment costs ratio	-	1.00	
Local vs. Canadian fuel costs ratio	-	2.08	
Local vs. Canadian labour costs ratio	-	0.23	
Equipment manufacture cost coefficient	-	1.00	0.50 to 1.00
Exchange rate	$/CAD	0.88	
Cold climate?	yes/no	No	
Number of turbines	turbine	2	
Flow per turbine	m³/s	5.6	
Approx. turbine runner diameter (per unit)	m	1.0	
Project classification:			
Suggested classification	-	Mini	
Selected classification	-	Mini	
Existing dam?	yes/no	Yes	
Rock at dam site?	yes/no	Yes	
Maximum hydraulic losses	%	3%	
Intake and miscellaneous losses	%	1%	1% to 5%
Access road required?	yes/no	No	
Tunnel required?	yes/no	No	
Canal required?	yes/no	No	
Penstock required?	yes/no	Yes	
Length	m	230.0	
Number of identical penstocks	penstock	1	
Allowable penstock headloss factor	%	1.7%	1.0% to 4.0%
Pipe diameter	m	2.15	
Average pipe wall thickness	mm	8.7	
Distance to borrow pits	km	5.0	
Transmission line			
Length	km	15.0	
Difficulty of terrain	-	1.0	1.0 to 2.0
Voltage	kV	33.0	
Interest rate	%	9.5%	

Initial Costs (Formula Method)	Cost (local currency)	Adjustment Factor	Amount (local currency)	Relative Costs
Feasibility Study	$ 198,293	0.00	$ -	0.0%
Development	$ 205,343	0.00	$ -	0.0%
Land rights			$ -	0.0%
Development Sub-total:			$ -	0.0%
Engineering	$ 262,627	0.00	$ -	0.0%
Energy Equipment	$ 2,986,726	1.00	$ **2,986,726**	56.3%
Balance of Plant				
Access road	$ -	1.00	$ -	0.0%
Transmission line	$ 290,829	1.00	$ 290,829	5.5%
Substation and transformer	$ 91,655	1.00	$ 91,655	1.7%
Penstock	$ 480,309	1.00	$ 480,309	9.1%
Canal	$ -	1.00	$ -	0.0%
Tunnel	$ -	1.00	$ -	0.0%
Civil works (other)	$ 1,024,952	1.00	$ 1,024,952	19.3%
Balance of Plant Sub-total:	$ 1,887,745		$ **1,887,745**	35.6%
Miscellaneous	$ 860,149	0.50	$ 430,074	8.1%
GHG baseline study and MP — Cost	$ -		$ -	0.0%
GHG validation and registration — Cost	$ -		$ -	0.0%
Miscellaneous Sub-total:			$ **430,074**	8.1%
Initial Costs - Total (Formula Method)	$ 6,400,882		$ 5,304,545	100.0%

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Land lease	project	1	$ -	$ -		-	-
Property taxes	%	0.0%	$ 5,304,545	$ -		-	-
Water rental	kW	3,675	$ -	$ -		-	-
Insurance premium	%	0.00%	$ 5,304,545	$ -		-	-
Transmission line maintenance	%	0.0%	$ 382,484	$ -		-	-
Spare parts	%	0.20%	$ 5,304,545	$ 10,609		-	-
O&M labour	p-yr	1.00	$ 30,000	$ 30,000		-	-
GHG monitoring and verification	project	0	$ -	$ -		-	-
Travel and accommodation	p-trip	0	$ 1,000	$ -		-	-
General and administrative	%	0%	$ 40,609	$ -		-	-
Other - O&M	Cost	0	$ -	$ -		-	-
Contingencies	%	0%	$ 40,609	$ -		-	-
Annual Costs - Total				$ **40,609**	100.0%		

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
Turbine overhaul	Cost	35 yr	$ 1,493,363	$ **1,493,363**	-	-
				$ -	-	-
				$ -	-	-
End of project life	Credit	-		$ -		

