A CASE STUDY ON FEASIBILITY ASSESSMENT OF SMALL HYDROPOWER SCHEME

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ABSTRACT

A CASE STUDY ON FEASIBITY ASSESSMENT
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Feasibility studies concerning decision-making for various types of items to be used in a small hydropower scheme is important for estimating the energy generation, the approximate cost of the project, and the required budget allocation. A computer program named RETScreen, which is commonly used in the North Americas, is capable of evaluating the energy generation, investment and maintenance costs for small hydro-projects. This thesis is based on application of this program to the Turkish practice. To this end, energy and cost equations dealing with energy generation and cost estimation of various items, such as costs of turbines, generators, installation of energy equipment, transmission line, etc., will be applied according to the common practice currently used in Turkey. A case study is performed to illustrate the use of this program. With the use of this program, it may be possible to perform quick successive runs to assess economic feasibility of several alternatives.

Keywords: Small Hydro, Economic Feasibility, RETScreen

ÖZ

KÜÇÜK HİDROELEKTRİK ENERJİ KONUSUNDA
BİR
VAKA ANALİZİ

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Küçük hidroelektrik enerji üretimi, ortalama maliyetin hesaplanması ve gerekli bütçenin oluşturulması için çeşitli bilinmeyenler hakkında doğru karar alınabilmesini sağlayan fizibilite çalışmaları önem arz etmektedir. Yaygın olarak Kuzey Amerika'da kullanılmakta olan RETScreen isimli bir bilgisayar programı, küçük hidroelektrik enerji fizibiltesini enerji üretimini ve yatırım ve işletme giderlerini hesaplamaktadır. Bu çalışma RETScreen isimli programın Türkiye koşullarında uygulanmasına dayanmaktadır. Buna göre, programın hesaplarında kullandığı enerji ve maliyet denklemlerinin Türkiye koşullarına uygunluğu sorgulanacaktır. Programın çalışma şeklini göstermek için bir durum çalışması yapılmıştır. Bu program sayesinde küçük hidroelektrik enerji projelerinin hızlı bir ön fizibilite çalışması yapılabilecektir.

Keywords: Küçük Hidroelektrik Enerji, Ekonomik Fizibilite, RETScreen

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The author is indebted to Prof Dr. Melih YANMAZ and Assist Prof. Dr. Şahnaz TİĞREK for their helpful guidance and precious suggestions throughout this study.

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Special thanks also go to my family and my colleagues for their support and encouraging me with endless patience and sincerity throughout this period.

Finally, the author wishes to express his special gratitude to RETScreen for developing and sharing the Small Hydro Project Software.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

$^\wedge e_d$	runner size adjustment to peak efficiency
$^\wedge e_{nq}$	specific speed adjustment to peak efficiency
$^\wedge e_p$	drop in efficiency at full load
A	access road difficulty factor
B	foreign costs civil works factor
C	civil cost factor
C_g	lower cost generation factor
C_v	concrete lining in tunnel (m^3)
d	runner diameter (m)
D	transmission line difficulty factor
d_p	diameter of penstock
e	overall efficiency (%)
E	engineering cost factor
E_{avail}	annual available energy (in kWh/yr)
E_c	equipment costs ratio
E_{dlvd}	renewable energy delivered
e_g	generator efficiency
e_p	turbine peak efficiency
e_q	efficiencies at flows below peak efficiency flow
e_r	drop in efficiency at full load
e_t	turbine efficiency
$e_{t,des}$	turbine efficiency at design flow
f	frost days at site
F	frost days factor
F_c	fuel costs ratio
g	acceleration due to gravity
G	grid connected factor
H_g	gross head (m)
h_{hydr}	hydraulic losses
H_n	net head

h_{tail}	tailrace effect
$h_{tail,max}$	maximum tailwater effect
i	interest rate (%)
J_t	vertical axis turbine factor
k	tunnel headloss (ratio to H_g)
k_1	runner diameter factor
k_2	tunnel speed factor
K	equipment manufacture cost ratio
K_t	small horizontal axis turbine factor
l_a	access road length (km)
l_b	distance to borrow pits (km)
L_c	labour costs ratio
$L_{C,2006}$	average labour cost in Canada for construction sector in 2006
l_{cr}	canal length in rock (m)
l_{cs}	canal length in impervious soil (m)
l_d	dam crest length (m)
l_{dt}	annual downtime losses
$l_{hydr,max}$	maximum hydraulic losses
l_p	penstock length (m)
l_{para}	parasitic electricity losses
l_t	tunnel length (m)
l_T	tranmission line length (km)
$L_{T,2001}$	average labour cost in Turkey for construction sector in 2001
$L_{T,2006}$	estimated labour cost in Turkey for construction sector in 2006
l_{trans}	transformer losses
MW	total capacity (MW)
MW_u	capacity per unit (MV)
n	number of turbines
n_p	number of penstocks
n_q	specific speed based on flow
P	transmission line wood or steel factor
Q	flow under consideration (m^3/s)

Q_d	design flow (m^3/s)
Q_{max}	maximum river flow
$Q_{n,used}$	maximum flow that can be used by the turbine
Q_p	peak efficiency flow
Q_r	residual flow
Q_u	flow per unit (m^3/s)
P	power (Watts)
P_{des}	plant capacity
R	rock factor
r_{2006}	Turkey versus. Canada labour costs ratio in 2006
R_m	turbine manufacture/design coefficient
$r_{T,2006-2001}$	rate of increase of the labour unit costs in turkey between 2006-2001
R_v	tunnel volume of rock excavation (m^3)
S_r	side slope of rock where canal is built (^{o})
S_s	side slope of soil where canal is built (^{o})
T	tote road factor
t_{ave}	average penstock thickness (mm)
t_b	penstock thickness at turbine (mm)
T_c	tunnel lining length ratio
t_t	penstock thickness at intake (mm)
V	transmission line voltage (kV)
W	penstock weight (steel) (kg)
ρ	density of water
φ	dimensionless parameter

ABBREVIATIONS

CAD	Canada Dollar.
DSİ	General Directorate of State Hydraulic Works
ESHA	European Small Hydro Association.
HEPP	Hydroelectric Power Plant.
ILO	International Labour Organization
Mteo	Million ton of equivalent oil.
SHP	Small Hydropower
RET	Renewable Energy Technology
TEDAŞ	Turkish Electricity Distribution Company
TEİAŞ	Turkish Electricity Transmission Company
TWh	Terawatt hour

CHAPTER 1

INTRODUCTION

1.1. Introductory Remarks and Literature Survey

The socio-economic development and increased living standards with the fast growing industry has led to a major increase in electricity demand and generation. Being the basic input of all kinds of economic activity, electrical energy has become an indispensable component of social life.

As a result of rapid increase in energy consumption and global warming threatening the environment together with the unbalanced and unpredictable increases of the fossil fuel prices has increased the importance of renewable energy sources.

In this respect, small hydropower (SHP) has emerged as an energy source which is accepted as renewable, easily developed, inexpensive and harmless to the environment. These features have increased small hydropower development in value giving rise to a new trend in renewable energy generation. (Adıgüzel et al., 2002)

Moreover, because of the considerable amount of financial requirements and insufficient financial sources of the national budget, together with the strong opposition of environmentalist civil organizations, large scale hydropower projects cannot be completed in the planned construction period generally, which lead to widely use of SHP in developing countries with its low investment cost, short construction period, and environment friendly nature.

Comprising these features, small hydropower has been getting the attention in both developed and developing countries. Europe and North America has already exploited most of their hydropower potential. On the other hand, Africa, Asia and South America have still substantial unused potential of hydropower (Altınbilek, 2005). Small hydro can be the remedy of the insufficient energy in developing countries, as China did with 43,000 small schemes and 265 GW of total installed capacity. (IHA, 2003).

Therefore, in order to increase renewable energy production, it is important to put enormous effort into developing efficient small hydro plants. European Small Hydro Association has developed a guideline for designing small hydro plants (ESHA, 2004).

In order to increase renewable energy production, enormous effort is needed for developing efficient small hydropower plants. European Small Hydro Association has developed a guideline for designing small hydro plants (ESHA, 2004). However, feasibility studies are very important for the correct evaluation and assessment of small hydro projects.

A Canadian organization, RETScreen has developed a software performing a pre-feasibility study of a SHP Project recently which can be used internationally. This user friendly software gives a general idea about the feasibility of a SHP project. It can also be used for performing sensitivity analysis or for monitoring the feasibility studies which have already been completed. Furthermore, the software can also be used to investigate the viability of energy production from existing dams which had not been planned as hydropower plants.

1.2. The Scope of the Study

Although there are several hydro scheme of every scale in Turkey, it is far behind of developing the full hydropower potential. In recent years, especially after the privatization in energy market, several private companies have engaged in the energy business. However, due to legislative limitations, these companies had to major on developing small hydropower which shows the importance of it. Recently, a few studies which pay attention to the importance of small hydropower, have been carried out. (Derinöz et al., 2005; Yüksel et al., 2005; Bakış and Bilgin, 2005).

In this study it is aimed to give a general idea about the feasibility assessment of small hydropower projects in Turkey. RETScreen-Small Hydro Software is selected to manage this since it is capable of performing desired computations and developed by highly experienced group of planners and engineers.

In this report two different case studies will be performed by using RETScreen-Small Hydro Software. These studies are the evaluation of two different alternatives in which the location of the water intake structure and, therefore, the other components differ. After these alternatives are performed in a case study, important parameters of the software will be specified and three different alternatives will be compared in order to carry out a sensitivity analysis.

In Chapter 1, brief description of the importance of the problem and literature review are explained. In Chapters 2 and 3, general knowledge about hydropower and small hydropower are discussed respectively. Chapter 4 is reserved for the introduction of RETScreen-Small Hydro Project Software. Chapters 5 and 6 explain the case studies and the conclusion of the study, respectively.

CHAPTER 2

HYDROPOWER

2.1. History of Hydropower

People have been benefiting from the power of water for more than two thousand years starting with the wooden waterwheel. Water wheels were used to grind wheat into flour as early as 100 B.C in many parts of Asia mostly for milling grain (Canadian Hydropower Association, 2007). Improved engineering skills during the 19th century, combined with the need to generate electricity, modern-day turbines gradually replaced the water wheel and soil and rock dams were built to control the flow of water and produce electricity. The golden age of hydropower started at the beginning of the 20th century before oil took the lead in energy generation. Europe and North America built large hydropower plants, equipment suppliers spread to supply this thriving business.

2.2. Hydroelectric Energy Potential

The concepts of gross potential, technical potential and economical potential become important in defining hydropower potential.

- Gross hydropower potential shows theoretical upper limit of hydroelectricity production of a river basin which represents the potential that existing fall and average flow constitute.

- Hydropower potential which can be technically evaluated shows the technological upper limit of hydroelectricity production of a river basin. Inevitable losses that can be formed depending on applied technology are excluded.

- Economic hydropower potential can be defined as total production of all hydropower projects which shows economic optimization of hydroelectricity production of a river basin, which can be technically developed and economically consistent. In other words, economic hydropower potential means, income of the project should be higher than its outcome.

2.3. Hydropower in the World

Hydropower is the most important source of renewable energy in the world for electrical power production. The world's technically feasible hydro potential is estimated as 14,370 TWh/year, which is equal to today's global electricity demand. The economically feasible proportion of this is 8,080 TWh/year. The exploited hydropower potential in the world in 1999 was 2,650 TWh which is about 19% of the world's electricity (Paish, 2002).

In 2001, Canada is the world's biggest producer of hydropower generating 350 TWh/year which is 13% of the global output. United States, Brazil, China and Russia are behind Canada in hydropower production. Hydropower production and economic potential of some countries including Turkey is shown in Figure 2.1 (ERE, 2005).

2.4. Hydropower in Turkey

Hydropower is one of the most important energy sources in Turkey. Energy production and consumption in Turkey for the year 2005 is shown in Table 2.1. Imported energy was about four times of the produced energy in 2005.

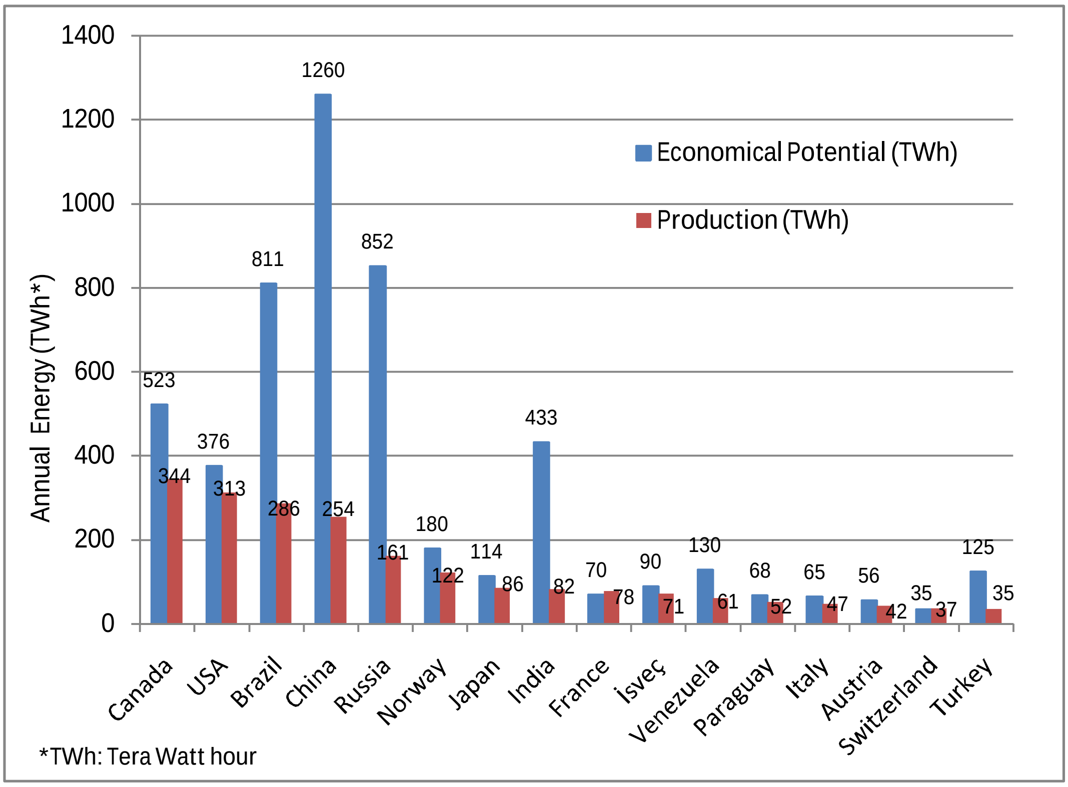


Figure 2.1. Hydropower Production and Economic Potential of Some Countries (ERE, 2005)

Table 2.1. Primary Energy Production and Consumption in Turkey in 2005 (Koyun et al, 2007)

Source	Production (Mteo*)		Consumption (Mteo*)	
Coal and Lignite	20.69	62.8%	35.46	27.4%
Oil	1.66	5.0%	40.01	30.9%
Natural Gas	0.16	0.5%	42.21	32.7%
Hydropower	4.16	12.6%	4.16	3.2%
Geothermal	0.70	2.1%	1.89	1.5%
Solar / Wind / Other	0.22	0.7%	0.22	0.2%
Biomass /Biogas / Wastes	5.33	16.2%	5.33	4.1%
TOTAL	32.92	100%	129.28	100%

* Mteo: Million ton of equivalent oil

The share of energy sources in electricity generation for the years 1996 and 2006 is shown in Table 2.2. In 1996, the percent of natural gas usage in electricity production was about 18%, while in 2006, it was increased to 44%. During the same period the percentage of hydropower in electricity generation is decreased from 43% to 25%. As the production of electricity from expensive natural gas is increased, Turkish goods, which are produced with this expensive energy, have small power to compete with their foreigner rivals. Besides, since gas is an export energy, Turkey's dependence on foreign sources gets higher. (USIAD 2004)

Table 2.2. Share of Energy Sources in Turkish Electricity Generation in 1996 and 2006 (Sources: DPT, 2001 and DPT, 2007)

Source	1996		2006	
	Energy (GWh)	Percentage	Energy (GWh)	Percentage
Hydropower	40,475	42.67%	44,146	25.13%
Lignite	27,840	29.35%	32,341	18.41%
Natural Gas	16,823	17.73%	77,428	44.08%
Oil	6,526	6.88%	5,368	3.06%
Hard Coal	2,574	2.71%	13,693	7.79%
Other	624	0.66%	2,691	1.53%
TOTAL	94,862	100.00%	175,666	100.00%

Gross hydropower potential, which is a function of topography and hydrology, has a degree of around 433 TWh/year in Turkey. Hydropower production in Turkey, which can be technically evaluated, is around 216 TWh/year and economic hydropower potential of Turkey is around 126 TWh/year (DSİ, 2007).

Present status of hydropower plants in Turkey is shown in Figure 2.2. In 1993, total installed capacity of hydropower projects were 9,683 MW (ERE, 2005); in 2006 total installed capacity of hydropower projects were 12,788 MW generating 45,930 GWh of annual electricity (Gürbüz, 2007).

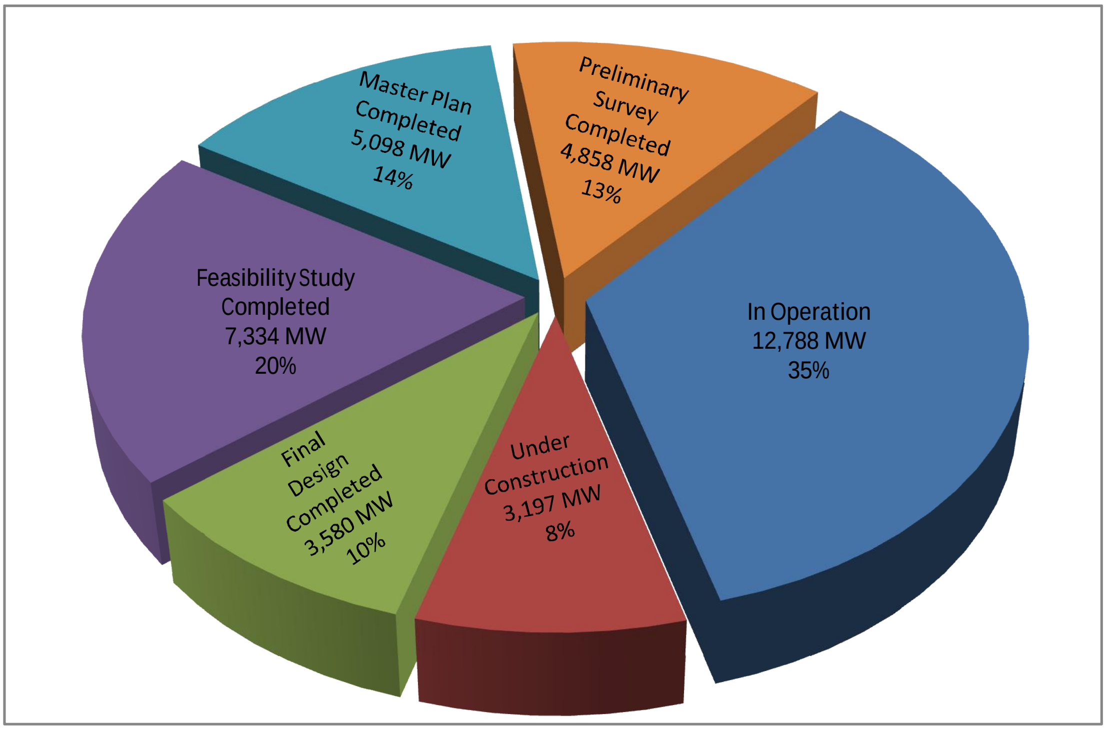


Figure 2.2. Present Status of Hydropower Plants in Turkey excluding the projects developed by private sector (Gürbüz, 2007)

2.5. Debates on Hydropower

The advantages of hydropower are listed below;

- Hydropower is accepted as a renewable source of energy because it uses the power of flowing water, without wasting or depleting.

- Hydropower facilities with reservoirs provide operational flexibility that allows them to respond to fluctuating demands of electricity.

- Hydropower reservoirs can be used for fresh water for drinking supply or irrigation. This fresh water storage protects aquifers from depletion, and reduces the possibility of floods or droughts.

- Hydropower is a clean source of electricity because it does not generate any toxic waste products, reduces air pollution and contributes to slow down global warming.

- Hydropower facilities bring electricity, roads, industry, commerce and employment to rural areas, developing the regional economy, and increasing the quality of life.

- Hydropower projects that are developed and operated in an economically viable, environmentally positive and socially responsible manner represent sustainable development (Kesharwani, 2006).

- Hydropower, being the most efficient energy, is currently capable of converting 90% of available energy into electricity, a level of efficiency higher than any other form of generation (Kesharwani, 2006).

- Hydropower provides national energy security which is a key issue for developing countries. Water used from rivers is a domestic resource that is not subject to fluctuations in fuel prices.

- Hydropower is an affordable power for today and tomorrow having an average life span of more than 50 years with very low operation and maintenance costs.

On the other hand, there are several disadvantages of hydropower projects, which are listed below;

- The construction of a dam may have a serious impact on the surrounding areas by changing the downstream environment, affecting plant life both aquatic and land-based, being disruptive to fish and birds and creating environmental problems such as relocation of people or historical artifact.

- Dams containing huge amounts of water have the risk of failure which may cause catastrophic results such as flooding.

- The initial cost of hydropower projects is high since construction of a dam and appurtenant facilities are required.

- Hydropower can only be used in areas where there is a sufficient supply of water.

2.6. Working Principle of Hydropower Plants

The basic principle of hydropower plants is that they convert water pressure into mechanical shaft power by turbines which can be used to generate electricity by generators. A typical hydropower scheme is illustrated in Figure 2.3.

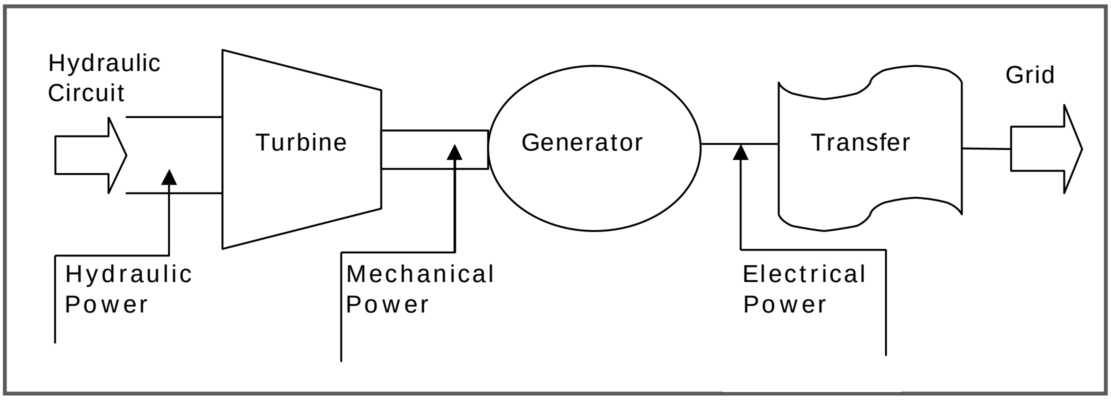


Figure 2.3. Electrical Power Conversion Scheme

Hydroelectric power capacity of a plant is proportional to the product of gross head and discharge which can be determined from:

$$P = e\rho g Q H_g \qquad (2.1)$$

where P is power (Watts), e is the overall efficiency (%), ρ is the density of water (1,000 kg/m^3), g is the acceleration due to gravity (9.81 m/s^2), Q is the water discharge passing through the turbine (m^3/s), and H_g is the gross head (m).

Electricity generation process of a hydropower plant is explained below and the components of a hydropower project are shown in Figures 2.4 and 2.5.

i. Water from a river or reservoir flows through water passages and then a penstock.

ii. Turbine blades are pushed by flowing water from the penstock, causing them to rotate.

iii. The shape and angle of the turbine blades transfers the energy of falling water to rotate the shaft.

iv. The shaft turns at the same speed as the turbine. The shaft connects the turbine to the generator.

v. The spinning shaft turns magnets inside a stationary ring of copper, moving electrons to produce electricity.

vi. Step-up transformers increase the voltage of electricity produced by the generator.

vii. Transmission lines carry electricity to substations in communities. The voltage is decreased and the power is distributed.

viii. The same amount of water that entered through the penstock flows back to the river through the draft tube.