Go to GHG Analysis sheet

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Figure F.4. "Cost Analysis" Worksheet of Porsuk Dam ($Q_d = Q_{25}$)

RETScreen® Financial Summary - Small Hydro Project

Annual Energy Balance

Project name		Porsuk Dam
Project location		Eskisehir
Renewable energy delivered	MWh	16,972
Excess RE available	MWh	-
Firm RE capacity	kW	0
Grid type		Central-grid

Financial Parameters

Avoided cost of energy	$/kWh	0.0750	Debt ratio	%	0.0%
RE production credit	$/kWh	-			
			Income tax analysis?	yes/no	Yes
			Effective income tax rate	%	20.0%
			Loss carryforward?	-	Yes
			Depreciation method	-	Straight-line
Avoided cost of capacity	$/kW-yr	-	Depreciation tax basis	%	93.5%
Energy cost escalation rate	%	0.0%			
Inflation	%	5.0%	Depreciation period	yr	50
Discount rate	%	9.5%	Tax holiday available?	yes/no	No
Project life	yr	50			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	0.0%	$	-	O&M	$	40,609
Development	0.0%	$	-			
Engineering	0.0%	$	-			
Energy equipment	56.3%	$	2,986,726	**Annual Costs and Debt - Total**	**$**	**40,609**
Balance of plant	35.6%	$	1,887,745			
Miscellaneous	8.1%	$	430,074	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**$**	**5,304,545**	Energy savings/income	$	1,272,871
				Capacity savings/income	$	-
Incentives/Grants		$	-			
				Annual Savings - Total	**$**	**1,272,871**
Periodic Costs (Credits)						
Turbine overhaul		$	1,493,363	Schedule yr # 35		
		$	-			
		$	-			
End of project life - Credit		$	-			

Financial Feasibility

			Calculate energy production cost?	yes/no	No
Pre-tax IRR and ROI	%	22.9%			
After-tax IRR and ROI	%	18.8%			
Simple Payback	yr	4.3			
Year-to-positive cash flow	yr	5.2	Project equity	$	5,304,545
Net Present Value - NPV	$	4,609,684			
Annual Life Cycle Savings	$	442,655			
Benefit-Cost (B-C) ratio	-	1.87			

Figure F.5. Data Sheet of "Financial Summary" Porsuk Dam ($Q_d = Q_{25}$)

Yearly Cash Flows			
Year #	Pre-tax $	After-tax $	Cumulative $
0	(5,304,545)	(5,304,545)	(5,304,545)
1	1,230,231	1,072,983	(4,231,562)
2	1,228,099	1,002,318	(3,229,243)
3	1,225,861	1,000,528	(2,228,716)
4	1,223,510	998,647	(1,230,068)
5	1,221,042	996,673	(233,396)
6	1,218,451	994,600	761,204
7	1,215,730	992,423	1,753,627
8	1,212,873	990,137	2,743,764
9	1,209,873	987,737	3,731,501
10	1,206,723	985,217	4,716,718
11	1,203,415	982,571	5,699,290
12	1,199,943	979,793	6,679,083
13	1,196,296	976,876	7,655,959
14	1,192,468	973,813	8,629,772
15	1,188,447	970,597	9,600,369
16	1,184,226	967,220	10,567,589
17	1,179,794	963,674	11,531,263
18	1,175,140	959,951	12,491,214
19	1,170,254	956,042	13,447,256
20	1,165,123	951,937	14,399,193
21	1,159,735	947,627	15,346,821
22	1,154,079	943,102	16,289,923
23	1,148,139	938,350	17,228,273
24	1,141,902	933,361	18,161,634
25	1,135,354	928,122	19,089,756
26	1,128,478	922,622	20,012,378
27	1,121,259	916,846	20,929,223
28	1,113,678	910,781	21,840,005
29	1,105,718	904,414	22,744,418
30	1,097,361	897,728	23,642,146
31	1,088,585	890,707	24,532,853
32	1,079,371	883,336	25,416,189
33	1,069,696	875,596	26,291,784
34	1,059,537	867,469	27,159,253
35	(7,188,542)	(7,188,542)	19,970,711
36	1,037,670	1,037,670	21,008,382
37	1,025,910	1,025,910	22,034,292
38	1,013,562	1,013,562	23,047,854
39	1,000,597	1,000,597	24,048,451
40	986,983	986,983	25,035,435
41	972,689	972,689	26,008,123
42	957,680	957,680	26,965,803
43	941,920	941,920	27,907,723
44	925,373	788,994	28,696,718
45	907,998	746,237	29,442,955
46	889,754	731,642	30,174,597
47	870,598	716,318	30,890,915
48	850,485	700,227	31,591,142
49	829,365	683,331	32,274,473
50	807,190	665,591	32,940,064

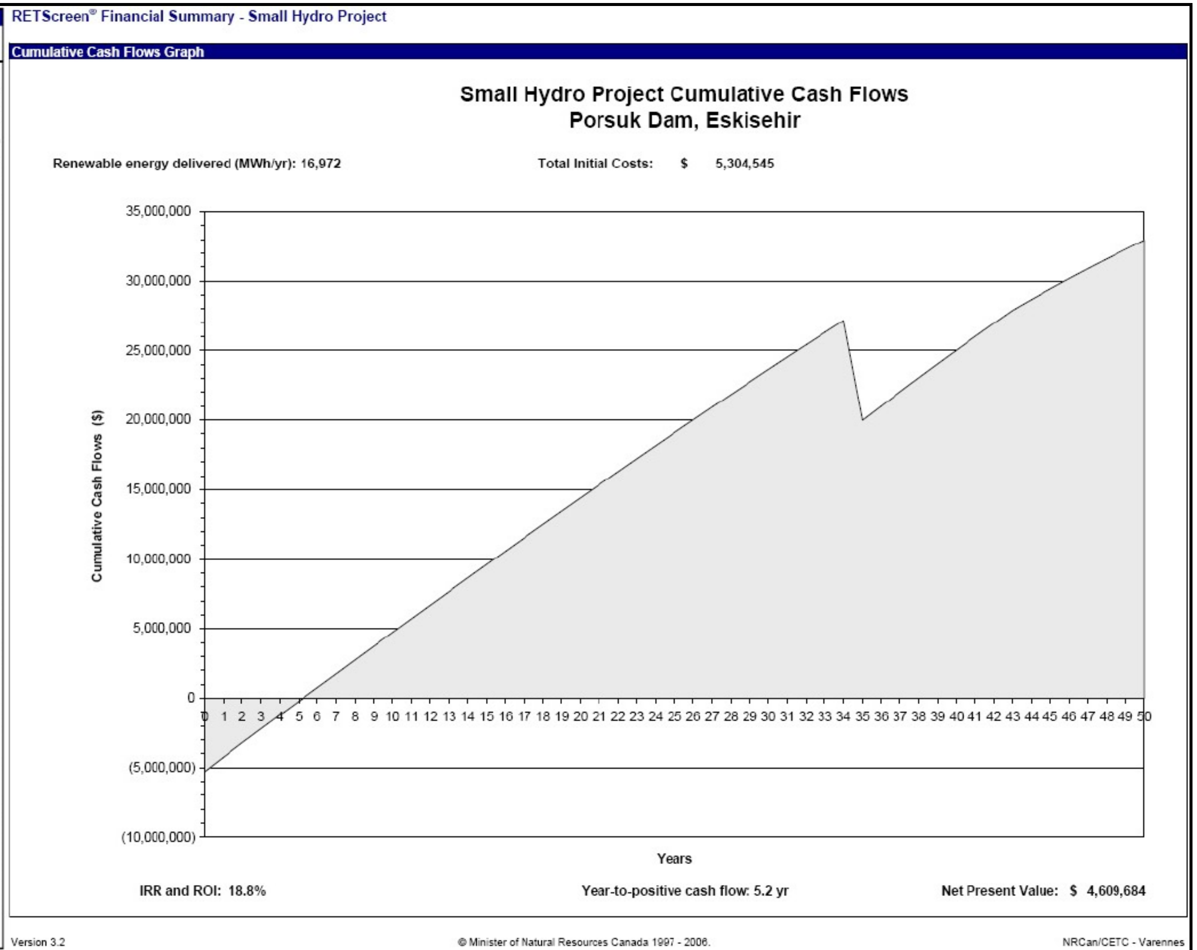


Figure F.6. Cash Flow of Porsuk Dam ($Q_d = Q_{25}$)