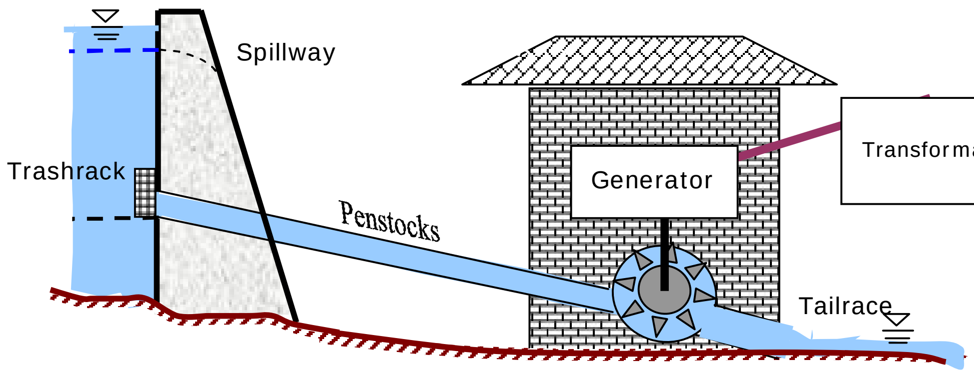


Figure 2.4. Components of a Hydropower Project - Section

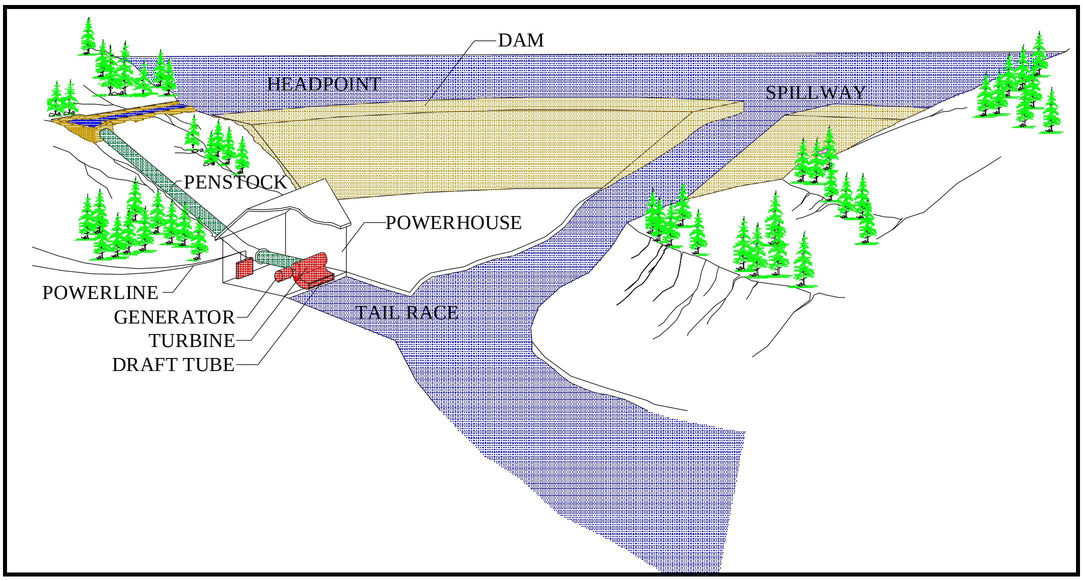


Figure 2.5. Components of a Hydropower Project (Overview)

CHAPTER 3

SMALL SCALE HYDROPOWER

3.1. Definition of Small Hydropower

There is no international consensus on the definition of the term “small hydro” which, depending on local definitions can range in size from a few kilowatts to 50 megawatts or more of rated power output. Internationally, “small” hydro power plant capacities typically range in size from 5 MW to 50 MW. Projects in the 100 kW to 5 MW range are sometimes referred to as “mini” hydro and projects less than 100 kW are referred to as “micro” hydro. However, installed capacity is not enough to define the size of the project (RETScreen, 2004-a).

3.2. Historical Background of Small Hydropower

After developed countries exploited their technically available hydropower potential, the large hydro manufacturers managed to maintain their business in export markets especially in developed countries. After 1970’s, crude oil prices increased because of the oil crisis and the people’s growing ecological sensitivity as well as the corresponding authority’s incentives caused small hydropower emerge as an important source of renewable energy. Attractive policies of few countries (notably Germany) have boosted the small hydro sector in recent years.

3.3. Small Hydropower in the World

Access to electricity is one of the keys to development because it provides light, heat and power used in production and communication.

According to the World Bank, the world's poor people spend more than 12% of their total income on energy and around 1.7 billion people do not have access to electricity (Laguna et al., 2006). Accepting this fact, small hydropower as a renewable energy source is suitable for rural electrification in developing countries. However, in 2004, the contribution of small hydropower, defined as hydropower projects having a capacity below 10 MW, to the worldwide electrical capacity was about 2% of the total capacity amounting to 48 GW as shown in Table 3.1.

Table 3.1. Installed SHP Capacity (<10 MW) by World Region in 2004 (Laguna et al., 2006)

Region	Capacity (MW)	Percentage
Asia	32,641	68.0%
Europe	10,723	22.3%
North America	2,929	6.1%
South America	1,280	2.7%
Africa	228	0.5%
Australasia	198	0.4%
TOTAL	47,997	100%

In the global small hydropower sector, China is the leader representing more than half of the world's small hydro capacity with 31,200 MW of installed capacity in 2005 (Laguna et al., 2006).

3.4. Small Hydropower Development in Turkey

In Turkey, the classification of hydropower project is named "Small" if the installed capacity of the plant is generally less than 10 MW. According to ESHA, the gross theoretical small hydropower potential of Turkey is around 50 TWh/year. The technically and economically feasible potential is 30 and 20 TWh/year, respectively, of which only 3.3% is developed so far (ESHA, 2004). Turkey's small hydropower potential is shown in Table 3.2.

Table 3.2. Turkey's Small Hydropower Potential in 2002 (ESHA, 2004)

Potential	Generation		Capacity (MW)
	GWh/year	Percentage	
Gross theoretical	50,000	100%	16,500
Technically feasible	30,000	60%	10,000
Economically feasible	20,000	40%	6,500
Economically feasible that has been developed	673	3.37%	177

As of 2001, 203 SHP projects have been developed in Turkey at various stages. 70 SHP projects have been put into operation with 175.5 MW installed capacity, 6 SHP projects are under construction and 126 SHP projects are considered at various project stages (Balat, 2006). In consideration with topographical and hydrological conditions of our country, many small hydropower plants can be installed along the streams and tributaries in the near future.

3.4.1. Renewable Energy Policy in Turkey

Small Hydropower is supported by the government with legislative incentives under the term of renewable energy in Turkey.

Renewable Energy is not a brand-new topic in Turkey, as it was introduced by the "Electricity Market Law" (Law No: 4628) in March, 2001 and the "Electricity Market Licensing Regulation" in August, 2002 as a legislative framework. According to the "Electricity Market Law" the

Energy Market Regulatory Authority is authorized to take the necessary measures to promote the utilization of renewable energy sources. The timeline of legislative framework of renewable energy in Turkey is shown in Figure 3.1. (Bakır, 2006)

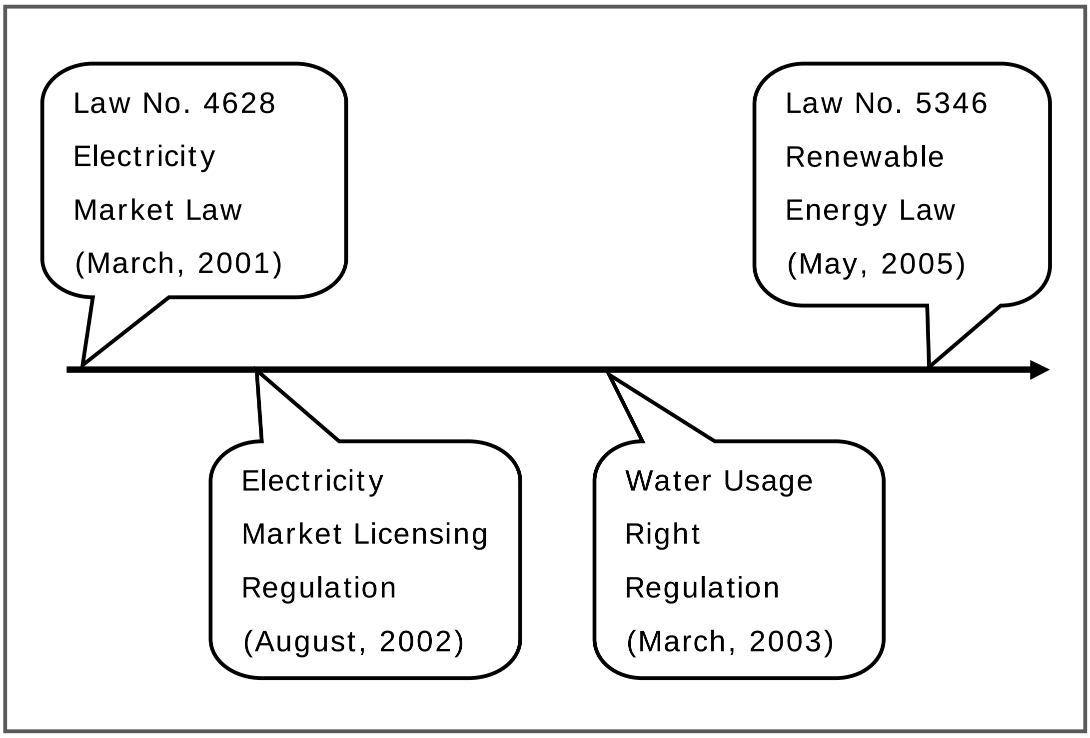


Figure 3.1. Timeline of Legislative Framework of Renewables in Turkey

One of the goals of the Turkish energy policy is promoting the use of renewable energy sources in order to maintain continuous, high-quality, cost effective and reliable energy supplies and to strengthen the geopolitical position of Turkey by using domestic resources (Balat, 2007). To achieve this goal, "Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy" (Law No. 5346) has been put into force in May 2005.

According to this law, renewable energy sources are defined as the electricity generation resources suitable for wind, solar, geothermal, biomass, biogas, wave, current and tidal energy resources together with hydraulic generation plants either canal or run of river type or with a reservoir area of less than 15 square kilometers (Official Newspaper, 2005).

The support mechanisms in the Law No. 5346 in place to promote renewable electricity are the following:

- Legal entities holding retail sale licenses shall purchase electricity from renewable energy source certificate holder generation facilities that are not older than 10 years. This purchase obligation is the proportion of the previous year's electrical energy sales of an entity to the total amount of electrical energy that the entity sold in the country (Secreteriat General for EU Affairs, 2006).

- The annual sale price of electricity generated from renewable energy sources is the national average wholesale price of the previous calendar year determined by the Energy Market Regulatory Authority. However, the applicable price cannot be less than the New Turkish Lira equivalent of 5 eurocents per kWh or more than the equivalent of 5.5 eurocents per kWh until the end of the year 2010. This annual price can be increased up to 20% by the authority at the beginning of each year. If renewable energy source certificate holder companies has been offered a price more than 5.5 eurocents per kWh in the free market, they may benefit from this offer. (Boden et al., 2007)

- Usage of state properties for electricity generation from renewable sources is allowed by the Government in the forms of permits, leases or right of usage. For facilities that start operation before the end of 2011, a discount of 85% shall be implemented for rent, right of access and usage permission for the first 10 years of their investment periods. (Boden et al., 2007)

In addition to the support mechanisms in the Law No. 5346, there are certain other support mechanisms in the Law No.4628 which are given below:

- The legal entities applying for licenses for construction of facilities based on domestic renewable energy sources shall only pay 1% of the total licensing fee. Moreover, these entities shall not pay annual license fees for the first eight years following the facility completion date inserted in their respective licenses. (Gaupp, 2007)

- The legal entities generating electricity from renewable energy sources may purchase electricity from private sector wholesale companies on the condition not to exceed the annual average generation amounts indicated in their licenses in a calendar year. (Boden et al., 2007)

- The retail licensees are obliged to purchase electricity generated from renewables for the purposes of re-sale to the non-eligible consumers, provided that the price of this electricity is equal to or lower than the sales price of TEDAŞ and there is no cheaper alternative. (Boden et al., 2007)

- TEIAŞ or other distribution licensees shall assign priority for system connection of generation facilities based on domestic renewable resources. (Boden et al., 2007)

3.4.1.1. Authorization procedures

A license is required for building and operating plants producing electricity from renewables in the electricity market. All legal entities shall obtain separate licenses for each activity they are engaged in, and for each facility where the same activity is conducted.

Electricity Market Licensing Regulation affirms the principles and procedures regarding the licenses to be granted to the legal entities in Turkish electricity market.

The licensing procedure for hydropower projects according to the Water Usage Right Regulation is given as follows (Secreteriat General for EU Affairs, 2006);

- Private companies apply to any of the projects listed in General Directorate of State Hydraulic Works website where the name of the companies is published for a month.

- After that, the project will not be applied by any other company.

- The applicant companies receive an official letter in order for them to prepare the feasibility reports of the project.

- Feasibility reports, prepared by the companies, shall be submitted to General Directorate of State Hydraulic Works in 6 months.

- After the evaluation of the feasibility reports, the eligible project is sent to Energy Market Regulatory Authority.

- Finally, General Directorate of State Hydraulic Works signs “Water Usage Right Agreement” with the designer of the eligible project and Energy Market Regulatory Authority grants license to the private company.

3.4.1.2. Analysis of the legislation

Renewable Energy Law lacks tax advantages that could be given to entities generating electricity from renewables in order to make renewable energy sources to be more competitive with other energy sources. (EkoEnerji, 2007)

Moreover, the legislation does not set a target for the amount of electricity generated from renewable energy sources by a certain year. (Gaupp, 2007)

Finally, although the base price of the electricity generated from renewables is set as 5 eurocents per kWh, fixing the ceiling price as 5.5 eurocents per kWh decreases the profitability of renewable energy projects including small hydropower.

3.5. Advantages of Small Hydropower

Small hydropower plants combine the advantages of hydropower without the disadvantages of large scale projects, further with the advantages listed below (Lins et al., 2004);

- Small hydropower mobilizes financial resources and contributes to the economic development of isolated populations with shorter construction period and lower initial cost compared to large scale hydropower.

- Small hydropower reduces the risk of flooding in rivers and in some cases it can increase biological diversity

- For isolated grid applications, transmission losses can be reduced.

- Small hydropower plants help an electricity system be more diversified.
- Small hydropower projects create an area of employment locally.

3.6. Components of Small Hydropower Plants

A small hydropower plant can be described under two main headings: civil works, and electromechanical equipment.

3.6.1. Civil Works

The main civil works of a small hydro project are the diversion dam or the weir, the water conduits, the powerhouse and electrical transmission works. Small hydro projects built at an isolated area are generally run-of-river developments where water is not stored in a reservoir and is used when it is available. The cost of large water storage dams cannot be justified for small hydro projects meaning that a low dam or diversion weir of the simplest construction is more feasible. Lowering the cost of intake structures for small hydro projects is very important as the cost of these structures may cause a project not financially feasible.

An intake structure should assure the required water supply in terms of amount and quality; minimize sediment, trash and debris entry; prevents ice along with being structurally safe, stable and practical in operation.

The water conduits of a small hydro project, which serve to convey water with optimum hydraulic losses to create head, include the following:

- An entrance to a canal, penstock or directly to the turbine depending on the type of development.

- A canal, tunnel and/or penstock, which carries the water to the powerhouse in developments where the powerhouse is located at a distance downstream from the intake. Canals are generally excavated and follow the contours of the existing terrain. Tunnels are underground and excavated by drilling and blasting or by using a tunnel-boring machine. Penstocks, which convey water under pressure, are generally made of steel. But in some cases, especially for micro projects, concrete or wood can be used.

- The entrance and exit of the turbine, which include the valves and gates necessary to shut off flow to the turbine for shutdown and maintenance. These components are generally made of steel or iron. Gates downstream of the turbine can be made of wood due to low applied force.

- A tailrace, which carries the water from the turbine exit back to the river. The tailrace, like the canal, is excavated.

The powerhouse contains the turbine(s) and most of the electromechanical equipment. Small hydro powerhouses are generally kept to the minimum size possible with adequate foundation strength and access for maintenance. Construction is of concrete or steel or other local building materials. A sketch of a powerhouse is shown in Figure 3.2.

The cost of transmission lines is proportional to the length, the difficulty of terrain through which the transmission line will be built and the voltage (kV) of the transmission line that is required to connect the site with the nearest existing transmission line of suitable voltage and capacity rating.

Easily constructed, simply designed civil structures are very important for a small hydro project in order to keep costs at minimum.

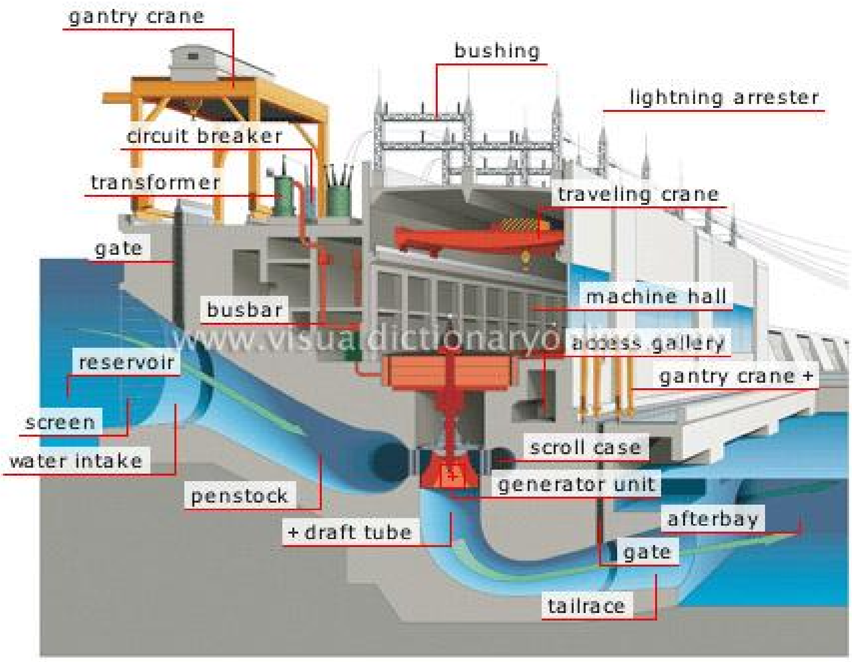


Figure 3.2. Sketch of a Powerhouse (Merriam-Webster Visual Dictionary, 2007)

3.6.2. Electrical and Mechanical Equipment

The primary electrical and mechanical components of a small hydro plant are the turbine(s), their governor(s) and generator(s).

3.6.2.1. Turbines

The turbine is the heart of a small hydropower plant because it determines the overall layout of the project (Canren, 2007). A number of different types of turbines have been designed to cover the broad range of hydropower site conditions found around the world. Turbines used for small hydro applications are scaled-down versions of turbines used in large hydro developments.

There are two types of hydro turbines, reaction turbines and impulse turbines. Turbines used for low to medium head applications are usually of the reaction type and a pressurized flow medium exists in a closed chamber in this case. Reaction types include Francis turbines where flow is radially inward or mixed, and Kaplan or Propeller turbines where flow is axial with fixed or adjustable blades respectively (Yanmaz, 2006). Turbines used for high-head applications are generally referred to as impulse turbines. Impulse types include the Pelton, Turgo and Crossflow turbines. The runner of an impulse turbine spins in the air and is driven by a high-speed jet of water which remains at atmospheric pressures.

The main reason of using different types of turbines at different heads is that electricity generation requires a shaft speed as close as possible to 1500 rpm to minimize the speed change between the turbine and the generator (Paish, 2002). The rotational speed of any given turbine, n, is determined from

$$n = \varphi\sqrt{2gH_n} \quad (3.1)$$

where φ is a dimensionless parameter and H_n is the net head (Yanmaz, 2006). Since turbine speed decreases in the proportion to the square root of the head, low head sites need turbines that are faster under a given operating condition.

Small hydro turbines can attain efficiencies of about 90%. Care must be given to selecting the preferred turbine design for each application as some turbines only operate efficiently over a limited flow range. For most run-of-river small hydro sites where flows vary considerably, turbines that operate efficiently over a wide flow range are usually preferred (e.g. Kaplan, Pelton, Turgo and crossflow designs). European Small Hydropower Association suggests the graph shown in Figure 3.3 to be used in selection of the suitable turbine type.

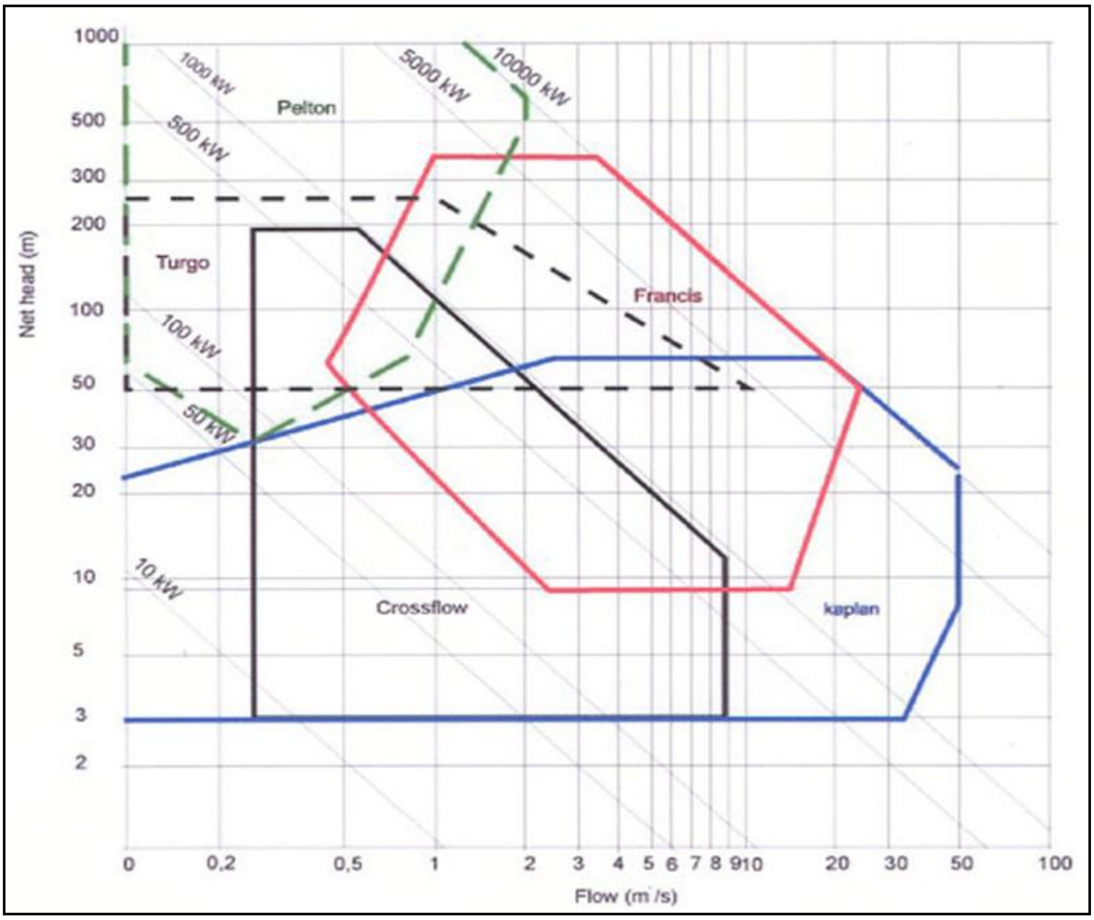


Figure 3.3. Turbine Selection Graph (Canren, 2007)

In this graph, the horizontal axis represents the turbine design flow limited to 50 m^3/s and the vertical axis represents the net head limited to 1000 m.

3.6.2.2. Governors

The rotational speed of turbines must be controlled within narrow limits to maintain the correct frequency. This speed control is provided by a governor that adjusts the water flow by sensing changes in speed. The correct frequency is between 50 to 60 MHz (Paish, 2002).

3.6.2.3. Generators

There are two basic types of generators used in small hydro plants, synchronous or induction (asynchronous). A synchronous generator can be operated in isolation while an induction generator must normally be operated in conjunction with other generators. Synchronous generators are used as the primary source of power produced by utilities and for isolated diesel-grid and stand-alone small hydro applications. Induction generators with capacities less than about 500 kW are generally best suited for small hydro plants providing energy to a large existing electricity grid (RETScreen, 2004-a).

3.6.2.4. Miscellaneous electromechanical equipment

Other mechanical and electrical components of a small hydro plant include:

- Water shut-off valve(s) for the turbine(s);
- River by-pass gate and controls (if required);
- Hydraulic control system for the turbine(s) and valve(s);
- Electrical protection and control system;
- Electrical switchgear;
- Transformers for station service and power transmission;
- Station service including lighting and heating and power to run control systems and switchgear;
- Water cooling and lubricating system (if required);
- Ventilation system;
- Backup power supply;
- Telecommunication system;
- Fire and security alarm systems (if required); and
- Utility interconnection or transmission and distribution system (RETScreen, 2004-a).

3.7. Small Hydro Project Development

The development of small hydro projects usually takes from 2 to 5 years to complete. After construction, small hydro plants require little maintenance over their useful life, which can be more than 50 years. Normally, one operator can easily handle operation and routine maintenance of a small hydro plant, while periodic maintenance of the larger components requires more labour.

The technical and financial viability of each potential small hydro project are very site specific. The amount of energy that can be generated depends on the quantity of water available and the variability of flow throughout the year. The economics of a site depends on the energy that a project can produce, and the price paid for the energy. In an isolated area the value of electricity is generally significantly more than for systems that are connected to a central-grid. However, isolated areas may not be able to use all the available energy from the small hydro plant because of seasonal variations in water flow and energy demand.

3.7.1. Types of Small Hydro Developments

3.7.1.1. Run-of river developments

Run-of-river hydropower projects use only the water that is available in the natural flow of the river meaning that there is no water storage and hence power fluctuates with the stream flow.

The power output of run-of-river small hydro plants fluctuates with the hydrologic cycle, so they are often best suited to provide energy to a larger electricity system which is very suitable for Turkey. Individually, they do not generally provide much firm capacity. Therefore, isolated areas that use small hydro resources often require supplemental power. A run-of-river plant can only supply all of the electrical needs of an isolated area or industry if the minimum flow in the river is sufficient to meet their peak power requirements.

Some of the run-of river plants are supplemented by a water pond which regulates storage to meet peaking loads.

3.7.1.2. Water storage (reservoir) developments

For a hydropower plant to provide power on demand, either to meet a fluctuating load or to provide peak power, water must be stored in a reservoir. Providing storage usually requires the construction of a dam and the creation of new lakes. This impacts the local environment in both negative and positive ways, although the scale of development often magnifies the negative impacts. This often presents a conflict, as larger hydro projects are attractive because they can provide “stored” power during peak demand periods.

New dams for storage reservoirs for small hydro plants is generally not financially viable except at isolated locations where the value of energy is possibly very high.

3.7.1.3. Developments using existing water networks

The use of water networks built for irrigation, drinking water and even wastewater can be used for energy development. The advantage of using existing networks is that the initial cost is lower compared to other developments.

In the case of irrigation or drinking water networks, the pressure caused by the strong slope between the reservoir and the consumers, has to be wasted in a surge tank. Instead of reducing the pressure it is often technically and financially possible to use a small Pelton turbine which uses this pressure. Therefore, water generates energy before being consumed. There are two possible energy generation methods for existing wastewater networks that the turbine can be set either before or after the treatment plant. In both cases optimal dimensioning of components is needed (MHylab, 2005).

Porsuk Dam has the potential of being an example of to the issue of electricity generation with small hydropower plants from irrigation dams after the article of Bakış and Bilgin is presented in International Symposium: Water for Development Worldwide (Bakış et al., 2005)

3.7.2. Small hydro project development and operation phases

There are normally four phases for engineering work required to develop a hydro project. However, for small hydro, the engineering work is often reduced to three phases in order to reduce total cost by combining the work involved in the first two phases described below and decreasing the level of detail (RETScreen, 2004-a). The other two phases are related with financial aspect of the project and the maintenance of the plant.

3.7.2.1. Reconnaissance surveys and hydraulic studies

This first phase of work covers map studies; characterization of the drainage basins; preliminary estimates of flow and floods; a short site visit; preliminary layout; cost estimates based on experience and a final ranking of alternatives based on optimization of power potential and initial estimated cost.

3.7.2.2. Pre-feasibility study

This second phase of work includes site mapping and geological investigations (with drilling and sampling); a reconnaissance for suitable borrow areas; a preliminary layout based on materials known to be available; preliminary selection of the main project characteristics; a cost estimate based on major quantities; and the identification of possible environmental impacts.

3.7.2.3. Feasibility study

In this third phase, work continues on the selected alternative with a major geographical investigation program; delineation and testing of all borrow pits; estimation of design and probable maximum floods; determination of power potential for a range of dam heights and installed capacities for project optimization; determination of the project design earthquake; design of all structures in sufficient detail; determination of the dewatering sequence and project schedule; optimization of the project layout, water levels and components; production of a detailed cost estimate; and finally, an economic and financial evaluation of the project along with a feasibility report.

3.7.2.4. System planning and project engineering

This last phase of engineering work would include final design of the transmission system; integration of the project into the power network; production of tender drawings and specifications; analysis of bids and detailed design of the project; production of detailed construction drawings and review of manufacturer’s equipment drawings (RETScreen, 2004-a).

3.7.2.5. Financing

The process financial arrangement for small-hydro projects is often difficult. Firstly a contract has to be obtained with a utility or organization which will purchase the produced electricity. With this contract in place the next step is to negotiate a bank loan or other source of financing. However, many banks lack knowledge of small-hydro projects and have no experience with this type of loan. In recent years some banks have acquired the necessary experience and now routinely provide loans for small-hydro projects (International Small Hydro Atlas, 2007).

3.7.2.6. Ownership and maintenance

There are some important factors for the effective operation of a small hydropower plant successfully depending on financial and management skills of the investor. These factors are listed below (International Small Hydro Atlas, 2007);

- Realistic assessment of project costs and benefits
- Personal and corporate financial strength
- Knowledgeable financial institution
- Design with special attention of operation and maintenance requirements
- Professional maintenance plan to minimize expense and downtime.

3.8. Assessment Tools and Methodologies for Small Hydropower Development

The assessment of sites available for small-hydro development represents a relatively high proportion of overall project costs. Over the last decade a variety of computer based assessment tools have been developed to make an initial assessment of the economic feasibility of a project before spending substantial sums of money and valuable time. The object of these software programs is to find a rapid and reasonably accurate means of predicting the energy output of a particular hydro scheme, and make economical analysis, and even perform a preliminary design. These predictions involve establishing the head that water can be dropped, and the quantity of water to be used. The first of these is a relatively simple matter of physical measurement together with some hydraulic loss calculations concerning pipe materials and water velocities, etc. The second is much more difficult and it is this part of the problem that is most intractable. There are two main approaches to determine the discharge, i.e., the flow duration curve (FDC) method and the simulated stream flow (SSF) method. (Wilson, 2000)

Table 3.3 summarizes the methodologies of the software used for making an initial assessment of a small hydropower project.

Among the tools listed in Table 3.3, Hydra, IMP, PEACH, Prophete and RETScreen stand out with their features.

Table 3.3. Small Hydropower Assessment Tools (IASH, 2007)

Assessment Tool		Features				
Software	Applicable Countries	Hydrology	Power/ Energy	Costing	Economic Evaluation	Preliminary Design
ASCE Small Hydro	USA	X				
HES	USA	X				
Hydra	Europe	X	X			
IMP	International	X	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	

3.8.1. Integrated Method for Power Analysis, IMP

IMP is developed by Charles Howard and Associates of Vancouver, Canada in association with Natural Resources, Canada. With IMP, and the relevant meteorological and topographical data, an ungauged hydro site can be evaluated within a short duration of time, including a power study, powerhouse and penstock optimization, fish habitat analysis and development of a flood frequency curve.

The software includes tips about hydrologic analysis of ungauged sites. Recorded stream flow data are not essential in IMP which uses topographic and daily weather data. The user inputs this information to perform flood frequency analysis and to synthesize hourly and daily stream flow and reservoir operations. Although IMP is said to be used internationally, only data of sites in North America may be acquired from within databases in the program. Weighted useable area theory is used to assess stream habitat for fish.

The program also contains modules in which proposed power projects are optimized, based on the value of energy and the cost of construction.

3.8.2. PROPHETE

The PROPHETE method, which is developed and used in France, allows the evaluation of site potential for small hydro stations as a function of catchment characteristics and proposed equipment.

There are two methods to assess flows. Firstly a comparison with neighboring watercourses in the database as a function of catchment area (which is available only for France) could be made, or the flows from a hydrologic model based on basin rainfall and predetermined averaged parameters derived from previous detailed studies can be calculated automatically.

After the estimation of a series of monthly flows by one of these two methods, the database allows the user to simulate automatically a small hydro station using a prescribed head and the turbine characteristics proposed by the program but can be changed manually. The software also permits calculation, with annual variation as required, of monthly production and revenues, based on actual selling prices of energy to the grid, prices which may be altered as required by the user.

The project parameters to be supplied by the user are the height of the fall to be equipped, the reserved flow from the watercourse, and the output from the turbine. The calculation of the receipts, if the user so requires, demands in addition the selection of a type of fixed price scale for sales or the purchase of electricity or the selection of possible auto-consumption of the electricity produced.

3.8.3. PEACH

PEACH is a sophisticated program designed by the French consulting firm ISL and is offered for sale. The program is designed to take a developer through all the necessary procedures in designing, building and operating a small hydro scheme and analyzing the financial benefits which may be expected. To do this, the user is led through six steps which are, site data definition, project creation, project design, plant design, economic and financial analysis, and report.

To start a PEACH study, a database must be selected. Therefore, the software is not eligible in countries other than France. The economic analysis is performed through a comparison between the hydro project and the equivalent thermal plant with a unit costs list entered by the user. The financial analysis allows taking into account the electricity sale terms and considering the possibilities for financing.

3.8.4. HydrA

HydrA broadly follows procedures laid out in the “Layman’s Guidebook on how to develop a small hydro site” (ESHA, 1998). It incorporates regional flow estimation models, which allow a synthetic flow duration curve to be derived at any site in U.K., Spain, Portugal, Italy, Ireland, Belgium and

Austria. The hydropower potential is then derived from the flow duration curve. The software is also able to calculate the hydropower potential of sites where gauged river flow data are available. HydrA comprises four main modules:

- Catchment Characteristics Module
- Flow Regime Estimation module
- Turbine Selection module
- Power Potential Module

3.8.5. RETScreen-Small Hydro Project Software

The RETScreen-Small Hydro Project Software is a renewable energy analysis tool provided by Natural Resources Canada. According to Table 3.3, RETScreen Software, being a free source is the most sophisticated tool comprising four important features. The detailed analysis of the software is performed in the next chapters.

CHAPTER 4

RETSCREEN-SMALL HYDRO PROJECT SOFTWARE

4.1. General

The RETScreen International Clean Energy Decision Support Centre is an organization seeking to help planners, designers, corporations and industry to implement renewable energy and invest in energy efficiency projects. This objective is achieved by developing decision-making software that reduce the cost and duration of pre-feasibility studies; help people make better and faster decisions; and training people to better analyze the technical and financial viability of possible projects.

4.2. RETScreen-Small Hydro Project Software

The RETScreen-Small Hydro Project Software, which is written in Visual Basic Code with iterative worksheets, provides a means to calculate the available energy at a potential small hydro site that could be provided to a central-grid or for isolated loads, and the financial viability of the project by estimating project costs. The model addresses both run-of-river and reservoir developments and calculates efficiencies of a wide variety of hydro turbines.

The Small Hydro model can be used to evaluate small hydro projects typically classified under the following three categories:

- Small hydro,
- Mini hydro,
- Micro hydro.

The classification can be entered manually or selected by the model. If the selection is done by the model the classification is related with the design flow of the project and the runner diameter of the turbine. Project classification of RETScreen Software is shown in Table 4.1.

Table 4.1. RETScreen's Project Classification (Source: RETScreen, 2004-a)

Project Classification	SMALL	MINI	MICRO
Design Flow (m^3/s)	>12.8	0.4-12.8	<0.4
Turbine Runner Diameter (m)	>0.8	0.3-0.8	<0.3

The reason for this selection is that the turbine runner diameter value of 0.8 meter corresponds to the largest turbine that can be transported to a project site as one package loaded on a truck.

The Small Hydro Project Model has been developed primarily to determine whether work on the small hydro project should proceed further or be dropped in favor of other alternatives (RETScreen, 2004-a).

Seven worksheets *Energy Model, Hydrology Analysis and Load Calculation (Hydrology and Load), Equipment Data, Cost Analysis, Greenhouse Gas Emission Reduction Analysis (GHG Analysis), Financial Summary* and *Sensitivity and Risk Analysis (Sensitivity)* are provided in the Small Hydro Project Workbook file (RETScreen, 2004-a).

RETScreen software suggests The *Energy Model*, *Hydrology & Load* and *Equipment Data* worksheets to be completed first. The *Cost Analysis* worksheet should then be completed, followed by the optional *GHG Analysis* Worksheet. The *Financial Summary* worksheet and the optional

Sensitivity worksheet should be finally completed. The *GHG Analysis* worksheet is provided to help the user estimate the greenhouse gas (GHG) mitigation potential of the proposed project. The *Sensitivity* worksheet is provided to help the user estimate the sensitivity of important financial indicators in relation to key technical and financial parameters. It is recommended that the user works from top-down for each of the worksheets although completing the *Hydrology and Load* and *Equipment Data* worksheets before the *Energy Model* worksheet. The order of the working principle of RETScreen software is illustrated in Figure 4.1 as a flow chart. This process can be repeated several times by the user in order to help optimize the design of the small hydro project from an energy use and cost standpoint (RETScreen, 2004-a). It should be noted that, the software itself does not make optimization.

Figure 4.1. The Order of Working Principle of RETScreen Software

The RETScreen-Small Hydro Project Model estimates the project costs with two different methods: the “Formula” and the “Detailed” costing methods. All the hydro cost equations used in the “Formula” costing method are empirical. If used correctly, the “Formula” costing method will provide a baseline cost estimate for a proposed project.

The “Detailed” costing method allows the user to estimate costs based on estimated quantities and unit costs. The use of this costing method requires that the user estimate the size and the layout of the required structures meaning that the project has to be pre-evaluated before the

“Detailed” analysis can be used. In this study, “Detailed” cost analysis will not be used.

The Small Hydro Project Model has been designed primarily to evaluate run-of-river small hydro projects. The evaluation of storage projects is also possible; however, variations in gross head due to changes in reservoir water level cannot be simulated. The model requires a single value for gross head. In the case of reservoir projects, an average value must be entered. The determination of the average head must be done outside of the model.

The user manual of the software is presented in tabulated form in Appendix A.

4.2.1. Hydrology Data

In RETScreen, hydrological data are required to be specified as a flow-duration curve, which represents the flow conditions in the river being studied over a period of time. For storage projects, data must be entered manually by the user and should represent the regulated flow that results from operating a reservoir; the head variation with storage drawdown is not included in the model.

After flow-duration curve is entered or calculated and the residual flow that should be kept in the river is entered, the model calculates the firm flow that will be available for electricity production. However, it should be noted that, the calculation of flow-duration curve is performed using the database on basins located in Canada, therefore, the calculation is only available for Canadian projects. The user, however, is allowed to enter a basin information in the database and then perform the calculation. Calculation of flow-duration curve is the most difficult part of a pre-feasibility report and RETScreen Software’s calculation method is a time saver tool for the developers.

4.2.1.1 Flow-duration curve

A flow-duration curve is a graph of the historical flow at a site ordered from maximum to minimum flow. It is used to assess the availability of flow over time and the power and energy, at a site. (RETScreen, 2004-a)

The flow-duration curve is specified by twenty-one values Q_0, Q_5..., Q_{100} representing the flow on the flow-duration curve in 5% increments. In other words, Q_n represents the flow that is equaled or exceeded *n*% of the time. An example of a flow-duration curve is shown in Figure 4.2.

4.2.1.2 Residual flow

Residual flow, Q_r, is the flow that must be left in the river throughout the year for environmental reasons. It is specified by the user and subtracted from all values of the flow-duration curve for the calculation of plant capacity, firm capacity and renewable energy available.

4.2.1.3 Firm flow

The firm flow is the flow being available p% of the time, where p is a percentage specified by the user and usually between 90% and 100%. The firm flow is calculated from the available flow-duration curve.

4.2.1.4 Design flow

The design flow is the maximum flow that can be used by the turbine. The selection of design flow depends on the available flow at the site. For run-of river projects, which are connected to a large grid, the optimum design flow is usually close to the flow that is equaled or exceeded about 30% (Q_{30}) of the time (RETScreen, 2004-a).

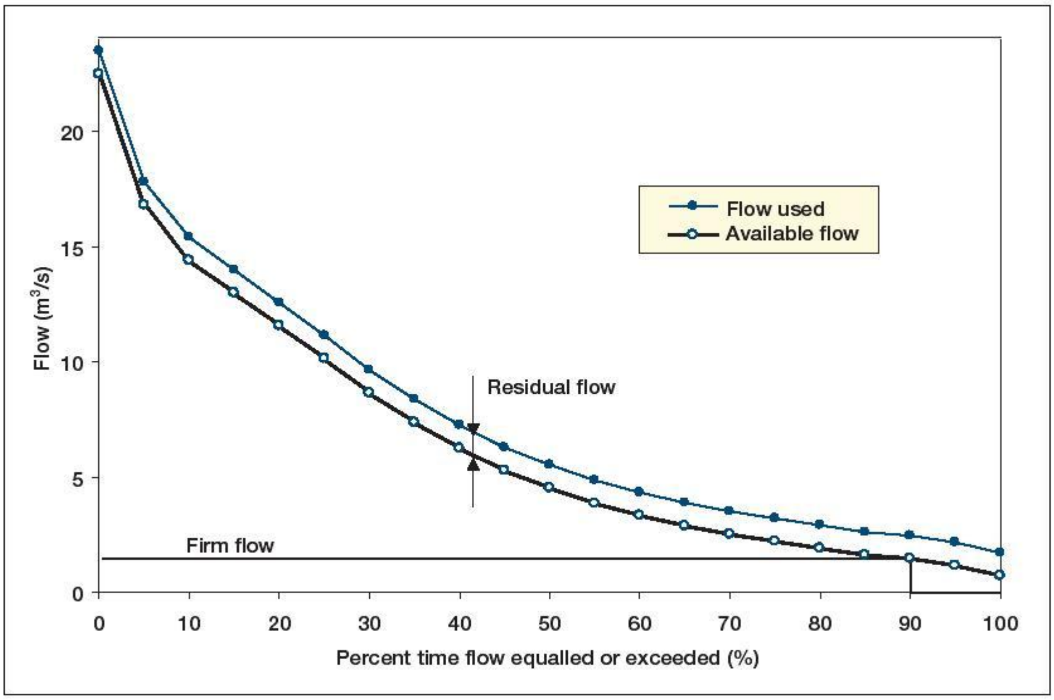


Figure 4.2. Example of a Flow-Duration Curve (RETScreen 2004-a)

4.2.2 Load Data

The load depends on the type of grid considered. If the small hydro power plant is connected to a central-grid, then it is assumed that the grid demands all of the energy production. If on the other hand the system is off-grid or connected to an isolated-grid, then the portion of the energy that can be delivered depends on the load.

Calculations for off-grid and isolated-grid systems are not used in the present study.

4.2.3 Energy Production

The RETScreen-Small Hydro Project Model calculates the estimated renewable energy delivered (MWh) based on the adjusted available flow (adjusted flow-duration curve), the design flow, the residual flow, the load (in case of isolated grid), the gross head and the efficiencies/losses.

4.2.3.1 Turbine efficiency curve

Small hydro turbine efficiency data can be entered manually or can be calculated by RETScreen. Standard turbine efficiency curves have been developed for Kaplan, Francis, Propeller, Pelton, Turgo and Crossflow turbine types.

The type of turbine is entered by the user based on its suitability to the available head and flow conditions. The turbine efficiency curve calculation is based on rated head (design gross head less maximum hydraulic losses), runner diameter (calculated), turbine specific speed (calculated for reaction turbines) and the turbine manufacture/design coefficient. The efficiency equations were derived from a large number of manufacture efficiency curves for different turbine types and head and flow conditions (RETScreen, 2004-a). It is a disadvantage that, the software does not include a feature that suggests the type of the turbine.

For multiple turbine applications it is assumed that all turbines are identical and that a single turbine will be used up to its maximum flow and then flow will be divided equally to the number turbines. Therefore, unidentical turbines used in the small hydro project are assumed to be identical by the model. The turbine efficiency equations and the number of turbines are used to calculate plant turbine efficiency from 0% to 100% of design flow at 5% intervals. An example turbine efficiency curve for 1 and 2 turbines, where the gross head and the design flow are 146 m and 1.90 m^3/s respectively, is shown in Figure 4.3.

Turbine efficiency equations used by RETScreen Software for Francis Turbines are presented in Appendix B.

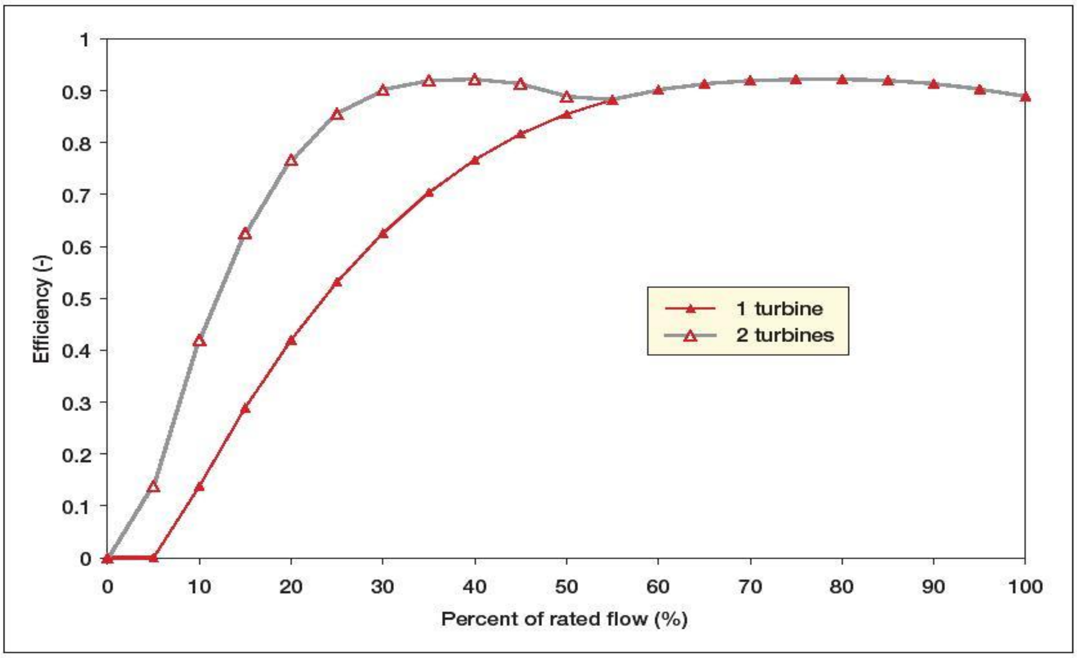


Figure 4.3. Example of a Turbine Efficiency Curve (RETScreen, 2004-a)

4.2.3.2 Power available as a function of flow

Actual power P available from the small hydro plant at any given flow value Q is given by Equation 4.1, in which the flow-dependent hydraulic losses and tailrace reduction are taken into account:

$$P = \rho g Q[H_g - (h_{hydr} + h_{tail})]e_t e_g (1 - l_{trans})(1 - l_{para}) \qquad (4.1)$$

where h_{hydr} and h_{tail} are respectively the hydraulic losses and tailrace effect associated with the flow; e_t is the turbine efficiency at flow Q; e_g is the generator efficiency, l_{trans} is the transformer losses, and l_{para} is the parasitic electricity losses (RETScreen, 2004-a).

Hydraulic losses are adjusted over the range of available flows based on the following relationship:

$$h_{hydro} = H_g l_{hydr,max} \frac{Q^2}{Q_d^{\ 2}} \tag{4.2}$$

where $l_{hydr,max}$ is the maximum hydraulic losses specified by the user, and Q_d is the design flow (RETScreen, 2004-a).

The maximum tailrace effect is adjusted over the range of available flows with the following relationship:

$$h_{tail} = h_{tail,max} \frac{(Q - Q_{des})^2}{(Q_{max} - Q_{des})^2} \tag{4.3}$$

where $h_{tail,max}$ is the maximum tailwater effect which is the maximum reduction in available gross head that will occur during times of high flows in the river. Q_{max} is the maximum river flow and Equation 4.3 is applied only to river flows that are greater than the plant design flow (when $Q>Q_{des}$) (RETScreen, 2004-a).

4.2.3.3 Plant capacity

Plant capacity P_{des} is calculated by re-writing Equation 4.1 at the design flow Q_{des}. The equation simplifies to:

$$P_{des} = \rho g Q_{des} H_g (1 - h_{hydr})] e_{t,des} e_g (1 - l_{trans})(1 - l_{para}) \tag{4.4}$$

where P_{des} is the plant capacity and $e_{t,des}$ the turbine efficiency at design flow, calculated from the turbine efficiency curve. The small hydro plant firm capacity is calculated again using Equation 4.4, but this time using the firm flow and corresponding turbine efficiency and hydraulic losses at this flow (RETScreen, 2004-a).

4.2.3.4 Power-duration curve

Calculation of power available as a function of flow using Equation 4.4 for all 21 values of the available flow Q'_0, Q'_5,..., Q'_{100} used to define the flow-duration curve, leads to 21 values of available power P_0, P_5,..., P_{100} defining a power-duration curve. Since the design flow is defined as the maximum flow that can be used by the turbine, the flow values used in Equations 4.1 and 4.2 are actually $Q_{n,used}$ defined as (RETScreen, 2004-a):

$$Q_{n,used} = \min(Q'_n, Q_{des}) \qquad (4.5)$$

An example power-duration curve is shown in Figure 4.4, with the design flow equal to 3 m^3/s.

4.2.3.5 Renewable energy available

Renewable energy available is the area under the power-duration curve assuming a straight-line between adjacent calculated power output values. Given that the flow-duration curve represents an annual cycle, each 5% interval on the curve is equivalent to 5% of 8,760 hours (number of hours per year). The annual available energy E_{avail} (in kWh/yr) is calculated from the values P (in kW) by:

$$E_{avail} = \sum_{k=1}^{20} \left(\frac{P_{5(k-1)} + P_{5k}}{2}\right) 438(1 - l_{dt}) \qquad (4.6)$$

where l_{dt} is the annual downtime losses (RETScreen, 2004-a).