APPENDIX G

RESULTS OF RETSCREEN SOFTWARE FOR PORSUK DAM

($Q_d = Q_{30}$)

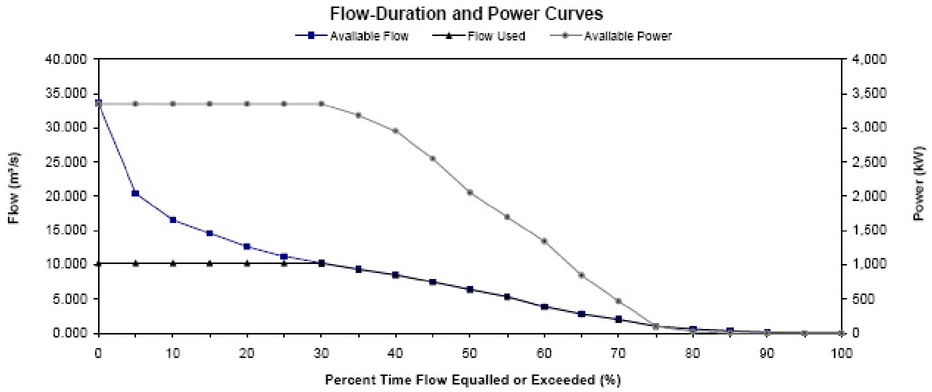
RETScreen® Energy Model - Small Hydro Project | Training & Support

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		Porsuk Dam	See Online Manual
Project location		Eskisehir	
Latitude of project location	°N	38°45 & 39°59	-90.00 to 90.00
Longitude of project location	°E	29°39 & 32°01	-180.00 to 180.00
Gross head	m	40.61	
Maximum tailwater effect	m	0.00	
Residual flow	m³/s	0.00	Complete Hydrology & Load sheet
Firm flow	m³/s	0.05	

System Characteristics		Estimate	Notes/Range
Grid type	-	Central-grid	
Design flow	m³/s	10.230	
Turbine type	-	Francis	Complete Equipment Data sheet
Number of turbines	turbine	2	
Turbine peak efficiency	%	92.0%	
Turbine efficiency at design flow	%	87.8%	
Maximum hydraulic losses	%	2%	2% to 7%
Generator efficiency	%	97%	93% to 97%
Transformer losses	%	1%	1% to 2%
Parasitic electricity losses	%	0%	1% to 3%
Annual downtime losses	%	0%	2% to 7%

Annual Energy Production		Estimate	Notes/Range
Small hydro plant capacity	kW	3,352	
	MW	3.352	
Small hydro plant firm capacity	kW	0	
Available flow adjustment factor	-	1.00	
Small hydro plant capacity factor	%	55%	40% to 95%
Renewable energy delivered	MWh	**16,220**	
	GJ	58,391	



Complete Cost Analysis sheet

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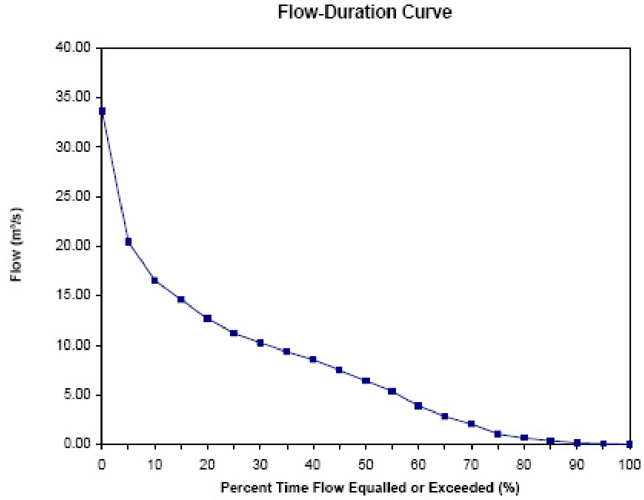
Figure G.1. "Energy Model" Worksheet of Porsuk Dam ($Q_d = Q_{30}$)