4.2.3.6 Renewable energy delivered

Equation 4.6 defines the amount of renewable energy available. The amount of energy actually delivered depends on the type of grid. For central-grid applications, it is assumed that the grid is able to absorb all the energy produced by the small hydro power plant. Therefore, all the renewable energy available will be delivered to the central-grid and the renewable energy delivered, E_{dlvd}, is simply (RETScreen, 2004-a):

$$E_{dlvd} = E_{avail} \tag{4.7}$$

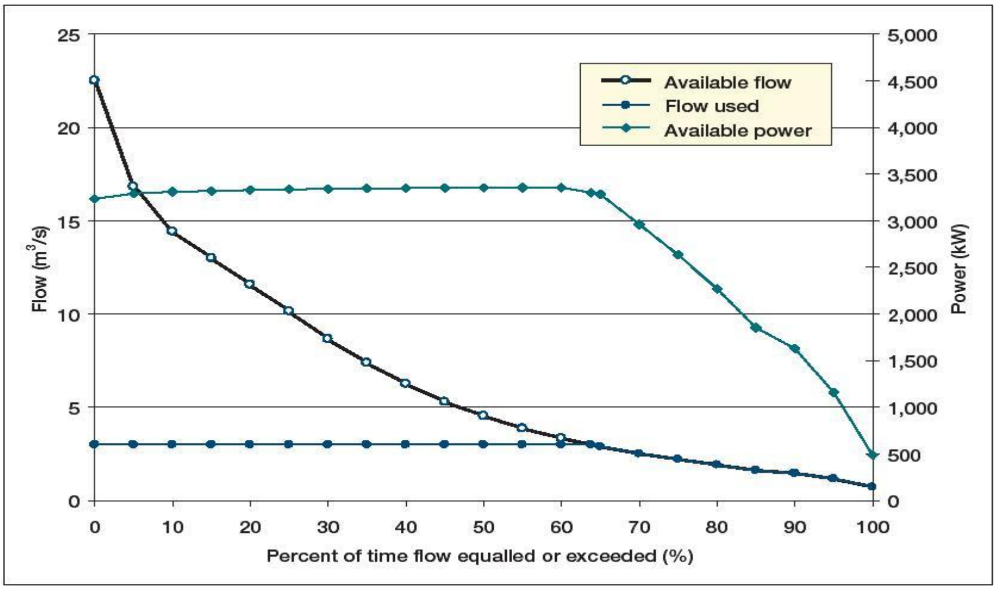


Figure 4.4. Example of a Power - Duration Curve (RETScreen, 2004-a)

4.2.4 Project Costing

The Small Hydro Project Model offers two methods for project costing; the detailed costing method and the formula costing method. The costing method is selected from the drop-down list in the beginning of *Cost Analysis* worksheet. The detailed costing method will not be used in this study. The formula costing method is based on empirical formulae that have been developed to relate project costs to key project parameters.

After selecting formula costing method for calculation of project costs, project country should be entered. The formula method uses Canadian projects as a baseline and then allows the user to adjust the results for local conditions. The cost of projects outside Canada compared to the cost of projects in Canada will depend, to a great extent, on the relative cost of equipment, fuel, labour and equipment manufacturing, and the currency of the country. For projects outside Canada, costs are adjusted based on the relative costs of these items and the exchange rate. The ratio of the costs of fuel and labour between Turkey and Canada for the year 2006 are examined and the following values are found:

- Canadian average diesel fuel cost was 0.78 US$/liter and Turkish average diesel fuel cost was 1,62 US$/liter in 2006 (GTZ, 2007). Therefore Turkish versus Canadian fuel costs ratio is calculated as 2.08.

- Turkish versus Canadian labour costs ratio in 2006 is calculated as 0.23 by Equations 4.8 and 4.9.

$$L_{T,2006} = L_{T,2001} r_{T,2006-2001} \tag{4.8}$$

$$r_{2006} = \left(\frac{L_{T,2006}}{L_{C,2006}}\right) \tag{4.9}$$

where the above variables and their calculation process are shown in Table 4.2.

Table 4.2. Estimation of Turkey vs. Canada Labour Costs Ratio

Average Labour Cost in Turkey for construction sector in 2001	$L_{T,2001}$	3,312.47 CAD [1]
Rate of Increase of the Labour Unit Costs in Turkey between 2006-2001	$r_{T,2006\text{-}2001}$	3.25 [2]
Estimated Labour Cost in Turkey for construction sector in 2006	$L_{T,2006}$	10,765.53 CAD
Average Labour Cost in Canada for construction sector in 2006	$L_{C,2006}$	46,550.92 CAD [3]
Turkey vs. Canada Labour Costs Ratio in 2006	r_{2006}	0.23

1: State Institute of Statistics, 2004
2: Birimfiyat.net, 2007
3: ILO, 2007

Turkish versus Canadian equipment costs ratio could not be calculated and assumed as unity. Turkish versus Canadian equipment manufacture cost ratio is also estimated as unity since the manufacturing sector for hydropower does not exist in Turkey and significant percentage of the equipment needed is generally exported. The average exchange rate between USD and CAD for the year 2006 is found as 0.88 (Bank of Canada, 2007).

The selection of project classification is an important parameter for the correct evaluation of project costing because the costs of certain components, particularly the civil works, are affected by this selection. This is due to larger projects requiring more conservative designs with higher associated risks.

The variables used in the formula costing method, the input data of formulae and the items calculated by the formulae are listed in Tables 4.3, 4.4 and 4.5.

Table 4.3. Vairables Used in Formula Method (RETScreen, 2004-a)

A	Access road difficulty factor	l_{cs}	Canal length in impervious soil (m)
B	Foreign costs civil works factor	l_d	Dam crest length (m)
C	Civil cost factor	l_p	Penstock length (m)
C_g	Lower cost generation factor	l_T	Tranmission line length (km)
C_v	Concrete lining in tunnel (m^3)	l_t	Tunnel length (m)
d	Runner diameter (m)	MW	Total capacity (MV)
D	Tranmission line difficulty factor	MW_u	Capacity per unit (MV)
d_p	Diameter of penstock	n	Number of turbines
E	Engineering cost factor	n_p	Number of penstocks
E_c	Equipment costs ratio	P	Transmission line wood or steel factor
f	Frost days at site	Q	Flow under consideration (m^3/s)
F	Frost days factor	Q_d	Design flow (m^3/s)
F_c	Fuel costs ratio	Q_u	Flow per unit (m^3/s)
G	Grid connected factor	R	Rock factor
H_g	Gross Head (m)	R_v	Tunnel volume of rock excavation (m^3)
i	Interest rate (%)	S_r	Side slope of rock where canal is built (^{o})
J_t	Vertical axis turbine factor	S_s	Side slope of soil where canal is built (^{o})
k	Tunnel headloss (ratio to H_g)	T	Tote road factor
K	Equipment manufacture cost ratio	t_{ave}	Average penstock thickness (mm)
K_t	Small horizontal axis turbine factor	t_b	Penstock thickness at turbine (mm)
l_a	Access road length (km)	T_c	Tunnel lining length ratio
l_b	Distance to borrow pits (km)	t_t	Penstock thickness at intake (mm)
L_c	Labour costs ratio	V	Transmission line voltage (kV)
l_{cr}	Canal length in rock (m)	W	Penstock weight (steel) (kg)

Table 4.4. Input Data of Formulae (RETScreen, 2004-a)

VARIABLE	SMALL HYDRO	MINI HYDRO	MICRO HYDRO
Q_d	*User-defined value*		
n	*User-defined value*		
Q_u	Q_d / n	Q_d / n	Q_d
d	$0.482(Q_u)^{0.45}$		
H_g	*User-defined value*		
Mw_u	$8.22Q_uH_g$ / 1000	$7.79Q_uH_g$ / 1000	$7.53Q_uH_g$ / 1000
MW	Mw_u.n		MW_u
E	= 0.67 if existing dam = 1.0 if no dam		
C_g	= 0.75 if MW < 10 = 1.0 if MW ≥ 10		
T	= 0.25 if tote road = 1.0 otherwise		
A	*User-defined factor with recommended range of 1 to 6*		
I_a	*User-defined value*		
D	*User-defined factor with recommended range of 1 to 2*		
I_T	*User-defined value*		
V	*User-defined value*		
P	= 0.85 if V < 69 = 1.0 if V ≥ 69		

Table 4.4. Continued (RETScreen, 2004-a)

VARIABLE	SMALL HYDRO	MINI HYDRO	MICRO HYDRO
C	= 0.44 if existing dam= 1.0 if no dam		
R	= 1 if rock at dam site = 1.05 if no rock		N/A
I_b	*User-defined value*		
I_d	*User-defined value*		
n_p	*User-defined value*		
l_p	*User-defined value*		
d_p	$(Q_d/n_p)^{0.43}/H_g^{0.14}$		
t_t	$d_p^{1.3}+6$		
t_b	$0.0375\ d_pH_g$		
t_{ave}	$0.5(t_t+t_b)$ if $t_b>t_t$ t_t if $t_b<t_t$		
W	$24.7d_pl_pt_{ave}$		
S_s	*User-defined value*		
S_r	*User-defined value*		
l_{cs}	*User-defined value*		
l_{cr}	*User-defined value*		

Table 4.4. Continued (RETScreen, 2004-a)

VARIABLE	SMALL	MINI	MICRO
I_t	*User-defined value*		*N/A*
k	*User-defined value*		*N/A*
R_v	$0.185*I_t^{1.375}*[Q_d^2/(k*H_g)]^{0.375}$		*N/A*
T_c	*User-defined value with range of 15% (excellent rock) to 100% (poor rock)*		*N/A*
C_v	$0.306R_vT_c$		*N/A*
i	*User-defined value*		
f	*User-defined value*		
F	$110/(365\text{-}f)^{0.9}$		
E_c	*User-defined value*		
F_c	*User-defined value*		
L_c	*User-defined value*		
B	$(0.3333E_c+0.3333F_c)/(E_c/L_c)^{0.5}+0.3333(E_c/L_c)^{0.5}L_c$		
K	*User-defined value*		
J_t	=1 if Hg ≤ 25 m =1.1 if Hg > 25 m		
K_t	=0.9 if d < 1.8 m =1 if d ≥ 1.8 m		

There are 15 categorized formulae in the RETScreen-Small Hydro Model Software to estimate the initial cost of a small hydropower project based on the input data listed in Table 4.4. The items and the corresponding formulae are listed in Table 4.5 according to the classification of the project.

Table 4.5. Formulae of the Formula Costing Method (RETScreen, 2004-a)

ITEM (NUMBER)	SMALL	MINI	MICRO
Feasibility Study (1)	$0.032\sum Eq(2 \text{ to } 15)$		$0.031\sum Eq(2 \text{ to } 15)$
Development (2)	$0.04\sum Eq(3 \text{ to } 14)$		
Engineering (3)	$0.37n^{0.1}E(MW/H_g^{0.3})^{0.54}10^6$		$0.04E(MW/H_g^{0.3})^{0.54}10^6$
Energy Equipment (4)	Generator and Control:	$0.82n^{0.96}C_g(MW/H_g^{0.28})^{0.9}10^6$	
	Kaplan turbine:	$0.27n^{0.96}J_tK_td^{1.47}(1.17*H_g^{0.12}+2)10^6$	
	Francis turbine:	$0.17n^{0.96}J_tK_td^{1.47}[(13+0.01H_g)^{0.3}+3]10^6$	
	Propeller turbine:	$0.125n^{0.96}J_tK_td^{1.47}(1.17H_g^{0.12}+4)10^6$	
	Pelton&Turgo turbine:	$3.47n^{0.96}(MW_u/H_g^{0.5})^{0.44}10^6$ *if* $(MW_u/H_g^{0.5})>0.4$ $5.34n^{0.96}(MW_u/H_g^{0.5})^{0.91}10^6$ *if* $(MW_u/H_g^{0.5})<0.5$	
	Cross-flow turbine:	(Cost of Pelton&Turgo) / 2	
Installation of Energy Equipment (5)	$B[0.15Eq(4)]$		
Access road (6)	$B[0.025TA^2I_a^{0.9}10^6]$		
Transmission line (7)	$B[0.0011DPl_t^{0.95}V10^6]$		

Table 4.5. Continued (RETScreen, 2004-a)

ITEM (NUMBER)	SMALL	MINI	MICRO
Substation - transformer (8)	$[0.0025n^{0.95}+0.02(n+0.1)](MW/0.95)^{0.9}V^{0.3}10^{6}$		
Substation - transformer installations (9)	$B[0.15Eq(8)]$		
Civil works (10)	$3.54n^{-0.04}BCR(MW/H_g^{0.3})^{0.82}$ $*(1+0.01l_b)(1+0.005l_d/H_g)10^{6}$	$1.97n^{-0.04}BCR(MW/H_g^{0.3})^{0.82}$ $*(1+0.01l_b)(1+0.005l_d/H_g)10^{6}$	
Penstock (11)	$20n_p^{0.95}W^{0.88}$		
Installation of Penstock (12)	$B[5W^{0.88}]$		
Canal (13)	$20B[(1.5+0.01S_s^{1.5})Q_d l_{cs}]^{0.9} + 100[(1.5+0.016S_r^{2})Q_d l_{cr}]^{0.9}$		
Tunnel (14)	$B[400R_v^{0.88} + 4000C_v^{0.88}]$		*N/A*
Miscellaneous (15)	$[(0.275iQ_d^{0.35})+0.1]\sum Eq(2\ to\ 14)$		$(0.187i+0.1)\sum Eq(2\ to\ 14)$
INITIAL COSTS (FORMULA METHOD)	1+2+3+4+5+6+7+8+9+10+11+12+13+14+15		

The cost category index which gives the outputs of initial costs is shown in Table 4.6. It should be noted that the installations of penstock, substation and transforms, and energy equipment are included in civil works category together with the item called civil works in Table 4.5.

Table 4.6. Cost Category Index (RETScreen, 2004-a)

COST ITEM	FORMULA(E) NUMBER(S)
Feasibility Study	1
Development	2
Engineering	3
Energy Equipment	4
Balance of Plant	
Access road	6
Transmission line	7
Substation and transformer	8
Penstock	11
Canal	13
Tunnel	14
Civil works	5 + 9 + 10 + 12
Subtotal	
Miscellaneous	15

4.2.5 Project Financing

The Small Hydro Project Model provides a financial analysis feature which allows the user to see pre-tax, after-tax and cumulative cash flows over the project life. This feature helps the developer to consider various financial parameters with relative ease with its financial input parameters and feasibility output items (RETScreen, 2004-b).

There are common six sections in the *Financial Analysis* worksheet; Annual Energy Balance, Financial Parameters, Project Costs and Savings, Financial Feasibility, Yearly Cash Flows and Cumulative Cash Flow Graph. The Annual Energy Balance and the Project Costs and Savings sections provide a summary of the *Energy Model, Cost Analysis* and *GHG Analysis* worksheets associated with each project studied. In addition to this summary information, the Financial Feasibility section provides financial indicators of the project analyzed, based on the data entered by the user in the Financial Parameters section. The Yearly Cash Flows section allows the user to visualize the stream of pre-tax, after-tax and cumulative cash flows over the project life.

RETScreen-Small Hydro Software is not capable of optimizing a project, however, different workbooks could be run of the same project and the gathered data from the *Energy Model* and *Financial Analysis* worksheets could be used in order to optimization manually.

4.2.6 Cell Color Coding

In RETScreen Software data are entered into "shaded" worksheet cells. All other cells that do not require input data are protected to prevent the user from mistakenly deleting a formula or reference cell and the software reports error if the user does so. The RETScreen Cell Color Coding chart for input and output cells is presented below in Table 4.7.

Table 4.7. RETScreen Color Coding (Source: RETScreen, 2004-a)

Input and Output Cells	
White	Model Output - calculated by the model
Yellow	User input - required to run the model
Blue	User input - required to run the model's online databases if necessary
Grey	User input - for reference purposes only

CHAPTER 5

CASE STUDY: KADINCIK-4 HEPP PROJECT

5.1. Selection of the Case Study

In this chapter, the applicability of RETScreen-Small Hydro Software into Turkish practice will be examined in detail by using a small hydro project named Kadıncık-4 Project. There are two alternative feasibility studies of Kadıncık-4 HEPP Project which are made by General Directorate of State Hydraulic Works (DSİ) and İÇTAŞ Energy and Trade Co. (İÇTAŞ) in 2006. In the first stage, the project will be described briefly. Then, the summary of the two alternative feasibility reports will be given. Afterwards, RETScreen Software will be used to evaluate the alternatives and the results will be given. Finally, further alternatives will be developed manually and evaluated by the software.

5.2. Description of the Project

Kadıncık-4 weir and hydropower plant are located on Kadıncık River at the countryside of Çamlıyayla of Mersin province where Mediterranean climate is seen. The average January temperature is 9.9 ^{o}C and the average August temperature is 26.8 ^{o}C (DSİ, 2006). Three-dimensional topographic map of Çamlıyayla and Kadıncık River is shown in Figure 5.1.

In the first alternative, which is the feasibility study of DSİ, Kadıncık-4 Weir is located on 599.50 m elevation with a drainage area of 258.4 km^2 (DSİ, 2006). In the second alternative, which is İÇTAŞ's feasibility study, Kadıncık-4 Weir is located on 479.20 m elevation with a drainage area of 322.0 km^2 (İÇTAŞ, 2006). The elevation of the weir is reduced approximately 120 m in order to generate electricity from Karasu stream which have significant amount of water joining to Kadıncık River at 499 m elevation. Figure 5.2 shows the unscaled illustration of these two alternatives for the Kadıncık-4 HEPP.

Figure 5.1. Three Dimensional Topographic Map of the Project Location (Microsoft Virtual Earth, 2007)

The geology of the site is acquired from the Earthquake Maps of Turkey prepared by The Ministry of Public Works and Settlement in 1996, the region of the project is classified in 3rd degree earthquake region (DSİ, 2006).

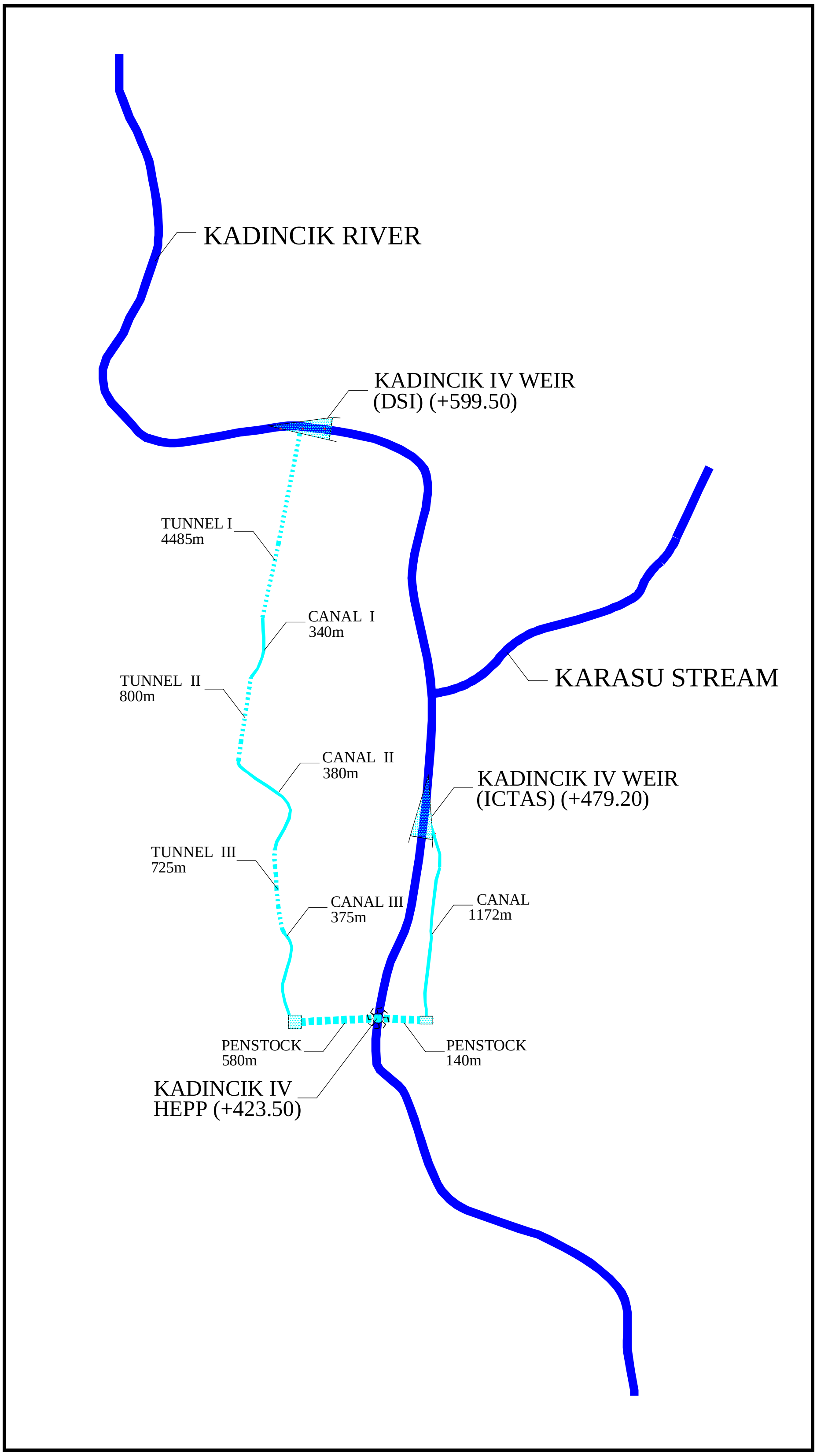


Figure 5.2. Illustration of the Two Alternatives

5.3. Design of General Directorate of State Hydraulic Works, Alternative I

Natural flows of springs, whom later merge together and form Kadıncık River, are diverted by Kadıncık-4 Weir into 3 transmission tunnels and 3 tunnels, and then through a penstock to the turbines with total installed power of 15 MW and annual energy generation of 54.52 GWh in Kadıncık-4 HEPP power house which is located at 423.50 m elevation (Figure 5.3). Water is then discharged back into Kadıncık River eventually flowing into the Mediterranean Sea. The gross head of the project is 178.82 m and the design flow is selected as 9.50 m^3/s (DSİ, 2006).

The coordinates of Kadıncık-4 Weir and HEPP are 37°20'48'' North - 34°38'54'' East and 37°9'14'' North - 34°43'14'' East which are calculated from the UTM coordinates by Franson CoordTrans Software (Source: DSİ, 2006).

5.3.1. Hydrology Data

The drainage area of Kadıncık-4 Weir 258.4 km^2 and the average annual precipitation is 1023.7 mm according to the data collected by Tarsus and Mersin stations (DSİ, 2006). The flow-duration curve is shown in Figure 5.3 and monthly flow data of Kadıncık-4 Weir are given in Table 5.1.

Kadıncık-4 Weir is not designed for other purposes such as water storage. For environmental reasons, 0.10 m^3/s of residual flow will be left in Kadıncık River. The firm flow is selected as the flow being available at 95% of the time (DSİ, 2006). The design flow is selected in the feasibility report as 9.5 m^3/s which corresponds to flow being available at about 22% of the time as seen in Figure 5.3.

Table 5.1. Kadıncık-4 Weir Monthly Flow Data 1972-2004 (m^3/s), Alternative I (DSİ, 2006)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1972	1.20	2.33	3.01	2.18	3.08	5.64	23.80	25.60	17.01	6.46	4.13	3.04
1973	3.29	2.83	2.16	1.72	2.74	4.44	5.87	6.00	4.08	1.93	1.25	1.08
1974	0.86	0.95	1.37	1.10	1.57	10.7	9.13	9.64	4.51	1.37	0.98	0.81
1975	0.80	0.85	5.90	6.28	7.86	10.7	32.93	28.89	18.98	6.37	2.17	1.22
1976	0.87	1.00	1.47	2.75	2.64	4.32	13.70	21.09	11.86	4.07	1.63	0.98
1977	1.94	2.94	6.66	4.19	7.65	5.39	13.44	17.35	9.74	3.38	1.36	1.12
1978	0.94	0.92	1.89	7.07	9.16	9.73	15.35	25.41	11.57	3.29	1.45	1.02
1979	1.80	2.04	3.23	5.74	6.08	6.47	12.63	11.55	10.18	3.80	2.06	1.37
1980	1.48	4.48	4.76	4.75	4.47	14.24	26.00	27.29	14.16	3.42	1.66	1.12
1981	1.00	1.45	1.38	10.44	13.1	18.21	21.76	22.69	24.95	8.90	2.63	1.58
1982	1.21	1.61	5.63	3.84	2.59	5.21	16.47	18.74	12.41	4.24	1.92	1.76
1983	1.57	1.16	1.20	3.47	3.53	10.16	19.08	20.45	11.02	3.26	2.25	1.68
1984	1.48	3.91	11.52	5.82	8.60	8.54	14.63	15.45	9.45	3.44	1.94	1.32
1985	1.13	3.26	1.57	2.54	4.72	5.85	14.04	13.35	6.75	2.37	1.41	1.06
1986	1.98	8.65	3.81	6.45	6.68	7.40	11.06	7.26	10.16	4.05	1.58	1.12
1987	1.00	1.40	1.52	3.66	3.25	6.91	10.05	14.81	8.40	3.00	1.56	1.15
1988	1.11	2.52	5.98	3.37	5.53	11.13	19.19	23.28	13.48	4.91	2.38	1.54
1989	3.07	4.04	4.05	4.44	4.06	7.87	11.45	7.56	3.48	1.66	1.25	1.08
1990	1.23	2.77	2.74	1.18	4.18	11.58	10.59	9.73	7.32	2.16	1.15	0.86
1991	0.84	0.81	1.15	0.87	1.69	4.99	7.40	5.34	3.51	1.87	1.29	1.06
1992	1.67	1.39	4.76	3.83	2.30	5.42	14.94	15.76	11.43	3.88	1.92	1.31
1993	1.09	2.38	4.27	2.74	3.50	7.36	14.00	14.18	9.92	3.52	1.99	1.53
1994	1.23	1.22	1.37	3.05	2.96	4.53	8.21	7.84	4.30	1.86	1.36	1.23
1995	1.05	3.61	2.57	3.13	4.03	5.83	10.40	19.18	13.28	3.39	1.96	1.31
1996	1.10	3.05	2.71	5.38	6.34	12.00	16.22	31.80	17.00	3.45	1.56	1.07
1997	1.91	1.52	10.07	6.06	2.79	3.73	10.35	21.82	11.67	3.21	1.64	1.41
1998	4.31	4.74	5.57	3.50	3.57	3.96	15.52	21.14	11.66	3.23	2.09	1.49
1999	1.44	1.93	4.61	3.64	4.82	7.33	14.80	18.29	9.30	4.12	1.98	1.50
2000	1.23	1.02	1.05	1.43	2.74	5.07	13.81	13.16	6.36	2.26	1.67	1.27
2001	1.24	1.93	2.92	2.59	2.58	5.51	5.77	9.94	3.31	1.67	1.36	1.20
2002	1.12	1.94	9.77	6.34	8.20	12.66	19.02	25.78	24.35	7.60	2.71	2.66
2003	1.55	1.60	1.51	1.99	2.72	5.50	12.92	15.21	10.04	2.75	1.65	1.38
2004	1.16	1.41	2.87	3.31	4.85	11.71	9.09	12.28	6.57	2.32	1.60	1.30
Avg	**1.48**	**2.35**	**3.79**	**3.90**	**4.68**	**7.88**	**14.35**	**16.90**	**10.67**	**3.55**	**1.81**	**1.35**

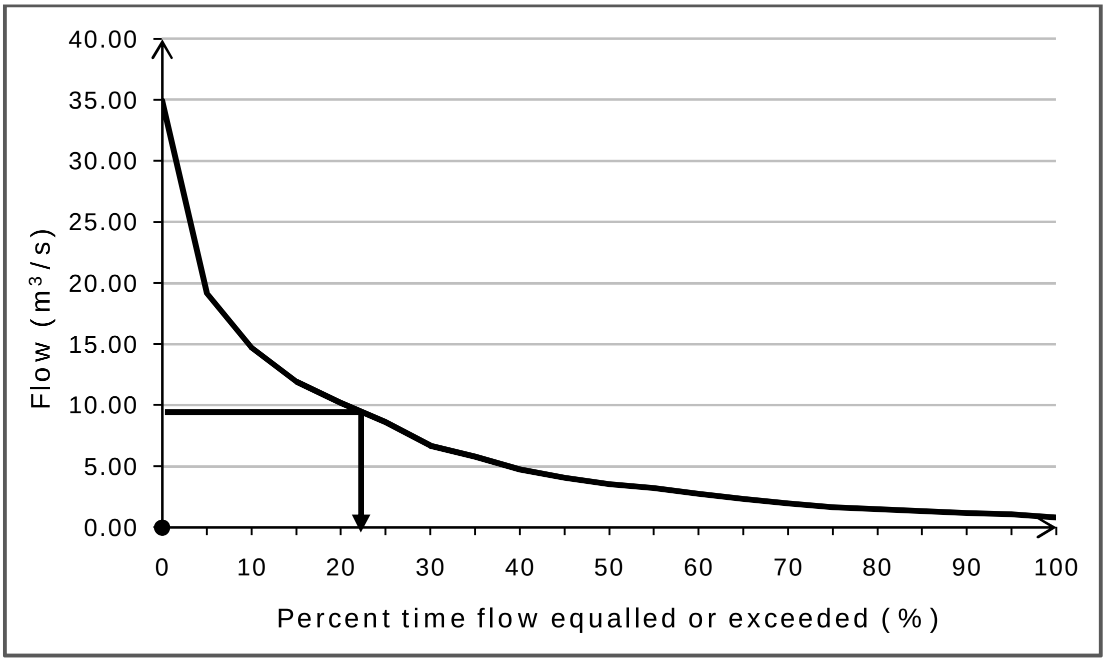


Figure 5.3. Flow-Duration Curve of Kadıncık-4 HEPP, Alternative I
(Source: DSİ, 2006)

5.3.2. Components of the Project

The components of Kadıncık-4 HEPP project, the feasibility of which is prepared by DSİ, are listed below;

- Kadıncık-4 Weir with 7.50 m crest height and 20 m crest length,
- Settling basin with dimensions 53.0 x 10.8 m,
- 3 canals with total length of 1,095 m and rectangular cross-section,
- 3 tunnels with total length of 6,105 m,
- Head pond with dimensions 25.0 x 10.0 m,
- Penstock with 1.6 m diameter and 565 m length,
- Power central building with dimensions 28 x 15 x 18.5 m,
- 2 Francis turbines with total capacity of 15 MW,
- 2 generators with total capacity of 17.8 MVA,
- 2 transformators with total capacity of 17.8 MVA,
- Transmission line of 3 km with 33 kV voltage,
- Site facilities for engineers and workers,

- 10 km of access road for the access to the components above.

5.3.3. Estimated Costs of the Project (DSİ, 2006)

The unit prices of General Directorate of State Hydraulic Works for 2006 are used for cost estimations.

The length of access roads, transmission canals and tunnels are estimated from the 1/25,000 scaled map of the area, therefore scaling inaccuracies should be considered.

The reinforcing steel is supplied from Iskenderun and the cement is supplied from Adana which are close to the location of the project.

The exchange rate is derived from the statistics of Central Bank of the Republic of Turkey for the year 2006 as 1.42 US$/YTL.

Expropriation fee for the Kadıncık-4 Hydropower Project is estimated as 100,000 US$. Miscellaneous costs are calculated by the summation of 5 percent of the cost of energy equipment and 10 percent of the total construction costs. The total cost of feasibility, development and engineering works is estimated that the cost of this item is the 10 percent of the total cost of other items.

The cost estimation of Kadıncık-4 Hydropower Project is tabulated in Table 5.2.

The revised cost estimation of Kadıncık-4 HEPP is tabulated in Table 5.3 in accordance with Tables 4.6 and 5.2 in order to show the cost items in the same format as RETScreen-Small Hydro Software shows.

Table 5.2. Cost Estimation of Kadıncık-4 HEPP, Alternative I (Source: DSİ, 2006)

NO	COST ITEM	COST	
		YTL	US$
1	Diversion Weir	919,888	647,808
2	Settling Basin	365,279	257,239
3	Transmission Canal - 1 (380 m)	243,918	171,773
4	Transmission Cana - 2 (340 m)	218,243	153,692
5	Transmission Canal - 3 (375 m)	240,709	169,513
6	Tunnel - 1 (L=4 485 m)	13,042,678	9,184,984
7	Tunnel - 2 (L=800 m)	2,014,605	1,418,736
8	Tunnel - 3 (L=725 m)	1,849,596	1,302,533
9	Head Pond	303,497	213,730
10	Penstock (L= 565 m)	2,875,470	2,024,979
11	Power Central Building	1,506,949	1,061,232
12	Transmission Line (L=3 km)	170,400	120,000
13	Access Roads	5,680,000	4,000,000
14	Construction Site Facilities	213,000	150,000
15	Land Right	142,000	100,000
	Construction Works Subtotal	29,786,231	20,976,219
16	Energy Equipment	7,810,743	5,500,523
	Subtotal	37,596,974	26,476,743
17	Miscellaneous (%5 Energy Eqp.+ %10 Constr. Works)	3,369,160	2,372,648
	Plant Subtotal	40,966,135	28,849,391
18	Feasibility, Development and Engineering (%10 Plant Subtotal)	4,096,613	2,884,939
	Total Project Cost	45,062,748	31,734,330

Table 5.3. Revised Cost Estimation of Kadıncık-4 HEPP, Alternative I

COST ITEM	FORMULA NUMBER(S) *(Table 4.6)*	COST ESTIMATION NUMBER(S) *(Table 5.2)*	COST (US$) *(Table 5.2)*
Feasibility Study	1	15 + 18	2,994,939
Development *(including land right)*	2		
Engineering	3		
Energy Equipment (including transformers, generators and installation)	4 + 5 + 8 + 9	16	5,500,523
Access road	6	13	4,000,000
Transmission line	7	12	120,000
Penstock	11 + 12	10	2,024,979
Canal	13	3 + 4 + 5	494,978
Tunnel	14	6 + 7 + 8	11,906,253
Civil works	10	1 + 2 + 9 + 11 + 14	2,330,009
Miscellaneous	15	17	2,372,648
TOTAL COST			31,734,330

5.3.4. Applying Kadıncık-4 HEPP Project to the RETScreen-Small Hydro Project Software

5.3.4.1. Energy model

The inputs and outputs of the *Energy Model* worksheet are shown in Figures 5.4 and 5.5.

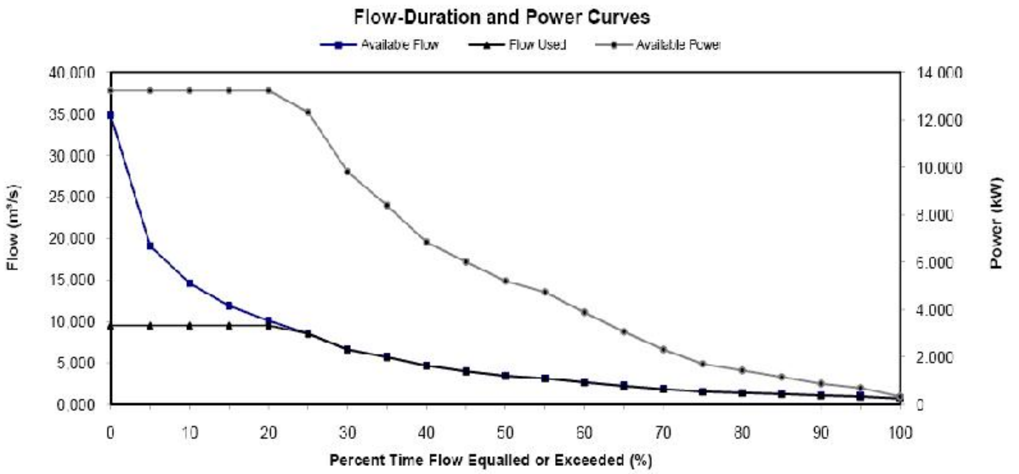
- Maximum tailwater effect is assumed to be zero, because there is no information on this value.
- Maximum hydraulic losses is estimated as 6% since the water conduits are long.
- Generator efficiency is given as 97% (DSİ, 2006).
- Transformer losses, parasitic energy losses and annual downtime losses are assumed as 1%, 2% and 3%, respectively.

Site Conditions		Estimate	Notes/Range
Project name		Kadıncık-4	See Online Manual
Project location		Çamlıyayla, Mersin	
Latitude of project location	°N	37.34	-90.00 to 90.00
Longitude of project location	°E	34.64	-180.00 to 180.00
Gross head	m	178.49	
Maximum tailwater effect	m	0.00	
Residual flow	m³/s	0.10	Complete Hydrology & Load sheet
Firm flow	m³/s	0.70	

System Characteristics		Estimate	Notes/Range
Grid type	-	Central-grid	
Design flow	m³/s	9.500	
Turbine type	-	Francis	Complete Equipment Data sheet
Number of turbines	turbine	2	
Turbine peak efficiency	%	93.1%	
Turbine efficiency at design flow	%	89.9%	
Maximum hydraulic losses	%	6%	2% to 7%
Generator efficiency	%	97%	93% to 97%
Transformer losses	%	1%	1% to 2%
Parasitic electricity losses	%	2%	1% to 3%
Annual downtime losses	%	3%	2% to 7%

Figure 5.4. Kadıncık-4 HEPP Alternative I, Energy Model

Annual Energy Production		Estimate	Notes/Range
Small hydro plant capacity	kW	13,232	
	MW	13.232	
Small hydro plant firm capacity	kW	**332**	
Available flow adjustment factor	-	1.00	
Small hydro plant capacity factor	%	47%	40% to 95%
Renewable energy delivered	MWh	**54,494**	
	GJ	196,179	



Complete Cost Analysis sheet

Figure 5.5. Kadıncık-4 HEPP Alternative I, Energy Model

Small hydro plant capacity of Kadıncık-4 HEPP is calculated as 13.232 MW and the renewable energy delivered by Kadıncık-4 HEPP is calculated as 54.494 GWh by the RETScreen-Small Hydro Software.

5.3.4.2. Hydrology and load

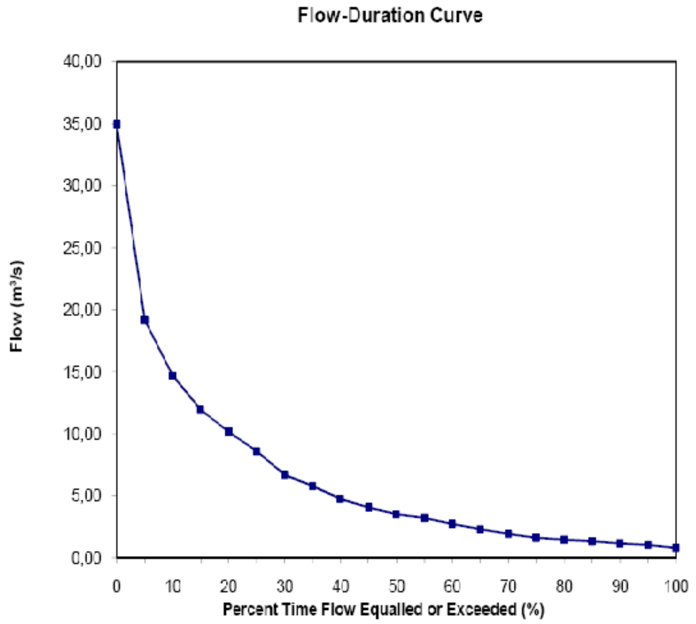
The inputs and outputs of the *Hydrology Analysis and Load Calculation* worksheet are shown in Figure 5.6. The following information is used;

- Residual Flow is given as 0.1 m^3/s
- Percent time firm flow is selected as 100% of time flow equaled or exceeded.
- The data of the flow-duration curve shown in Figure 5.4 are entered into the model.
- The grid type is selected as Central-Grid since the energy delivered by Kadıncık-4 HEPP will be transmitted to the national grid.

Hydrology Analysis		Estimate	Notes/Range
Project type		Run-of-river	
Hydrology method		User-defined	
Hydrology Parameters			
Residual flow	m³/s	0.1	
Percent time firm flow available	%	100%	90% to 100%
Firm flow	m³/s	0.70	

Flow-Duration Curve Data

Time (%)	Flow (m³/s)
0%	34.95
5%	19.18
10%	14.70
15%	11.95
20%	10.17
25%	8.60
30%	6.70
35%	5.79
40%	4.75
45%	4.07
50%	3.52
55%	3.23
60%	2.74
65%	2.31
70%	1.93
75%	1.63
80%	1.48
85%	1.34
90%	1.17
95%	1.05
100%	0.80



Load Characteristics	Estimate	Notes/Range
Grid type	Central-grid	
		Return to Energy Model sheet

Figure 5.6. Kadıncık-4 HEPP Alternative I, Hydrology Analysis

5.3.4.3. Equipment data

The inputs and outputs of the *Equipment Data* worksheet and the efficiency curve for 2 Francis turbines are shown in Figure 5.7.

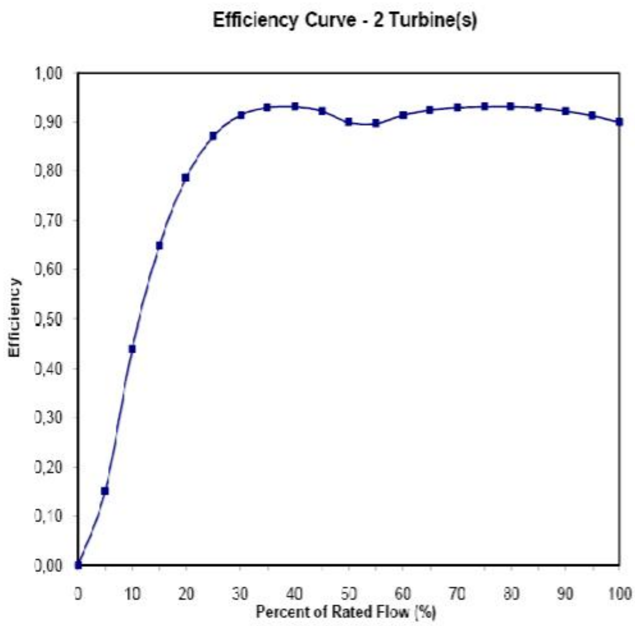
- Turbine manufacture/design coefficient is selected as the default value, 4.5.

- Efficiency adjustment factor is selected as 0%. This adjustment factor can be useful if the efficiency at design flow is given by a turbine manufacturer.

Small Hydro Turbine Characteristics		Estimate	Notes/Range
Gross head	m	178.49	
Design flow	m³/s	9.500	
Turbine type	-	Francis	See Product Database
Turbine efficiency curve data source	-	Standard	
Number of turbines	turbine	2	
Small hydro turbine manufacturer		ABC Ltd.	
Small hydro turbine model		model XYZ	
Turbine manufacture/design coefficient	-	4.5	2.8 to 6.1; Default = 4.5
Efficiency adjustment	%	0%	-5% to 5%
Turbine peak efficiency	%	93.1%	
Flow at peak efficiency	m³/s	7.5	
Turbine efficiency at design flow	%	89.9%	

Turbine Efficiency Curve Data

Flow (%)	Turbine efficiency	Turbines running #	Combined turbine efficiency
0%	0.00	0	0.00
5%	0.00	1	0.15
10%	0.15	1	0.44
15%	0.31	1	0.65
20%	0.44	1	0.79
25%	0.55	1	0.87
30%	0.65	1	0.91
35%	0.73	1	0.93
40%	0.79	1	0.93
45%	0.84	1	0.92
50%	0.87	1	0.90
55%	0.90	2	0.90
60%	0.91	2	0.91
65%	0.92	2	0.92
70%	0.93	2	0.93
75%	0.93	2	0.93
80%	0.93	2	0.93
85%	0.93	2	0.93
90%	0.92	2	0.92
95%	0.91	2	0.91
100%	0.90	2	0.90



Return to Energy Model sheet

Figure 5.7. Kadıncık-4 HEPP Alternative I, Equipment Data

Turbine efficiency at design flow of 9.5 m^3/s is calculated as 89.9% by the RETScreen-Small Hydro Software as seen in Figure 5.7.

5.3.4.4. Cost analysis

The inputs and outputs of the *Cost Analysis* worksheet are shown in Figures 5.8, 5.9 and 5.10. The source of the inputs listed below is the feasibility report of DSİ on Kadıncık-4 HEPP Project except for the project classification selection.

- The climate is selected as not cold.
- Project classification is selected as Mini as the model suggests.
- New dam crest length is entered as 20 m.
- Access road length is entered as 10 km and the terrain difficulty is selected as 6 because the terrain is very hilly. The road will not be used only as a tote road and will be used after construction ends.
- Length of tunnel is entered as 6,105 m and the head loss in tunnel is selected as 4%. The lined portion of the tunnel is assumed to be 15% which is the minimum ratio determined by the model because there is no information on this value.
- Length of canal which is built completely on rock earth is entered as 1,095 m, where there is 5 degrees of slope in the terrain.
- The total length of the penstock is entered as 580 m, and the head loss in penstock is selected as 1%.
- Distance to borrow pits is entered as 5 km.
- Length of transmission line is entered as 3 km and transmission line voltage is entered as 33 kV. The difficulty of terrain over which transmission line is constructed, is selected as 1.5 because of the hilly terrain.
- Interest rate is entered as 9.5%.

Formula Costing Method		
Input Parameters		
Project country		Enter name
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
Exchange rate	$/CAD	0.88
Cold climate?	yes/no	No
Number of turbines	turbine	2
Flow per turbine	m^3/s	4.8
Approx. turbine runner diameter (per unit)	m	1.0
Project classification:		
Suggested classification	-	Mini
Selected classification	-	Mini
Existing dam?	yes/no	No
New dam crest length	m	20.0
Rock at dam site?	yes/no	Yes
Maximum hydraulic losses	%	6%
Intake and miscellaneous losses	%	1%
Access road required?	yes/no	Yes
Length	km	10.0
Tote road only?	yes/no	No
Difficulty of terrain	-	6.0
Tunnel required?	yes/no	Yes
Length	m	6,105
Allowable tunnel headloss factor	%	4.0%
Percent length of tunnel that is lined	%	15%
Tunnel excavation method	-	Mechanised
Tunnel diameter	m	3.9
Canal required?	yes/no	Yes
Length in rock	m	1,095
Terrain side slope in rock (average)	°	5
Length in impervious soil	m	0
Terrain side slope in soil (average)	°	0
Total canal headloss	m	1.095
Penstock required?	yes/no	Yes
Length	m	580.0
Number of identical penstocks	penstock	1
Allowable penstock headloss factor	%	1.0%
Pipe diameter	m	2.01
Average pipe wall thickness	mm	11.3
Distance to borrow pits	km	5.0
Transmission line		
Length	km	3.0
Difficulty of terrain	-	1.5
Voltage	kV	33.0
Interest rate	%	9.5%

Figure 5.8. Kadıncık-4 HEPP Alternative I, Cost Analysis, Inputs

Initial Costs (Formula Method)		Cost (local currency)	Adjustment Factor	Amount (local currency)	Relative Costs
Feasibility Study		$ 940,774	1.00	$ 940,774	3.1%
Development		$ 976,924	1.00	$ 976,924	3.2%
Land rights				$ 100,000	0.3%
Development Sub-total:				$ 1,076,924	3.5%
Engineering		$ 627,770	1.00	$ 627,770	2.1%
Energy Equipment		$ 5,497,400	1.00	$ 5,497,400	18.1%
Balance of Plant					
Access road		$ 4,255,084	1.00	$ 4,255,084	14.0%
Transmission line		$ 94,342	1.00	$ 94,342	0.3%
Substation and transformer		$ 299,778	1.00	$ 299,778	1.0%
Penstock		$ 1,291,691	1.00	$ 1,291,691	4.2%
Canal		$ 437,323	1.00	$ 437,323	1.4%
Tunnel		$ 8,151,317	1.00	$ 8,151,317	26.8%
Civil works (other)		$ 3,778,966	1.00	$ 3,778,966	12.4%
Balance of Plant Sub-total:		$ 18,308,501		$ 18,308,501	60.1%
Miscellaneous		$ 4,001,155	1.00	$ 4,001,155	13.1%
GHG baseline study and MP	Cost	$ -		$ -	0.0%
GHG validation and registration	Cost	$ -		$ -	0.0%
Miscellaneous Sub-total:				$ 4,001,155	13.1%
Initial Costs - Total (Formula Method)		$ 30,352,523		$ 30,452,523	100.0%

Figure 5.9. Kadıncık-4 HEPP Alternative I, Cost Analysis, Initial Costs

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs
O&M					
Land lease	project	1	$ -	$ -	
Property taxes	%	0.0%	$ 30,452,523	$ -	
Water rental	kW	13,232	$ -	$ -	
Insurance premium	%	0.40%	$ 30,452,523	$ 121,810	
Transmission line maintenance	%	5.0%	$ 394,120	$ 19,706	
Spare parts	%	0.50%	$ 30,452,523	$ 152,263	
O&M labour	p-yr	2.00	$ 35,000	$ 70,000	
GHG monitoring and verification	project	0	$ -	$ -	
Travel and accommodation	p-trip	6	$ 1,000	$ 6,000	
General and administrative	%	10%	$ 369,779	$ 36,978	
Other - O&M	Cost	0	$ -	$ -	
Contingencies	%	10%	$ 406,757	$ 40,676	
Annual Costs - Total				$ 447,432	100.0%
Periodic Costs (Credits)		**Period**	**Unit Cost**	**Amount**	
Turbine overhaul	Cost	35 yr	$ 5,497,400	$ 5,497,400	
				$ -	
				$ -	
End of project life	Credit	-		$ -	

Figure 5.10. Kadıncık-4 HEPP Alternative I, Cost Analysis, Annual & Periodic Costs

The total initial and annual costs of the Kadıncık-4 HEPP Project are calculated as 30,452,523 US$ and 447,432 US$ by RETScreen-Small Hydro Software respectively. The energy equipment is assumed to be renewed at the end of the 35th year. The salvage value of the project is taken as zero.

5.3.4.5. Financial summary

The inputs and outputs of the Financial Summary worksheet are shown in Figures 5.11, 5.12, 5.13 and 5.14. The following information is used;

- The avoided cost of energy is entered as 0.075 US$/kWh which was the average value in the market in the year 2006. (DSİ, 2006)
- Energy cost escalation rate is assumed as 0% because there is no guarantee from the government to increase the cost of energy every year.
- The inflation is predicted as 5% for the project life of the Kadıncık-4 HEPP.
- The discount rate is entered as 9.5% (DSİ, 2006).
- The debt ratio is selected as 0% which means all of the initial costs will be paid by the investor himself.
- Effective income tax rate is entered as 20%.
- The depreciation tax basis is 93.3% of the total initial costs and the depreciation method is selected as straight line.
- The depreciation period is 50 years which is equal to the project life of the HEPP, and there will be no tax holiday during this project life.