RETScreen® Hydrology Analysis and Load Calculation - Small Hydro Project

Hydrology Analysis		Estimate	Notes/Range
Project type		Run-of-river	
Hydrology method		User-defined	
Hydrology Parameters			
Residual flow	m³/s	0	
Percent time firm flow available	%	95%	90% to 100%
Firm flow	m³/s	0.05	

Flow-Duration Curve Data

Time (%)	Flow (m³/s)
0%	33.60
5%	20.45
10%	16.55
15%	14.60
20%	12.69
25%	11.24
30%	10.23
35%	9.35
40%	8.55
45%	7.48
50%	6.40
55%	5.36
60%	3.88
65%	2.83
70%	2.04
75%	1.05
80%	0.65
85%	0.37
90%	0.16
95%	0.05
100%	0.00



Load Characteristics	Estimate	Notes/Range
Grid type	Central-grid	

Return to Energy Model sheet

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Figure G.2. "Hydrology Analysis and Load Calculation" Worksheet of Porsuk Dam ($Q_d = Q_{30}$)

RETScreen® Equipment Data - Small Hydro Project

Small Hydro Turbine Characteristics		Estimate	Notes/Range
Gross head	m	40.61	
Design flow	m³/s	10.230	
Turbine type	-	Francis	See Product Database
Turbine efficiency curve data source	-	Standard	
Number of turbines	turbine	2	
Small hydro turbine manufacturer			
Small hydro turbine model			
Turbine manufacture/design coefficient	-	4.5	2.8 to 6.1; Default = 4.5
Efficiency adjustment	%	1%	-5% to 5%
Turbine peak efficiency	%	92.0%	
Flow at peak efficiency	m³/s	8.4	
Turbine efficiency at design flow	%	87.8%	

Turbine Efficiency Curve Data

Flow (%)	Turbine efficiency	Turbines running #	Combined turbine efficiency
0%	0.01	0	0.00
5%	0.01	1	0.04
10%	0.04	1	0.26
15%	0.15	1	0.45
20%	0.26	1	0.61
25%	0.36	1	0.74
30%	0.45	1	0.83
35%	0.53	1	0.89
40%	0.61	1	0.92
45%	0.68	1	0.91
50%	0.74	1	0.88
55%	0.79	2	0.79
60%	0.83	2	0.83
65%	0.87	2	0.87
70%	0.89	2	0.89
75%	0.91	2	0.91
80%	0.92	2	0.92
85%	0.92	2	0.92
90%	0.91	2	0.91
95%	0.90	2	0.90
100%	0.88	2	0.88

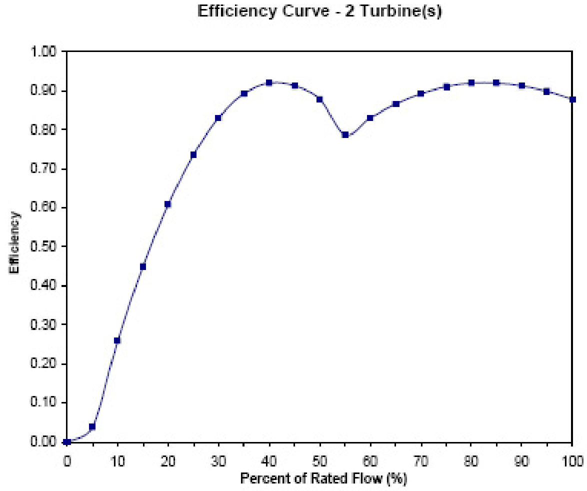

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Figure G.4. "Equipment Data" Worksheet of Porsuk Dam ($Q_d = Q_{30}$)