The project is not feasible according to RETScreen-Small Hydro Software as the net present value and internal rate of return are negative, and the benefit cost ratio is below 1 which is shown in Figure 5.12. The simple payback is after 8.4 years and after the year of 10.3, cash flow becomes positive as shown in Figure 5.14.

Annual Energy Balance

Project name		Kadıncık-4
Project location		Çamlıyayla, Mersin
Renewable energy delivered	MWh	54,494
Excess RE available	MWh	-
Firm RE capacity	kW	332
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	%	93.3%
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			

Figure 5.11. Kadıncık-4 HEPP Alternative I, Financial Summary, Inputs

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	3.1%	$	940,774	O&M	$	447,432
Development	3.5%	$	1,076,924			
Engineering	2.1%	$	627,770			
Energy equipment	18.1%	$	5,497,400	**Annual Costs and Debt - Total**	**$**	**447,432**
Balance of plant	60.1%	$	18,308,501			
Miscellaneous	13.1%	$	4,001,155	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**$**	**30,452,523**	Energy savings/income	$	4,087,071
				Capacity savings/income	$	-
Incentives/Grants		$	-			
				Annual Savings - Total	**$**	**4,087,071**
Periodic Costs (Credits)						
Turbine overhaul		$	5,497,400	Schedule yr # 35		
		$	-			
		$	-			
End of project life - Credit		$	-			

Figure 5.12. Kadıncık-4 HEPP Alternative I, Financial Summary, Feasibility

The yearly cash flows and the cumulative cash flow are shown in Figure 5.13 and 5.14, respectively.

Yearly Cash Flows			
Year	Pre-tax	After-tax	Cumulative
#	$	$	$
0	(30,452,523)	(30,452,523)	(30,452,523)
1	3,617,268	3,415,527	(27,036,996)
2	3,593,777	2,988,671	(24,048,325)
3	3,569,113	2,968,939	(21,079,386)
4	3,543,215	2,948,221	(18,131,166)
5	3,516,022	2,926,466	(15,204,699)
6	3,487,469	2,903,624	(12,301,075)
7	3,457,489	2,879,640	(9,421,435)
8	3,426,010	2,854,457	(6,566,978)
9	3,392,957	2,828,014	(3,738,964)
10	3,358,251	2,800,250	(938,714)
11	3,321,810	2,771,097	1,832,384
12	3,283,547	2,740,487	4,572,870
13	3,243,371	2,708,346	7,281,216
14	3,201,186	2,674,598	9,955,814
15	3,156,892	2,639,162	12,594,976
16	3,110,383	2,601,955	15,196,931
17	3,061,548	2,562,888	17,759,819
18	3,010,272	2,521,867	20,281,685
19	2,956,432	2,478,795	22,760,480
20	2,899,900	2,433,569	25,194,049
21	2,840,542	2,386,082	27,580,132
22	2,778,215	2,336,221	29,916,353
23	2,712,773	2,283,867	32,200,220
24	2,644,058	2,228,895	34,429,115
25	2,571,907	2,171,174	36,600,289
26	2,496,149	2,110,568	38,710,857
27	2,416,603	2,046,931	40,757,788
28	2,333,079	1,980,112	42,737,900
29	2,245,380	1,909,953	44,647,853
30	2,153,295	1,836,285	46,484,138
31	2,056,606	1,758,934	48,243,071
32	1,955,083	1,677,715	49,920,787
33	1,848,484	1,592,436	51,513,222
34	1,736,554	1,502,892	53,016,114
35	(28,704,712)	(28,704,712)	24,311,403
36	1,495,626	1,495,626	25,807,029
37	1,366,054	1,366,054	27,173,083
38	1,230,003	1,230,003	28,403,086
39	1,087,150	1,087,150	29,490,235
40	937,154	937,154	30,427,389
41	779,658	779,658	31,207,046
42	614,287	614,287	31,821,333
43	440,648	440,648	32,261,981
44	258,327	258,327	32,520,308
45	66,889	66,889	32,587,197
46	(134,120)	(134,120)	32,453,077
47	(345,179)	(345,179)	32,107,898
48	(566,792)	(566,792)	31,541,106
49	(799,485)	(799,485)	30,741,621
50	(1,043,813)	(1,043,813)	29,697,808

Figure 5.13. Kadıncık-4 HEPP Alternative I, Financial Summary, Yearly Cash Flows

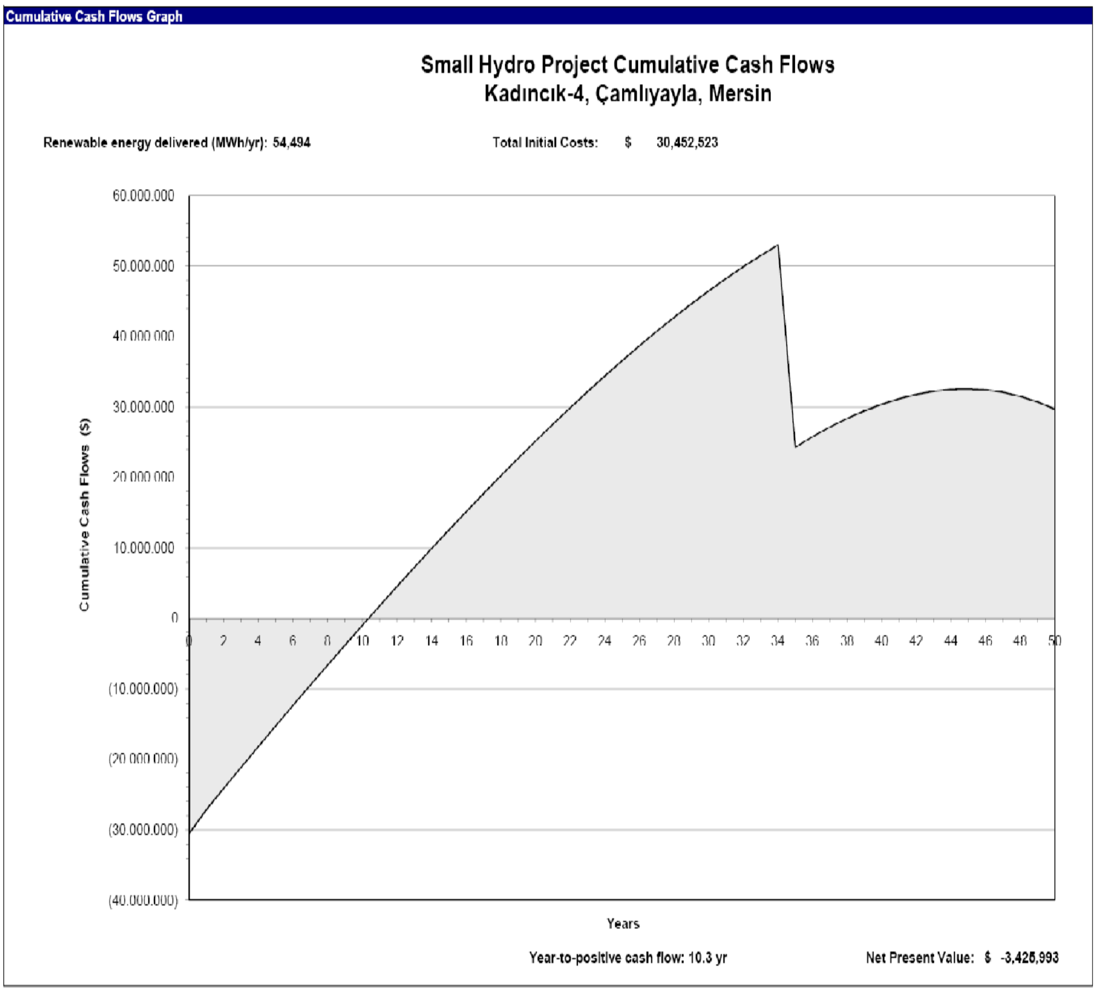


Figure 5.14. Kadıncık-4 HEPP Alternative I, Financial Summary, Cash Flow Graph

5.3.5. Analysis and Comparison of the Outputs

5.3.5.1. Delivered energy and installed power

The comparison of the energy and power output results of Kadıncık-4 HEPP Project between RETScreen-Small Hydro Software and the feasibility study of General Directorate of State Hydraulic Works is shown in Table 5.4.

RETScreen-Small Hydro Software estimated the same amount of delivered annual energy as General Directorate of State Hydraulics estimated in the feasibility report. But there is a difference of 11.8% in the estimated installed capacity values.

Table 5.4. The Comparison of Energy Output Results of Kadıncık-4 HEPP, Alternative I

Parameter	RETScreen's Estimation	DSİ's Estimation	Ratio
Installed Capacity	13.23 MW	15 MW	88.2%
Delivered Energy	54.49 GWh/year	54.52 GWh/year	99.9%

5.3.5.2. Cost of the project

In the feasibility study of General Directorate of State Hydraulic Works, the cost of transformers is included in the total cost of energy equipment with all the installation works. However, RETScreen-Small Hydro Model calculates the cost of transformers separately and all of the installation works are included in the cost of Civil Works as discussed earlier. This occurs also for the calculation of the cost of penstock. Therefore, using the formulae specified in Table 4.5, all of the costs related with the work categories are tabulated in order to make a reliable comparison. The comparison between two calculations is shown in Table 5.5.

Table 5.5. The Comparison of Cost Estimations of Kadıncık-4 HEPP, Alternative I

COST ITEM	RETSCREEN-SMALL HYDRO SOFTWARE		FEASIBILITY STUDY		RATIO
	FORMULA NUMBER	COST US$	ITEM NUMBER	COST US$	
Feasibility Study	1	2,645,468	15+18	2,994,939	88.3%
Development (including land right)	2				
Engineering	3				
Energy Equipment	4	6,141,536	16	5,500,523	111.7%
Installation of Energy Equipment	5				
Substation and transformer	8				
Installation of substation and transformer	9				
Access road	6	4,255,084	13	4,000,000	106.4%
Transmission line	7	94,342	12	120,000	78.6%
Civil works	10	3,368,464	1 + 2 + 9 + 11 + 14	2,330,009	140.9%
Penstock	11	1,357,884	10	2,024,979	67.1%
Installation of Penstock	12				
Canal	13	437,323	3 + 4 + 5	494,978	88.4%
Tunnel	14	8,151,317	6 + 7 + 8	11,906,253	68.5%
Miscellaneous	15	4,001,155	17	2,372,648	168.6%
INITIAL COSTS - TOTAL	∑	30,452,573	∑	31,744,329	95.9%

The RETScreen-Small Hydro Software calculated total cost is 4.1% lower than the General Directorate of State Hydraulics calculation in the feasibility study, which is an acceptable error (See Table 5.5). However, there are major differences in the costs of tunnels, civil works, penstock, and miscellaneous.

In the calculation of the cost of the tunnels, the length of lined surface is very important which has to be assumed to be minimum in the RETScreen's estimation. Therefore the 31.5% difference between the two estimations is because of the lack of information.

There is also a lack of information about the equipment costs ratio between Canada and Turkey which is assumed to be unity causing the estimated cost of civil works differ by 40.9%.

RETScreen-Small Hydro Software does not allow the user to enter a value for the diameter of the penstock, instead, this value is calculated by the software using the value entered for the head loss in the penstock. The calculated value of the diameter by the software and the value given in the feasibility report differs. In the feasibility report, diameter is given as 1.6 meters while it is calculated as 2.01 meters by the software. Although, the diameter is calculated 20% larger by the software, the cost of penstock is calculated 32.9% smaller, which could not be explained.

The 68.6% difference in the cost of miscellaneous works is caused because of the different approaches used in estimating it by RETScreen and General Directorate of State Hydraulic Works. RETScreen estimated miscellaneous costs as 13.1% of the total cost while the feasibility study estimated miscellaneous costs as 7.4% of the total cost, which is 56.9% smaller. This can be adjusted by using this percentage as an adjustment factor.

5.3.5.3. Financial summary

In the feasibility study of General Directorate of State Hydraulic Works, the method of financial analysis is based on comparing the avoided cost of energy of the HEPP with the equivalent energy generated from coal, which is very different with the method used by RETScreen.

The method used by RETScreen-Small Hydro Model in the financial summary worksheet was described in previous chapters. The initial cost of the project is assumed to be spent at the beginning of the construction. Therefore, the cumulative cash flow starts with the negative value of the total initial cost in the year zero. The project is not feasible according to RETScreen-Small Hydro Model as described in Section 5.3.4.5.

5.4. Design of İÇTAŞ Energy and Trade Co. Alternative II

In this alternative, the location of the Kadıncık-4 Weir is changed which can be seen in Figure 5.3 and the new coordinates of the weir is 37^o10’23’’ North - 34^o42’33’’ East (İÇTAŞ, 2006). The water of Kadıncık River is diverted by Kadıncık-4 Weir to a transmission canal and then, through a penstock to the turbines with total installed power of 21.9 MW and annual energy generation of 91.52 GWh in Kadıncık-4 HEPP powerhouse which is located on 423.50 m elevation. Water is then discharged back into Kadıncık River, eventually flowing into the Mediterranean Sea. The gross head of the project is 60.58 m and the design flow is selected as 41.00 m^3/s (İÇTAŞ, 2006).

5.4.1. Hydrology Data

The drainage area of Kadıncık-4 Weir in this alternative is 322.0 km^2 and the average annual precipitation is 1023.7 mm according to the data collected by Tarsus and Mersin stations. The monthly flow data of

Kadıncık-4 Weir are given in Table 5.6 and the flow-duration curve is shown in Figure 5.15.

Table 5.6. Kadıncık-4 Weir Monthly Flow Data 1972-2004 (m^3/s) – Alternative II (İÇTAŞ,2006)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1972	8.70	13.33	15.57	12.91	15.97	23.76	59.57	65.29	49.78	26.33	19.70	16.06
1973	16.79	15.35	12.81	11.04	14.88	20.51	24.80	25.16	19.43	11.90	8.95	8.12
1974	7.00	7.45	9.44	8.20	10.07	34.81	33.09	34.31	20.57	9.46	7.59	6.68
1975	6.55	6.90	24.22	25.52	29.94	36.61	76.22	71.05	53.50	25.74	12.82	8.79
1976	7.02	7.45	9.73	14.60	14.58	19.68	42.76	57.55	39.16	19.31	10.60	7.63
1977	10.93	14.42	26.69	19.67	29.48	23.30	42.51	50.74	34.45	17.09	9.45	8.29
1978	7.38	7.30	11.66	27.66	32.99	34.50	46.70	65.25	38.63	16.67	9.83	7.81
1979	10.05	12.00	16.42	23.94	25.32	26.18	40.96	39.69	35.47	18.47	12.43	9.51
1980	9.98	18.56	20.99	20.93	20.43	37.99	65.65	68.33	43.65	17.24	10.77	8.32
1981	7.72	9.62	9.45	33.27	41.89	51.79	57.71	60.56	64.49	31.86	14.55	10.43
1982	8.76	10.29	22.58	18.59	14.01	22.84	48.75	53.35	40.50	19.91	11.88	11.17
1983	10.34	8.51	8.60	16.23	17.71	34.39	53.88	56.28	37.11	16.77	13.19	10.87
1984	10.01	17.80	32.49	22.91	31.86	31.71	44.92	46.96	33.69	17.35	11.92	9.30
1985	8.40	16.43	10.41	14.09	20.49	24.05	44.00	42.56	26.94	13.69	9.70	8.02
1986	11.17	28.07	18.57	26.29	27.01	28.93	37.68	28.44	35.54	19.23	10.41	8.32
1987	7.69	9.53	9.76	17.83	16.79	27.30	35.38	45.56	30.99	15.87	10.36	8.49
1988	8.29	14.01	21.38	17.12	23.59	37.65	53.91	61.54	42.63	21.89	13.59	10.26
1989	15.28	19.31	19.08	20.56	19.46	29.98	38.50	29.21	17.46	10.77	8.97	8.12
1990	8.85	13.41	14.63	8.60	18.51	37.33	36.46	34.35	28.19	12.76	8.44	6.99
1991	6.86	6.73	8.34	7.02	10.62	21.67	28.86	23.08	17.58	11.64	9.16	8.03
1992	10.50	9.54	20.60	18.57	13.35	22.54	45.88	47.45	38.32	18.73	11.83	9.22
1993	8.17	12.48	19.73	15.02	17.30	28.71	43.51	44.30	34.79	17.62	12.15	10.21
1994	8.86	8.83	9.51	15.69	15.80	20.82	30.85	29.96	19.99	11.64	9.46	8.87
1995	8.14	12.72	11.88	13.26	15.94	21.18	35.86	50.84	38.79	19.39	12.57	9.35
1996	7.42	11.68	13.03	26.00	28.28	36.46	48.13	69.58	44.88	25.66	16.85	12.28
1997	9.95	8.24	27.05	22.91	16.05	16.27	33.03	48.07	38.33	23.27	13.64	11.15
1998	16.95	19.43	24.46	18.10	17.30	19.23	49.94	55.26	37.12	21.72	13.46	10.05
1999	9.42	8.79	17.77	17.62	23.62	27.37	46.39	48.79	33.17	20.38	14.49	11.17
2000	9.15	8.25	7.40	7.94	12.62	17.80	41.94	42.94	28.90	16.66	12.22	10.19
2001	8.56	8.68	11.02	10.06	9.74	17.84	20.60	27.79	14.16	9.66	7.54	6.35
2002	5.57	6.53	38.43	30.33	31.59	44.12	66.19	73.57	66.56	40.44	25.03	21.81
2003	16.25	12.27	10.41	10.79	13.90	19.79	42.54	45.03	37.55	21.61	15.93	12.00
2004	9.57	9.13	11.90	16.31	22.27	41.63	37.78	38.90	29.54	18.32	12.31	9.67
Avg	**9.58**	**11.91**	**16.55**	**17.87**	**20.40**	**28.45**	**44.09**	**47.93**	**35.51**	**18.76**	**12.18**	**9.80**

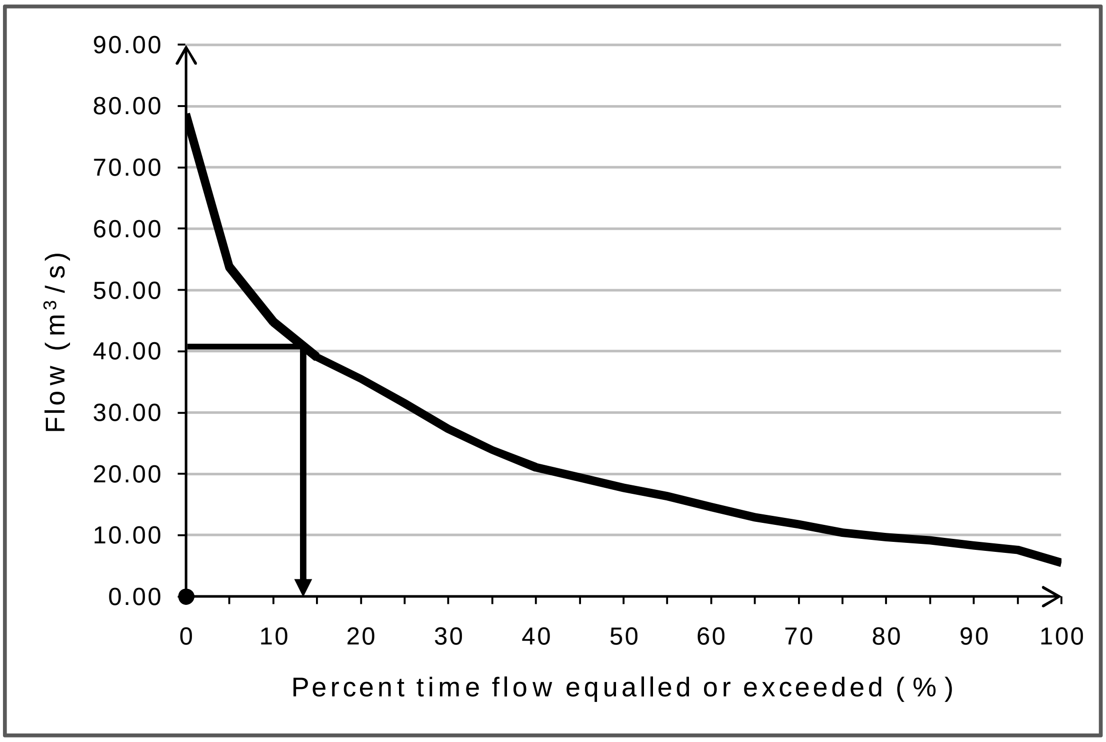


Figure 5.15. Flow-Duration Curve of Kadıncık-4 HEPP, Alternative II
(Source: İÇTAŞ, 2006)

Kadıncık-4 Weir is not designed for other purposes such as water storage. For environmental reasons, 0.05 m^3/s of residual flow will be left in Kadıncık River. The firm flow is selected as the flow being available at 95% of time. The design flow is determined in the feasibility report as 41.0 m^3/s which corresponds to flow being available at 13% of the time as seen in Figure 5.15, which is a very low percentage.

5.4.2. Components of the Project

- Kadıncık-4 Weir with 5.90 m crest height and 20 m crest length.
- Settling basin with dimensions 53.0 x 30.4 m.
- 1 canal of 1,172 m length with rectangular cross-section.
- Head pond with dimensions 75.0 x 25.0 m.
- Penstock with 3.2 m diameter and 140 m length.

- Power central building with dimensions 48 x 17 x 20 m.
- 2 identical Francis turbines with total capacity of 21.9 MW.
- 3 identical generators with total capacity of 25.8 MVA.
- 3 transformators with total capacity of 27 MVA.
- Transmission line of 3 km with 33 kV voltage.
- Site facilities for engineers and workers,
- 10 km of access road for the access to the components above.

5.4.3. Estimated Costs of the Project

The information given in Section 5.3.3 are valid for this feasibility report prepared by İÇTAŞ.

The cost estimation of Kadıncık-4 HEPP is tabulated in Table 5.7.

The revised cost estimation of Kadıncık-4 HEPP is tabulated in Table 5.8 in accordance with Tables 4.6 and 5.7 in order to show the cost items in the same format as RETScreen-Small Hydro Software shows.

Table 5.7. Cost Estimation of Kadıncık-4 HEPP, Alternative II (Source: İÇTAŞ, 2006)

NO	ITEM	COST	
		YTL	US$
1	Diversion Weir	798,015	561,982
2	Settling Basin	1,578,136	1,111,363
3	Transmission Canal (1.172 m)	1,900,868	1,338,639
4	Head Pond	1,407,549	991,232
5	Penstock (L= 565 m)	1,987,596	1,399,715
6	Power Central Building	1,671,212	1,176,910
7	Transmission Line (L=3 km)	170,400	120,000
8	Access Roads	1,704,000	1,200,000
9	Construction Site Facilities	213,000	150,000
10	Land Right	142,000	100,000
	Construction Works Subtotal	11,572,776	8,149,842
11	Energy Equipment	11,452,116	8,064,870
	Subtotal	23,024,892	16,214,713
12	Miscellaneous (%5 Energy Eqp.+ %10 Constr. Works)	1,729,883	1,218,228
	Plant Subtotal	24,754,775	17,432,940
13	Feasibility, Development and Engineering (%10 Plant Subtotal)	2,475,478	1,743,294
	Total Project Cost	27,230,253	19,176,234

Table 5.8. Revised Cost Estimation of Kadıncık-4 HEPP, Alternative II (Source: İÇTAŞ, 2006)

COST ITEM	FORMULA(E) NUMBER(S) *(Table 10)*	COST ESTIMATION NUMBER(S) *(Table 19)*	COST (US$) *(Table 19)*
Feasibility Study	1	10+13	1,843,294
Development *(including land right)*	2		
Engineering	3		
Energy Equipment (including transformers, generators and installation)	4 + 5 + 8 + 9	11	8,064,870
Access road	6	8	1,200,000
Transmission line	7	7	120,000
Penstock	11 + 12	5	1,399,715
Canal	13	3	1,338,639
Civil works	10	1 + 2 + 4 + 6 + 9	3,991,487
Miscellaneous	15	12	1,218,228
TOTAL COST			19,176,234

5.4.4. Applying Kadıncık-4 HEPP Project to the RETScreen-Small Hydro Project Software

5.4.4.1. Energy model

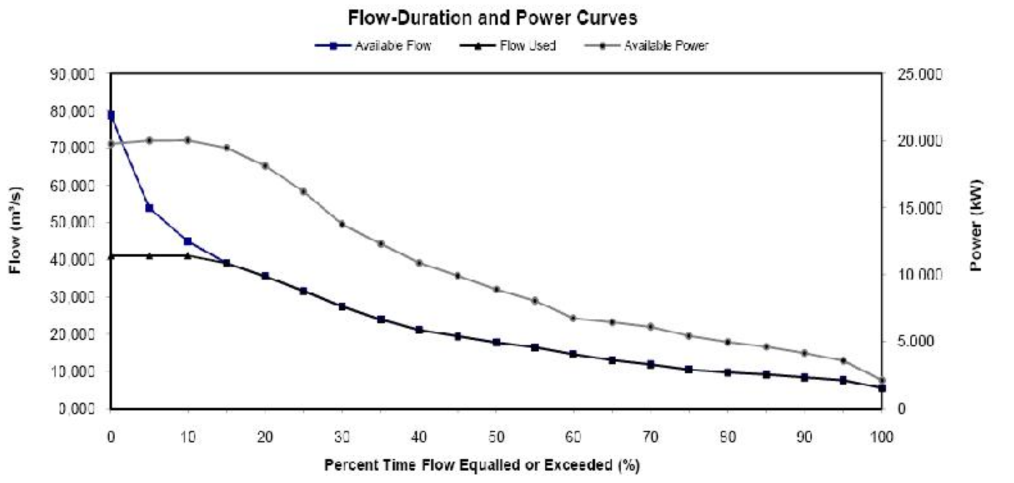
The inputs and outputs of the *Energy Model* worksheet are shown in Figures 5.16 and 5.17, respectively.

Site Conditions		Estimate		Notes/Range
Project name		Kadıncık-4		See Online Manual
Project location		Çamlıyayla, Mersin		
Latitude of project location	°N	37.34		-90.00 to 90.00
Longitude of project location	°E	34.64		-180.00 to 180.00
Gross head	m	60.58		
Maximum tailwater effect	m	0.00		
Residual flow	m³/s	0.05	➡	Complete Hydrology & Load sheet
Firm flow	m³/s	7.57		

System Characteristics		Estimate		Notes/Range
Grid type	-	Central-grid		
Design flow	m³/s	41.000		
Turbine type	-	Francis	➡	Complete Equipment Data sheet
Number of turbines	turbine	3		
Turbine peak efficiency	%	93.0%		
Turbine efficiency at design flow	%	89.1%		
Maximum hydraulic losses	%	2%		2% to 7%
Generator efficiency	%	97%		93% to 97%
Transformer losses	%	1%		1% to 2%
Parasitic electricity losses	%	2%		1% to 3%
Annual downtime losses	%	3%		2% to 7%

Figure 5.16. Kadıncık-4 HEPP Alternative II, Energy Model

Annual Energy Production		Estimate	Notes/Range
Small hydro plant capacity	kW	20.014	
	MW	20,014	
Small hydro plant firm capacity	kW	**3.545**	
Available flow adjustment factor	-	1.00	
Small hydro plant capacity factor	%	51%	40% to 95%
Renewable energy delivered	MWh	**89.407**	
	GJ	321.866	



Complete Cost Analysis sheet

Figure 5.17. Kadıncık-4 HEPP Alternative II, Energy Model

Small hydro plant capacity of Kadıncık-4 Hydropower Project for the second alternative is calculated as 20.014 MW and the renewable energy delivered by Kadıncık-4 HEPP is calculated as 89.407 GWh/year by the RETScreen-Small Hydro Software as seen in Figure 5.18.

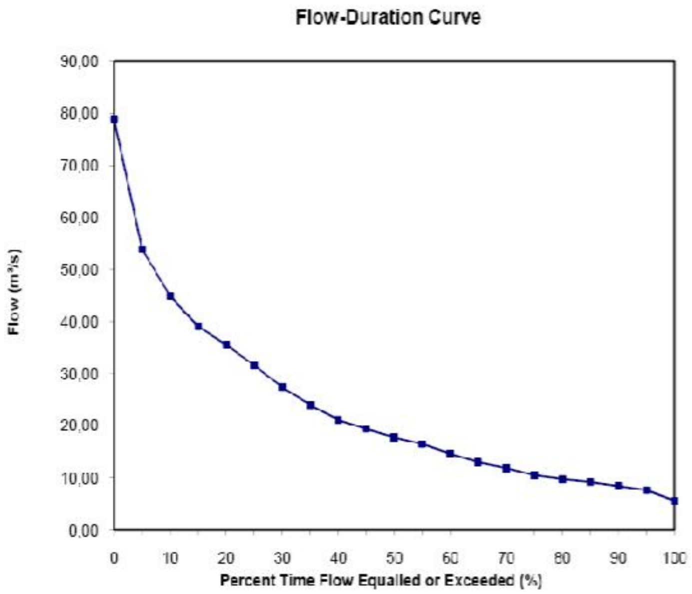
5.4.4.2. Hydrology and load

The inputs and outputs of the *Hydrology Analysis and Load Calculation* worksheet are shown in Figure 5.18.

Hydrology Analysis		Estimate	Notes/Range
Project type		Run-of-river	
Hydrology method		User-defined	
Hydrology Parameters			
Residual flow	m^3/s	0.05	
Percent time firm flow available	%	95%	90% to 100%
Firm flow	m^3/s	7.57	

Flow-Duration Curve Data

Time (%)	Flow (m^3/s)
0%	78.81
5%	53.89
10%	44.90
15%	39.06
20%	35.53
25%	31.59
30%	27.43
35%	23.98
40%	21.10
45%	19.43
50%	17.80
55%	16.48
60%	14.61
65%	12.98
70%	11.88
75%	10.50
80%	9.74
85%	9.18
90%	8.42
95%	7.62
100%	5.57



Load Characteristics	Estimate	Notes/Range
Grid type	Central-grid	
		Return to Energy Model sheet

Figure 5.18. Kadıncık-4 HEPP Alternative II, Hydrology Analysis

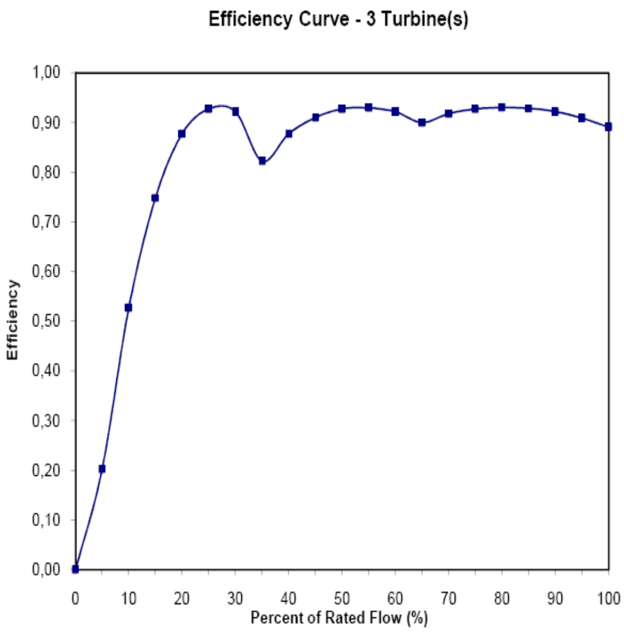
5.4.4.3. Equipment data

The inputs and outputs of the *Equipment Data* worksheet and the efficiency curve for 3 Francis turbines are shown in Figure 5.19.

Small Hydro Turbine Characteristics		Estimate	Notes/Range
Gross head	m	60,58	
Design flow	m³/s	41,000	
Turbine type	-	Francis	See Product Database
Turbine efficiency curve data source	-	Standard	
Number of turbines	turbine	3	
Small hydro turbine manufacturer			
Small hydro turbine model			
Turbine manufacture/design coefficient	-	4,5	2.8 to 6.1; Default = 4.5
Efficiency adjustment	%	0%	-5% to 5%
Turbine peak efficiency	%	93,0%	
Flow at peak efficiency	m³/s	33,3	
Turbine efficiency at design flow	%	89,1%	

Turbine Efficiency Curve Data

Flow (%)	Turbine efficiency	Turbines running #	Combined turbine efficiency
0%	0,00	0	0,00
5%	0,00	1	0,20
10%	0,07	1	0,53
15%	0,20	1	0,75
20%	0,32	1	0,88
25%	0,43	1	0,93
30%	0,53	1	0,92
35%	0,61	2	0,82
40%	0,69	2	0,88
45%	0,75	2	0,91
50%	0,80	2	0,93
55%	0,84	2	0,93
60%	0,88	2	0,92
65%	0,90	2	0,90
70%	0,92	3	0,92
75%	0,93	3	0,93
80%	0,93	3	0,93
85%	0,93	3	0,93
90%	0,92	3	0,92
95%	0,91	3	0,91
100%	0,89	3	0,89



Return to
Energy Model sheet

Figure 5.19. Kadıncık-4 HEPP Alternative II, Equipment Data

Turbine efficiency at design flow of 41.0 m^3/s is calculated as 89.1% by the RETScreen-Small Hydro Software.

5.4.4.4. Cost analysis

The inputs and outputs of the *Cost Analysis* worksheet are shown in Figures 5.20, 5.21 and 5.22. The source of the inputs listed below is the feasibility report of İÇTAŞ on Kadıncık-4 HEPP Project with an exception in the project classification selection.

- The climate is selected as not cold.
- Project classification is selected as Small as the model suggests Small.
- Access road length is entered as 3 km and the terrain difficulty is selected as 6. The road is not used only as a tote road.
- Length of canal, which is built completely in rock, where there is slope with 5 degrees, is entered as 1,172 m.
- Length of penstock is entered as 140 m, and the head loss in penstock is selected as 1%.
- Distance to borrow pits is entered as 5 km.

Formula Costing Method		
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
Exchange rate	$/CAD	0.88
Cold climate?	yes/no	No
Number of turbines	turbine	3
Flow per turbine	m³/s	13.7
Approx. turbine runner diameter (per unit)	m	1.6
Project classification:		
Suggested classification	-	Small
Selected classification	-	Small
Existing dam?	yes/no	No
New dam crest length	m	20.0
Rock at dam site?	yes/no	Yes
Maximum hydraulic losses	%	2%
Intake and miscellaneous losses	%	1%
Access road required?	yes/no	Yes
Length	km	3.0
Tote road only?	yes/no	No
Difficulty of terrain	-	6.0
Tunnel required?	yes/no	No
Canal required?	yes/no	Yes
Length in rock	m	1,172
Terrain side slope in rock (average)	°	5
Length in impervious soil	m	0
Terrain side slope in soil (average)	°	0
Total canal headloss	m	1.172
Penstock required?	yes/no	Yes
Length	m	140.0
Number of identical penstocks	penstock	1
Allowable penstock headloss factor	%	1.0%
Pipe diameter	m	3.29
Average pipe wall thickness	mm	10.7
Distance to borrow pits	km	5.0
Transmission line		
Length	km	3.0
Difficulty of terrain	-	1.5
Voltage	kV	33.0
Interest rate	%	9.5%

Figure 5.20. Kadıncık-4 HEPP Alternative II, Cost Analysis

Initial Costs (Formula Method)		Cost (local currency)	Adjustment Factor	Amount (local currency)	Relative Costs
Feasibility Study		$ 1,308,443	1.00	$ 1,308,443	3.1%
Development		$ 1,315,496	1.00	$ 1,315,496	3.1%
Land rights				$ 100,000	0.2%
Development Sub-total:				$ 1,415,496	3.3%
Engineering		$ 984,859	1.00	$ 984,859	2.3%
Energy Equipment		$ 15,868,837	1.00	$ 15,868,837	37.5%
Balance of Plant					
Access road		$ 1,439,816	1.00	$ 1,439,816	3.4%
Transmission line		$ 94,342	1.00	$ 94,342	0.2%
Substation and transformer		$ 618,953	1.00	$ 618,953	1.5%
Penstock		$ 542,246	1.00	$ 542,246	1.3%
Canal		$ 1,734,304	1.00	$ 1,734,304	4.1%
Tunnel		$ -	1.00	$ -	0.0%
Civil works (other)		$ 11,598,764	1.00	$ 11,598,764	27.4%
Balance of Plant Sub-total:		$ 16,028,424		$ 16,028,424	37.9%
Miscellaneous		$ 6,697,393	1.00	$ 6,697,393	15.8%
GHG baseline study and MP	Cost	$ -		$ -	0.0%
GHG validation and registration	Cost	$ -		$ -	0.0%
Miscellaneous Sub-total:				$ 6,697,393	15.8%
Initial Costs - Total (Formula Method)		$ 42,203,452		$ 42,303,452	100.0%

Figure 5.21. Kadıncık-4 HEPP Alternative II, Cost Analysis, Initial Costs

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs
O&M					
Land lease	project	1	$ -	$ -	
Property taxes	%	0.0%	$ 42,303,452	$ -	
Water rental	kW	20,014	$ -	$ -	
Insurance premium	%	0.40%	$ 42,303,452	$ 169,214	
Transmission line maintenance	%	2.0%	$ 713,295	$ 14,266	
Spare parts	%	0.50%	$ 42,303,452	$ 211,517	
O&M labour	p-yr	2.00	$ 35,000	$ 70,000	
GHG monitoring and verification	project	0	$ -	$ -	
Travel and accommodation	p-trip	6	$ 1,000	$ 6,000	
General and administrative	%	10%	$ 470,997	$ 47,100	
Other - O&M	Cost	0	$ -	$ -	
Contingencies	%	10%	$ 518,097	$ 51,810	
Annual Costs - Total				$ 569,906	100.0%

Periodic Costs (Credits)		Period	Unit Cost	Amount
Turbine overhaul	Cost	35 yr	$ 15,868,837	$ 15,868,837
				$ -
				$ -
End of project life	Credit	-		$ -

Figure 5.22. Kadıncık-4 HEPP Alternative II, Cost Analysis, Annual Costs

The total initial and annual costs of the Kadıncık-4 HEPP Project are calculated as 42,303,452 US$ and 569,906 US$ by RETScreen-Small

Hydro Model, respectively. The energy equipment is assumed to be renewed at the end of the 35th year. The salvage value of the project is taken as zero.

5.4.4.5. Financial summary

The inputs and outputs of the Financial Summary worksheet are shown in Figures 5.23, 5.24, 5.25, and 5.26.

Annual Energy Balance		
Project name		Kadıncık-4
Project location		Çamlıyayla, Mersin
Renewable energy delivered	MWh	89,474
Excess RE available	MWh	-
Firm RE capacity	kW	3,545
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			

Figure 5.23. Kadıncık-4 HEPP Alternative II, Financial Summary, Inputs

The project is feasible according to RETScreen-Small Hydro Model as the net present value and internal rate of return are positive and the benefit cost ratio is above 1 which is shown in Figure 5.24. The simple payback is after 6.9 years and cash-flow turns positive after the year 8.4.

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	3.1%	$	1,308,443	O&M	$	569,906
Development	3.3%	$	1,415,496			
Engineering	2.3%	$	984,859			
Energy equipment	37.5%	$	15,868,837	**Annual Costs and Debt - Total**	**$**	**569,906**
Balance of plant	37.9%	$	16,028,424			
Miscellaneous	15.8%	$	6,697,393	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**$**	**42,303,452**	Energy savings/income	$	6,710,550
				Capacity savings/income	$	-
Incentives/Grants		$	-			
				Annual Savings - Total	**$**	**6,710,550**
Periodic Costs (Credits)						
Turbine overhaul		$	15,868,837	Schedule yr # 35		
		$	-			
		$	-			
End of project life - Credit		$	-			

Financial Feasibility

			Calculate energy production cost?	yes/no	No
Pre-tax IRR and ROI	%	13.3%			
After-tax IRR and ROI	%	10.5%			
Simple Payback	yr	6.9			
Year-to-positive cash flow	yr	8.4	Project equity	$	42,303,452
Net Present Value - NPV	$	2,889,290			
Annual Life Cycle Savings	$	277,451			
Benefit-Cost (B-C) ratio	-	1.07			

Figure 5.24. Kadıncık-4 HEPP Alternative II, Financial Summary, Feasibility

The yearly cash flows and the cumulative cash flow are shown in Figures 5.25 and 5.26, respectively.

Yearly Cash Flows			
Year \#	Pre-tax $	After-tax $	Cumulative $
0	(42,303,452)	(42,303,452)	(42,303,452)
1	6,112,149	5,597,879	(36,705,574)
2	6,082,228	5,023,998	(31,681,576)
3	6,050,812	4,998,865	(26,682,711)
4	6,017,825	4,972,475	(21,710,236)
5	5,983,109	4,944,766	(16,765,470)
6	5,946,021	4,915,672	(11,849,798)
7	5,908,636	4,885,123	(6,964,675)
8	5,868,539	4,853,046	(2,111,629)
9	5,826,438	4,819,366	2,707,737
10	5,782,233	4,784,001	7,491,738
11	5,735,817	4,746,868	12,238,606
12	5,687,080	4,707,879	16,946,485
13	5,635,907	4,666,940	21,613,425
14	5,582,175	4,623,955	26,237,380
15	5,525,756	4,578,820	30,816,200
16	5,466,516	4,531,428	35,347,628
17	5,404,314	4,401,666	39,029,294
18	5,339,003	4,429,417	44,250,711
19	5,270,425	4,374,555	48,633,266
20	5,198,419	4,316,950	52,950,216
21	5,122,812	4,256,465	57,206,681
22	5,043,426	4,192,955	61,399,637
23	4,960,069	4,126,270	65,525,907
24	4,872,545	4,056,251	69,582,158
25	4,780,645	3,982,731	73,564,889
26	4,684,150	3,905,535	77,470,424
27	4,582,830	3,824,479	81,294,903
28	4,476,444	3,739,370	85,034,272
29	4,364,738	3,650,006	88,684,278
30	4,247,448	3,556,173	92,240,451
31	4,124,293	3,457,649	95,698,100
32	3,994,980	3,354,199	99,052,299
33	3,859,201	3,245,576	102,297,875
34	3,716,634	3,131,522	105,429,397
35	(83,965,809)	(83,965,809)	21,463,589
36	3,409,757	3,409,757	24,873,346
37	3,244,718	3,244,718	28,118,064
38	3,071,426	3,071,426	31,189,490
39	2,889,470	2,889,470	34,078,960
40	2,698,416	2,698,416	36,777,376
41	2,497,809	2,497,809	39,275,185
42	2,287,172	2,287,172	41,562,357
43	2,066,003	2,066,003	43,628,361
44	1,833,776	1,833,776	45,462,137
45	1,589,937	1,589,937	47,052,074
46	1,333,907	1,333,907	48,385,981
47	1,065,074	1,065,074	49,451,055
48	782,801	782,801	50,233,856
49	486,413	486,413	50,720,269
50	175,206	175,206	50,895,475

Figure 5.25. Kadıncık-4 HEPP Alternative II, Financial Summary, Yearly Cash Flows

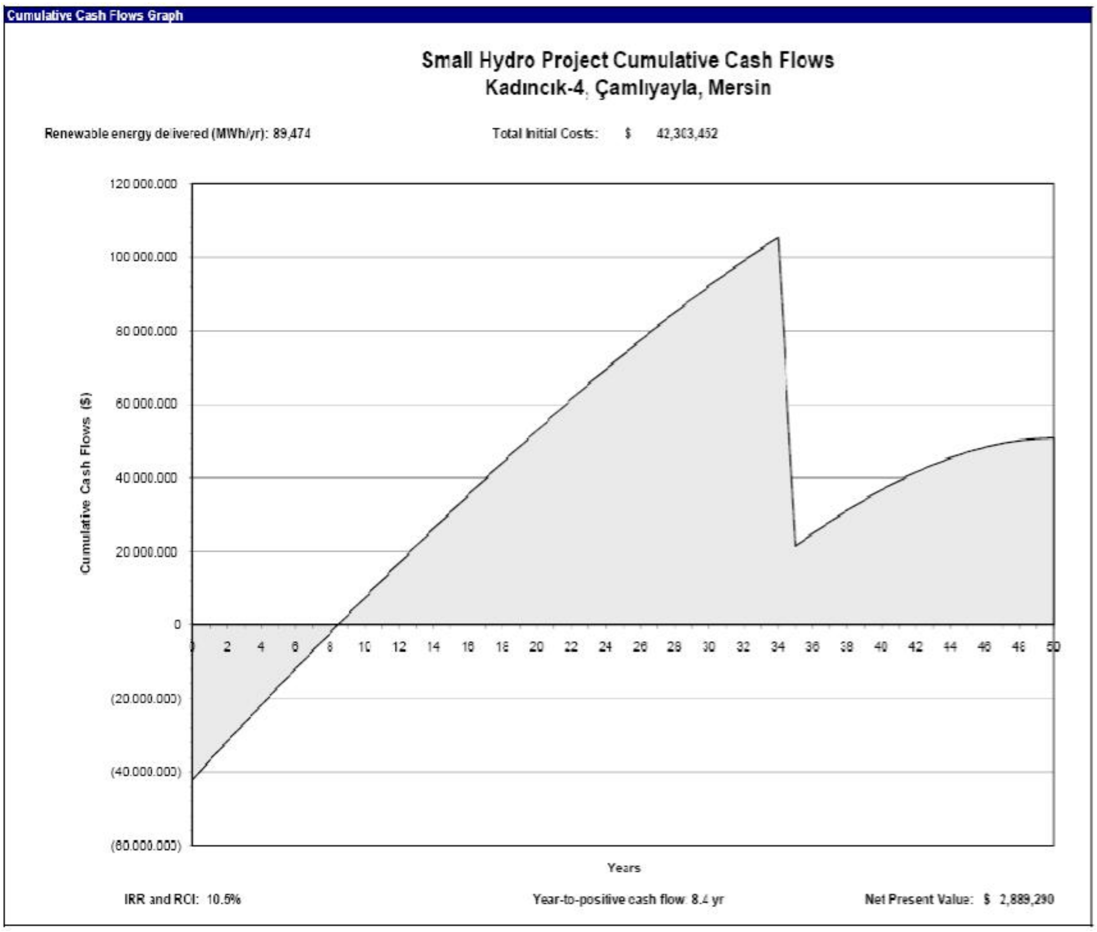


Figure 5.26. Kadıncık-4 HEPP Alternative II, Financial Summary, Cash Flow Graph

5.4.5. Analysis of the Outputs

5.4.5.1. Delivered energy and installed power

The comparison of the energy output results of Kadıncık-4 HEPP Project between RETScreen-Small Hydro Software and the feasibility study of İÇTAŞ is shown in Table 5.9.

RETScreen-Small Hydro Software estimated the nearly same amount of delivered annual energy as İÇTAŞ estimated in the feasibility report. But there is a difference of 8.6% in the estimated installed capacity values.

Table 5.9. The Comparison of Energy Output Results of Kadıncık-4 HEPP, Alternative II

Parameter	RETScreen's Estimation	İÇTAŞ's Estimation	Ratio
Installed Capacity	20.01 MW	21.90 MW	91.4%
Delivered Energy	89.47 GWh/year	91.52 GWh/year	97.8%

5.4.5.2. Cost of the project

The comparison of the cost estimations of Kadıncık-4 HEPP Project between RETScreen-Small Hydro Software and the feasibility study of İÇTAŞ Energy and Trade Co., is shown in Table 5.10.

The RETScreen-Small Hydro Software calculated the total cost as 120.6% higher than İÇTAŞ calculation in the feasibility study. There are major cost differences for almost all of the items. However, if the classification is selected as Mini even though the model suggests Small, this ratio is decreased to 91.3% which is still unacceptable.

RETScreen acknowledges that Small Hydro Model may give bad results for low head, high design flow projects. Besides, the feasibility study of İÇTAŞ may contain some inaccuracies since low-head projects with high design flows require larger energy equipment with higher costs and therefore higher investment costs.

Table 5.10. The Comparison of Cost Estimations of Kadıncık-4 HEPP, Alternative II

COST ITEM	RETSCREEN-SMALL HYDRO SOFTWARE		FEASIBILITY STUDY		RATIO
	FORMULA NUMBER	COST US$	ITEM NUMBER	COST US$	
Feasibility Study	1	3.708.798	10+13	1.843.294	201,2%
Development (including land right)	2				
Engineering	3				
Energy Equipment	4	17.447.151	11	8.064.870	216,3%
Installation of Energy Equipment	5				
Substation and transformer	8				
Installation of substation and transformer	9				
Access road	6	1.439.816	8	1.200.000	120,0%
Transmission line	7	94.342	7	120.000	78,6%
Civil works	10	10.607.193	1 + 2 + 4 + 6 + 9	3.991.487	265,7%
Penstock	11	574.455	5	1.399.715	41,0%
Installation of Penstock	12				
Canal	13	1.734.304	3	1.338.639	129,6%
Miscellaneous	15	6.697.393	12	1.218.228	549,8%
INITIAL COSTS - TOTAL	∑	42.303.452	∑	19.176.233	220,6%

5.4.5.3. Financial summary

The project is feasible according to RETScreen-Small Hydro Model as described in Section 5.4.4.5.

5.6. Optimization of the Kadıncık-4 HEPP Project

The optimization will be based on İÇTAŞ's feasibility report because, the annual energy delivered by that alternative is nearly 65% higher than the first alternative, while the total initial cost is nearly 37% which make it feasible according to the outputs of RETScreen-Small Hydro Model.

In order to optimize the project, the important parameters have to be determined first.

5.6.1. Important Parameters in RETScreen's Feasibility Estimations

Three most important parameters in the order of decreasing importance are;

1. Design Flow
2. Number of the turbines
3. Type of the turbines

Design flow is the fundamental parameter because it affects both energy and power capacity and the cost of a small hydropower project. When design flow decreases both power capacity and initial cost values decrease.

In the feasibility report of İÇTAŞ, design flow is selected as 41.0 m^3/s which is said to be very high. This value is gradually decreased to 21.0

m^3/s by 1.0 m^3/s, and for every design flow value, the software is run successively with the results tabulated in Table 5.11.