RETScreen® Cost Analysis - Small Hydro Project

Costing method: Formula | Currency: $ | Cost references: None

Formula Costing Method			Notes/Range
Input Parameters			
Project country		TURKEY	
Local vs. Canadian equipment costs ratio	-	1.00	
Local vs. Canadian fuel costs ratio	-	2.08	
Local vs. Canadian labour costs ratio	-	0.23	
Equipment manufacture cost coefficient	-	1.00	0.50 to 1.00
Exchange rate	$/CAD	0.88	
Cold climate?	yes/no	No	
Number of turbines	turbine	2	
Flow per turbine	m³/s	5.1	
Approx. turbine runner diameter (per unit)	m	1.0	
Project classification:			
Suggested classification	-	Mini	
Selected classification	-	Mini	
Existing dam?	yes/no	Yes	
Rock at dam site?	yes/no	Yes	
Maximum hydraulic losses	%	2%	
Intake and miscellaneous losses	%	1%	1% to 5%
Access road required?	yes/no	No	
Tunnel required?	yes/no	No	
Canal required?	yes/no	No	
Penstock required?	yes/no	Yes	
Length	m	230.0	
Number of identical penstocks	penstock	1	
Allowable penstock headloss factor	%	1.5%	1.0% to 4.0%
Pipe diameter	m	2.14	
Average pipe wall thickness	mm	8.7	
Distance to borrow pits	km	5.0	
Transmission line			
Length	km	15.0	
Difficulty of terrain	-	1.0	1.0 to 2.0
Voltage	kV	33.0	
Interest rate	%	9.5%	

Initial Costs (Formula Method)		Cost (local currency)	Adjustment Factor	Amount (local currency)	Relative Costs
Feasibility Study		$ 186,836	0.00	$ -	0.0%
Development		$ 193,886	0.00	$ -	0.0%
Land rights				$ -	0.0%
Development Sub-total:				$ -	0.0%
Engineering		$ 249,408	0.00	$ -	0.0%
Energy Equipment		$ 2,778,739	1.00	$ 2,778,739	55.7%
Balance of Plant					
Access road		$ -	1.00	$ -	0.0%
Transmission line		$ 290,829	1.00	$ 290,829	5.8%
Substation and transformer		$ 84,605	1.00	$ 84,605	1.7%
Penstock		$ 478,546	1.00	$ 478,546	9.6%
Canal		$ -	1.00	$ -	0.0%
Tunnel		$ -	1.00	$ -	0.0%
Civil works (other)		$ 956,211	1.00	$ 956,211	19.2%
Balance of Plant Sub-total:		$ 1,810,190		$ 1,810,190	36.3%
Miscellaneous		$ 800,220	0.50	$ 400,110	8.0%
GHG baseline study and MP	Cost	$ -		$ -	0.0%
GHG validation and registration	Cost	$ -		$ -	0.0%
Miscellaneous Sub-total:				$ 400,110	8.0%
Initial Costs - Total (Formula Method)		$ 6,019,279		$ 4,989,039	100.0%

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Land lease	project	1	$ -	$ -		-	-
Property taxes	%	0.0%	$ 4,989,039	$ -		-	-
Water rental	kW	3,352	$ -	$ -		-	-
Insurance premium	%	0.00%	$ 4,989,039	$ -		-	-
Transmission line maintenance	%	0.0%	$ 375,434	$ -		-	-
Spare parts	%	0.20%	$ 4,989,039	$ 9,978		-	-
O&M labour	p-yr	1.00	$ 30,000	$ 30,000		-	-
GHG monitoring and verification	project	0	$ -	$ -		-	-
Travel and accommodation	p-trip	0	$ 1,000	$ -		-	-
General and administrative	%	0%	$ 39,978	$ -		-	-
Other - O&M	Cost	0	$ -	$ -		-	-
Contingencies	%	0%	$ 39,978	$ -		-	-
Annual Costs - Total				$ 39,978	100.0%		

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
Turbine overhaul	Cost	35 yr	$ 1,389,369	$ 1,389,369	-	-
				$ -	-	-
				$ -	-	-
End of project life	Credit	-		$ -		

Go to GHG Analysis sheet

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Figure G.4. "Cost Analysis" Worksheet of Porsuk Dam ($Q_d = Q_{30}$)

RETScreen® Financial Summary - Small Hydro Project

Annual Energy Balance

Project name		Porsuk Dam
Project location		Eskisehir
Renewable energy delivered	MWh	16,220
Excess RE available	MWh	-
Firm RE capacity	kW	0
Grid type		Central-grid

Financial Parameters

Avoided cost of energy	$/kWh	0.0750	Debt ratio	%	0.0%
RE production credit	$/kWh	-			
			Income tax analysis?	yes/no	Yes
			Effective income tax rate	%	20.0%
			Loss carryforward?	-	Yes
			Depreciation method	-	Straight-line
Avoided cost of capacity	$/kW-yr	-	Depreciation tax basis	%	93.5%
Energy cost escalation rate	%	0.0%			
Inflation	%	5.0%	Depreciation period	yr	50
Discount rate	%	9.5%	Tax holiday available?	yes/no	No
Project life	yr	50			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	0.0%	$	-	O&M	$	39,978
Development	0.0%	$	-			
Engineering	0.0%	$	-			
Energy equipment	55.7%	$	2,778,739	**Annual Costs and Debt - Total**	**$**	**39,978**
Balance of plant	36.3%	$	1,810,190			
Miscellaneous	8.0%	$	400,110	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**$**	**4,989,039**	Energy savings/income	$	1,216,471
				Capacity savings/income	$	-
Incentives/Grants		$	-			
				Annual Savings - Total	**$**	**1,216,471**
Periodic Costs (Credits)						
Turbine overhaul		$	1,389,369	Schedule yr # 35		
		$	-			
		$	-			
End of project life - Credit		$	-			

Financial Feasibility

			Calculate energy production cost?	yes/no	No
Pre-tax IRR and ROI	%	23.3%			
After-tax IRR and ROI	%	19.1%			
Simple Payback	yr	4.2			
Year-to-positive cash flow	yr	5.2	Project equity	$	4,989,039
Net Present Value - NPV	$	4,470,492			
Annual Life Cycle Savings	$	429,289			
Benefit-Cost (B-C) ratio	-	1.90			

Figure G.5. Data Sheet of "Financial Summary" Porsuk Dam ($Q_d = Q_{30}$)

Yearly Cash Flows

Year #	Pre-tax $	After-tax $	Cumulative $
0	(4,989,039)	(4,989,039)	(4,989,039)
1	1,174,494	1,023,112	(3,965,927)
2	1,172,395	956,575	(3,009,352)
3	1,170,192	954,812	(2,054,540)
4	1,167,878	952,961	(1,101,579)
5	1,165,448	951,017	(150,561)
6	1,162,897	948,976	798,415
7	1,160,218	946,833	1,745,248
8	1,157,405	944,583	2,689,832
9	1,154,452	942,221	3,632,052
10	1,151,351	939,740	4,571,792
11	1,148,095	937,135	5,508,927
12	1,144,676	934,400	6,443,327
13	1,141,087	931,528	7,374,856
14	1,137,317	928,513	8,303,369
15	1,133,360	925,347	9,228,715
16	1,129,204	922,022	10,150,738
17	1,124,841	918,532	11,069,269
18	1,120,259	914,866	11,984,135
19	1,115,449	911,018	12,895,153
20	1,110,397	906,977	13,802,130
21	1,105,094	902,734	14,704,864
22	1,099,525	898,279	15,603,143
23	1,093,678	893,601	16,496,744
24	1,087,538	888,689	17,385,434
25	1,081,091	883,532	18,268,966
26	1,074,322	878,117	19,147,082
27	1,067,215	872,431	20,019,513
28	1,059,752	866,461	20,885,974
29	1,051,916	860,192	21,746,166
30	1,043,688	853,610	22,599,775
31	1,035,049	846,698	23,446,474
32	1,025,978	839,441	24,285,915
33	1,016,453	831,822	25,117,737
34	1,006,452	823,821	25,941,558
35	(6,667,832)	(6,667,832)	19,273,726
36	984,926	984,926	20,258,651
37	973,348	973,348	21,232,000
38	961,192	961,192	22,193,192
39	948,428	948,428	23,141,620
40	935,026	935,026	24,076,646
41	920,954	920,954	24,997,599
42	906,178	906,178	25,903,777
43	890,663	888,018	26,791,795
44	874,373	718,157	27,509,952
45	857,268	704,473	28,214,425
46	839,308	690,105	28,904,531
47	820,450	675,019	29,579,549
48	800,648	659,178	30,238,727
49	779,857	642,545	30,881,272
50	758,027	625,080	31,506,352

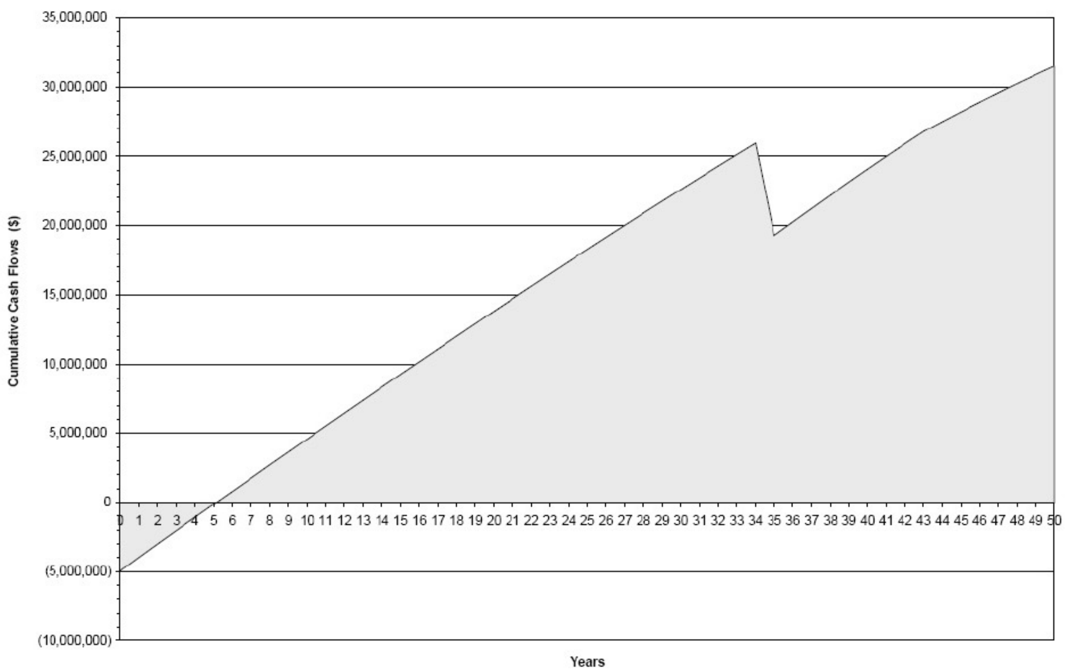
RETScreen® Financial Summary - Small Hydro Project

Cumulative Cash Flows Graph

Small Hydro Project Cumulative Cash Flows
Porsuk Dam, Eskisehir

Renewable energy delivered (MWh/yr): 16,220

Total Initial Costs: $ 4,989,039



IRR and ROI: 19.1%

Year-to-positive cash flow: 5.2 yr

Net Present Value: $ 4,470,492

Version 3.2

NRCan/CETC - Varennes

Figure G.6. Cash Flow of Porsuk Dam ($Q_d = Q_{30}$)