Table 5.11. Outputs of RETScreen Software through successive runs with variable design flow values

Q_d		P		E_{dlvd}		B-C Ratio	
m^3/s	%	MW	%	GWh	%	#	%
41.00	0.0	20.01	0.0	89.47	0.0	1.10	0.0
40.00	-2.4	19.52	-2.5	88.94	-0.6	1.12	1.7
39.00	-4.9	19.03	-4.9	88.33	-1.3	1.13	3.4
38.00	-7.3	18.54	-7.4	87.59	-2.1	1.15	5.0
37.00	-9.8	18.05	-9.8	86.76	-3.0	1.17	6.5
36.00	-12.2	17.56	-12.3	85.98	-3.9	1.19	8.1
35.00	-14.6	17.07	-14.7	85.15	-4.8	1.20	9.8
34.00	-17.1	16.58	-17.2	84.17	-5.9	1.22	11.3
33.00	-19.5	16.09	-19.6	83.19	-7.0	1.24	12.9
32.00	-22.0	15.60	-22.1	82.14	-8.2	1.26	14.5
31.00	-24.4	15.11	-24.5	81.00	-9.5	1.27	16.0
30.00	-26.8	14.62	-27.0	79.80	-10.8	1.29	17.5
29.00	-29.3	14.13	-29.4	78.58	-12.2	1.31	19.1
28.00	-31.7	13.64	-31.9	77.28	-13.6	1.32	20.6
27.00	-34.1	13.15	-34.3	75.94	-15.1	1.34	22.2
26.00	-36.6	12.66	-36.8	74.60	-16.6	1.36	23.9
25.00	-39.0	12.17	-39.2	73.21	-18.2	1.38	25.6
24.00	-41.5	11.68	-41.7	71.75	-19.8	1.40	27.3
23.00	-43.9	11.19	-44.1	70.25	-21.5	1.42	29.0
22.00	-46.3	10.70	-46.6	68.64	-23.3	1.43	30.7
21.00	-48.8	10.21	-49.0	67.00	-25.1	1.45	32.4

The percentage of decrease in the value of installed power is almost the same as the percentage of decrease of the design flow. On the other hand, the percentage of increase of benefit - cost ratio is not as steep as the decrease in power capacity. This means that, the hydropower potential of the project would not be optimally exploited if the design flow is selected too small or the project would not be financially viable if the design flow is selected too high. In İÇTAŞ's feasibility report, design flow is selected as the 15% of available flow, which is said to be high. Therefore, design flow could be selected as 30% of available water corresponding to a value of approximately to 30.0 m^3/s.

The second important parameter is the selection of number of turbines, which is also related with the design flow. Decreasing the number of turbines decreases the delivered energy but increases the benefit-cost ratio significantly. İÇTAŞ uses 3 turbines with the design flow of 41.0 m^3/s. Figure 5.27 shows the difference between benefit – cost ratios and Figure 5.28 shows the difference between the delivered energies, when the number of turbines is kept constant at 2 and 3, and the design flow is decreased gradually from 35 to 21 m^3/s.

Decreasing the number of turbines does not affect the delivered energy after a certain value of design flow but affects very positively the ratio of benefit to cost.

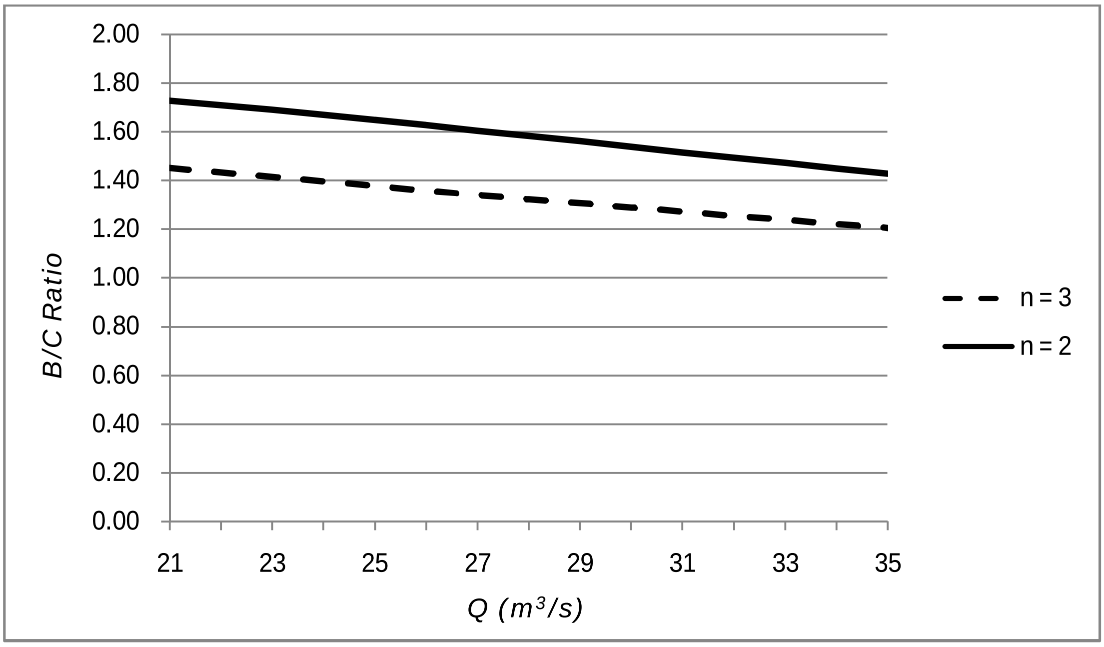


Figure 5.27. The Effect of the Number of Turbines on B-C Ratio

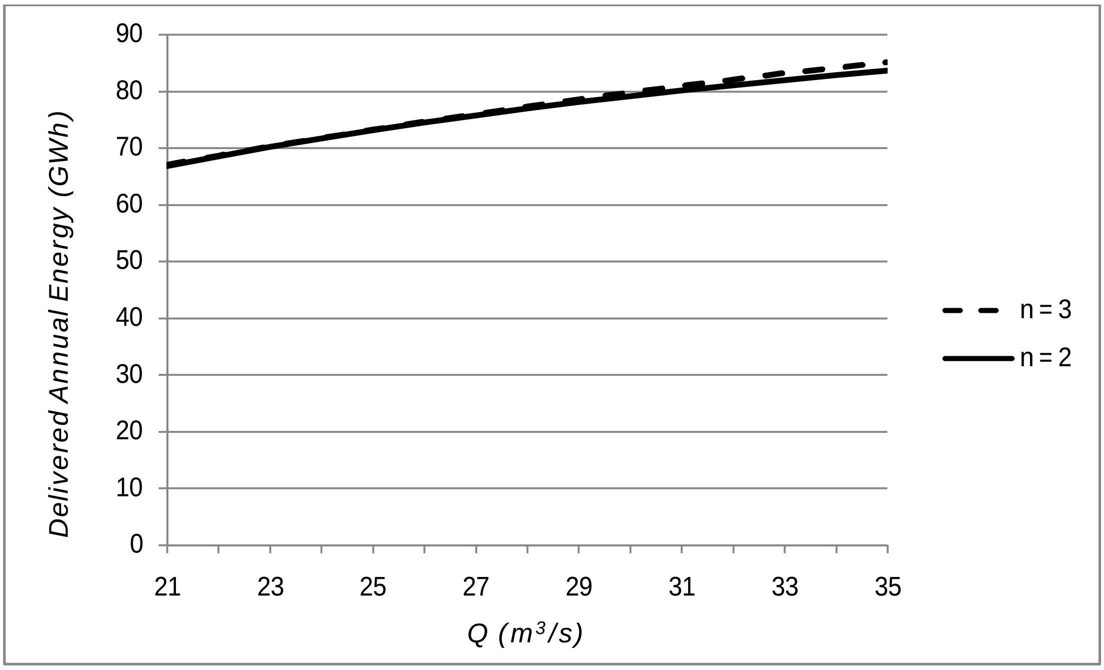


Figure 5.28. The Effect of the Number of Turbines on Delivered Energy

The third important parameter is the turbine type. According to Figure 3.3, for a design flow of 30 m^3/s, İÇTAŞ could have the chance to use Kaplan turbines. Table 5.12 shows the comparison between the outputs of the RETScreen Software if two Kaplan turbines are used instead of two Francis Turbines with the design flow decreased gradually from 30 to 21 m^3/s. According to Table 5.12, two Kaplan Turbines would be more feasible to use because the increase in the delivered energy is more than the decrease in benefit-cost ratio.

Table 5.12. The Effect of Turbine Type on the Feasibility of a Small Hydro Project

Q_d	2 Francis Turbines		2 Kaplan Turbines	
m^3/s	E_{dlvd} (GWh)	B-C Ratio	E_{dlvd} (GWh)	B-C Ratio
30.00	79.12	1.54	81.54	1.53
29.00	78.09	1.56	80.33	1.55
28.00	76.98	1.58	79.07	1.57
27.00	75.77	1.61	77.75	1.59
26.00	74.51	1.63	76.37	1.61
25.00	73.17	1.65	74.92	1.63
24.00	71.72	1.67	73.41	1.65
23.00	70.19	1.69	71.84	1.67
22.00	68.58	1.71	70.18	1.69
21.00	66.87	1.73	68.45	1.71

5.6.2. Comparison of Other Alternatives

In order to realize a more feasible project, 3 more alternatives is performed by RETScreen Software and the results are compared in Table 5.13.

In Alternative III, the number of turbines is reduced to 2 which is the only difference from the data of Alternative II. In Alternative IV, the number of turbines is reduced to 2 and the design flow is reduced to 30 m^3/s. In Alternative V, the turbine type is selected as Kaplan which is the only difference from the data of Alternative IV (See Table 5.13).

Table 5.13. Comparison of Alternatives

Output Item	Unit	I	II	III	IV	*V*
		DSİ	İÇTAŞ	n=2	$Q_d=30m^3/s$	*Kaplan*
Installed Power	MW	13.23	20.01	20.01	14.62	*15.07*
Renewable Energy Delivered	GWh	54.49	89.41	87.46	79.12	*81.54*
Total Initial Cost	US$	30,871,330	42,303,452	36,902,158	28,418,441	*29,295,732*
Annual Costs	US$	451,993	569,906	506,861	411,828	*421,382*
After Tax IRR	%	6.1%	10.5%	12.5%	15,3%	*15.3%*
NPV	US$	-3,901,165	2,889,290	8,689,960	13,809,655	*14,197,715*
Positive Cash Flow	yr	10.5	8.4	7.5	6.3	*6.3*
Benefit Cost Ratio	-	0.87	1.07	1.24	1.48	*1.48*

Alternative V is the best alternative among others according to RETScreen-Small Hydro Software as seen Table 5.13, with the highest renewable energy delivered, installed power and net present value.

CHAPTER 6

CONCLUSION

Small Hydropower projects cannot be dealt with the same category as large scale hydropower projects. Rather than optimization of system to maximize delivered energy, cost effectiveness should be the primary objective.

The RETScreen International Clean Energy Project Analysis Software is a decision support tool which can be used worldwide to evaluate the energy production and savings, life-cycle costs, emission reductions, financial viability and risk for various types of energy efficient and renewable energy technologies (RETs) such as small hydropower.

RETScreen-Small Hydro Software is capable of making optimizations to maximize the delivered energy and minimize the initial cost of a SHP project within a short duration of time, without detailed study. For reservoir and run-off river type of projects, a pre-feasibility report can be prepared in a small period of time compared to the traditional feasibility studies. Moreover, the report can be revised every time by changing some variables and thus different alternatives can be compared easily without extensive calculation which is really helpful for the designers.

Kadıncık-4 Hydropower Project located in Çamlıyayla, Mersin is selected as a case study with two-alternative feasibility reports of which the locations and hence the elevations of the weir differ. The data collected from the feasibility reports of both alternatives are entered into the RETScreen Software and the outputs are analyzed in detail. Additional alternatives, which take into account the effects of discharge, and number and type of turbines are carried out.

The results of this study show that RETScreen Software can be used in Turkish SHP Projects. The adjustment factors can be further developed by testing additional SHP project data. The Labour Costs ratio calculated by Equation 4.8 and 4.9 can be adjusted to give more accurate results according to the data bank about the construction sector in Turkey announced by State Institute of Statistics to be published in 2008. This survey report can be very helpful to calculate the exact ratio for labour and equipment costs.

In 2006, diesel fuel costs in Turkey are more than 2 times of the diesel fuel costs in Canada and this fuel cost ratio is increasing every year because of the unstable prices of oil around the world. Energy, when it is renewable, is a key member for development. Energy generated from fossil fuels has been continuously consumed and will be totally finished in the future; but renewable sources together with hydropower will always be available. Countries generating green energy such as small hydropower will be self-dependent and their industries will be more competitive than the fossil fuel exporting countries. Among these countries, Turkey has an opportunity with its high economical hydropower potential which is an insurance for the unpredictable future of the world.

So as to initiate the development of SHP in Turkey the strategies of self-management and self consumption should be adopted. All necessary arrangements on legislative, administrative and economical issues should be made in order to accelerate SHP projects all around Turkey. It should be recognized that SHP is a key policy issue of socio-economic development of rural areas in Turkey.

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APPENDIX A

RETSCREEN-SMALL HYDRO PROJECT SOFTWARE USER MANUAL

A.1. Energy Model

As part of the RETScreen Clean Energy Project Analysis Software, the *Energy Model* worksheet is used to help the user calculate the annual energy production for a small hydro project based upon local site conditions and system characteristics. Results are calculated in common megawatt-hour (MWh) units for easy comparison of different technologies. (RETScreen, 2004-b)

A.1.1. Site Conditions

Table A.1. Items Related With Site Condition

Item	Data Type	Remarks
Project Name	User-defined	For reference purposes
Project Location	User-defined	For reference purposes
Gross Head	User-defined	To calculate the potential
Maximum Tail Water Effect	User-defined	Reduction in head due to high flows
Residual Flow	User-defined	Copied from Hydrology & Load
Firm Flow	Calculated by Model	Copied from Hydrology & Load

A.1.2. System Characteristics

Table A.2. Items Related With System Characteristics

Item	Data Type	Remarks
Grid Type	User-defined	Copied from Hydrology & Load
Design Flow	User-defined	
Turbine Type	User-defined	Copied from Equipment Data
Number of Turbines	User-defined	Copied from Equipment Data
Turbine Peak Efficiency	Calculated by Model	Copied from Equipment Data
Turbine Efficiency at Design Flow	Calculated by Model	Copied from Equipment Data
Maximum Hydraulic Losses	User-defined	Hydraulic losses (%) in water passages
Generator Efficiency	User-defined	
Transformer Losses	User-defined	
Parasitic Energy Losses	User-defined	
Annual Downtime Losses	User-defined	

A.1.3. Annual Energy Production

Table A.3. Items Related With Annual Energy Production

Item	Data Type	Remarks
Small Hydro Plant Capacity	Calculated by Model	
Small Hydro Plant Firm Capacity	Calculated by the Model	
Available Flow Adjustment Factor	User-defined	
Small Hydro Plant Capacity Factor	Calculated by Model	
Renewable Energy Available	Calculated by Model	

A.2. Hydrology & Load

As part of the RETScreen Clean Energy Project Analysis Software, the *Hydrology Analysis and Load Calculation* worksheet is used to enter the flow data and the electrical demand data (for isolated-grid and off-grid applications) for the site under study. The data entered in this worksheet provides the basis for calculating the renewable energy delivered.

A.2.1. Hydrology Analysis

Table A.4. Items Related With Hydrology Analysis

Item	Data Type	Remarks
Project Type	User-defined from two options	"Run-of-river" and "Reservoir" options
Hydrology Method	User-defined from two options	"Specific run-off" and "User-defined" options
Residual Flow	User-defined	
Percent Time Firm Flow Available	User-defined	
Firm Flow	Calculated by Model	
Flow-Duration Curve	User-defined	

A.2.2. Load Characteristics

Table A.5. Items Related With Load Characteristics

Item	Data Type	Remarks
Grid Type	User-defined from three options	"Central-grid," "Isolated-grid" and "Off-grid."

A.3. Equipment Data

As part of the RETScreen Clean Energy Project Analysis Software, the *Equipment Data* worksheet is used to specify the small hydro turbine(s) for the project. The results of this worksheet are transferred to the *Energy Model* worksheet. The user should return to the *Energy Model* worksheet after completing the *Equipment Data* worksheet.

A.3.1. Small Hydro Turbine Characteristics

Table A.6. Items Related With Turbine Characteristics

Item	Data Type	Remarks
Gross Head	User-defined	Copied from Energy Model
Design Flow	User-defined	Copied from Energy Model
Turbine Type	User-defined form options	"Kaplan," "Francis," "Propeller," "Pelton," "Turgo," "Cross-flow," and "Other."
Turbine Efficiency Curve Data Source	User-defined form two options	"Standard" and "User-defined."
Number of Jets for Impulse Turbine	User-defined	If the user selected "Pelton" or "Turgo" as the type of turbine, the number of jets can vary from 1 to 6 which may affect turbine efficiency. A value of 2 can be used as a default.
Number of Turbines	User-defined	It is assumed that multiple turbines are all identical.
Efficiency Adjustment	User-defined	Applies to the entire efficiency curve if needed
Turbine Peak Efficiency	Calculated by Model	Based on the standard turbine efficiency curve data.
Flow at Peak Efficiency	Calculated by Model	The turbine performs at peak efficiency.
Turbine Efficiency at Design Flow	Calculated by Model	This value can range from 80% to over 90%.
Turbine Efficiency Curve Data	Calculated by Model	

A.4. Cost Analysis

As part of the RETScreen Clean Energy Project Analysis Software, the *Cost Analysis* worksheet is used to help the user estimate costs associated with a small hydro project. These costs are addressed from the initial, or investment, cost standpoint and from the annual, or recurring, cost standpoint.

A.4.1. Formula Costing Method

Table A.7. Items Related With Formula Costing Method

Item	Data Type	Remarks
Project Country	User-defined from two options	"Canada" and "Enter name."
Local vs. Canadian Equipment Costs Ratio	User-defined	
Local vs. Canadian Fuel Costs Ratio	User-defined	
Local vs. Canadian Labour Costs Ratio	User-defined	
Equipment Manufacture Cost Coefficient	User-defined	
Exchange Rate	User-defined	
Cold Climate?	User-defined	
Number of Turbines	User-defined	Copied from Equipment Data
Flow per Turbine	Calculated by Model	
Approximate Turbine Runner Diameter (per unit)	Calculated by Model assuming that each turbine is identical	Indicator of the size of each turbine and therefore, the size of the required powerhouse.
Project Classification / Suggested Classification	Calculated by Model	
Project Classification / Selected Classification	User-defined from three options	"Micro," "Mini" and "Small."
Existing Dam?	User-defined	

Table A.7. Continued

Item	Data Type	Remarks
New Dam Crest Length	User-defined	
Rock at Dam Site?	User-defined	
Maximum Hydraulic Losses	User-defined	Copied from Energy Model
Intake and Miscellaneous Losses	User-defined	Accounts for hydraulic losses other than in water passages
Access Road Required?	User-defined	
Length	User-defined	Connect the site to the nearest existing suitable road.
Tote Road Only?	User-defined	Whether or not the access road is to be constructed for construction purposes only.
Difficulty of Terrain	User-defined	Value between 1 and 6 representing the difficulty of the terrain through which the access road will be built.
Tunnel Required?	User-defined	Whether or not a tunnel is required for the small hydro project
Length	User-defined	Estimated length
Allowable Tunnel Headloss Factor	User-defined	The ratio of the allowable headloss in the tunnel compared to the available gross head expressed as a decimal
Percent Length of Tunnel that is lined	User-defined	The ratio of the length of tunnel that requires lining compared to the total tunnel length and is expressed as a decimal.
Tunnel Excavation Method	User-defined from the two options	"Hand-built" and "Mechanized." Used to calculate the diameter of the tunnel.
Tunnel Diameter	Calculated by the Model	Approximate diameter of the tunnel based on the tunnel length and allowable tunnel headloss factor

Table A.7. Continued

Item	Data Type	Remarks
Canal Required?	User-defined	
Length in Rock	User-defined	For canals in varying terrain, the lengths in rock and soil should reflect the totals of the individual sections
Terrain Side Slope in Rock (average)	User-defined	Canals constructed in rock with terrain side slopes greater than approximately 45º not financially viable.
Length in Impervious Soil	User-defined	For canals in varying terrain, the lengths in rock and soil reflect the totals of the individual sections
Terrain Side Slope in Soil (average)	User-defined	Canals constructed in soil with terrain side slopes greater than approximately 15º are not financially viable.
Total Canal Headloss	Calculated by Model	Assuming an average bottom slope of approximately 0.001
Penstock Required?	User-defined	
Length	User-defined	
Number of Identical Penstocks	User-defined	
Allowable Penstock Headloss Factor	User-defined	The ratio of the allowable headloss in the penstock(s) compared to the available gross head and is expressed as a percentage.
Pipe Diameter	Calculated by Model	For reference purposes only.
Average Pipe Wall Thickness	Calculated by Model	
Distance to Borrow Pits	User-defined	
Transmission Line	User-defined	
Length	User-defined	
Difficulty of Terrain	User-defined	A factor between 1 and 2. One (1) represents flat terrain and two (2) is used to represent mountainous terrain.
Voltage	User-defined	
Interest Rate	User-defined	

A.4.2. Initial Costs (Formula Method)

Table A.8. Items Related With Initial Costs

Item	Data Type	Remarks
Feasibility Study	Calculated by Model	The estimated cost of the required feasibility
Development	Calculated by Model	Include legal fees
Land Rights	User-defined	Necessary for the construction of the project structures
Engineering	Calculated by Model	Function of the project's plant capacity and gross head and does not include any engineering of the water-to-wire equipment other than the
Energy Equipment	Calculated by Model	Including the costs of the turbine(s), generator(s), governor and controls based on the type of turbine
Balance of Plant	Calculated by Model	Access road, transmission line, substation and transformer, penstock, canal, tunnel and other civil works costs
Access Road	Calculated by Model	Calculated based on the length and difficulty of terrain and whether or not the road will be built as a tote road for construction purposes only
Transmission Line	Calculated by Model	Calculated based on its length, difficulty of terrain and voltage. It is assumed that for transmission line voltages less than 69 kV wood pole construction can be used. For larger voltages a higher cost steel tower line is assumed
Substation and Transformer	Calculated by Model	Based on the plant capacity and transmission line voltage
Penstock	Calculated by Model	The cost of the penstock is based on the approximate weight of the penstock(s) assuming steel construction.
Canal	Calculated by Model	The cost of the canal is based on the approximate volume of excavation in rock and soil

Table A.8. Continued

Item	Data Type	Remarks
Tunnel	Calculated by Model	The cost of the tunnel is based on the approximate volumes of rock excavation and tunnel lining required
Civil Works (other)	Calculated by Model	The balance of the site civil works cost is based on a formula that has different cost coefficients for the size of the turbine runner (i.e. based on the site classification). This is due to the use of more simple designs for micro and mini hydro compared with small hydro.
Miscellaneous	Calculated by Model	include unforeseen costs and interest during construction. An allowance of 10% of the other project costs (excluding land rights) is included in the calculation of miscellaneous costs to allow for unforeseen costs

A.4.3. Annual Costs

There will be a number of annual costs associated with the operation of a small hydro project. These will include land lease, property taxes, water rental, insurance premium, transmission line maintenance, spare parts, O&M labour, GHG monitoring and verification, travel and accommodation and general and administrative expenses. In addition, costs for contingencies will also be incurred.

Table A.9. Items Related with Annual Costs

Item	Data Type	Remarks
Land Lease	User-defined	Depend on the area and value of land that is leased
Property Taxes	Calculated as a percentage of the total initial costs.	Property tax might be levied on a small hydro energy project, depending upon the jurisdiction
Water Rental	User-defined	An annual charge for the use of the water in the river
Insurance Premium	Calculated as a percentage of the total initial costs	
Transmission Line Maintenance	Calculated as a percentage of the total tranmission line costs	
Spare Parts	Calculated as a percentage of the total initial costs	
O&M Labour	User-defined	The labour cost item summarizes the cost of annual labour required for routine and emergency maintenance and operation of the small hydro plant
Travel and Accommodation	User-defined	For small hydro plants in isolated locations, an annual allowance should be made for travel and accommodation costs associated with annual maintenance
General and Administrative	Calculated as a percentage of the annual costs	Costs of bookkeeping, preparation of annual statements, bank charges, communication, etc.
Contingencies	Calculated as a percentage of the annual costs	

A.5. Financial Summary

A.5.1. Annual Energy Balance

Table A.10. Items Related with Annual Energy Balance

Item	Data Type	Remarks
Project Name	User-defined	For reference purposes only
Project Location	User-defined	For reference purposes only
Renewable Energy Delivered	Calculated by Model	Copied from Energy Model
Firm RE Capacity	Calculated by Model	Copied from Energy Model
Grid Type	Calculated by Model	Copied from Hydrology & Load

A.5.2. Financial Parameters

Table A.11. Items Related with Financial Parameters

Item	Data Type	Remarks
Avoided Cost of Energy	User-defined	
RE Production Credit	User-defined	
RE Production Credit Duration	User-defined	
RE Credit Escalation Rate	User-defined	
Avoided Cost of Capacity	User-defined	
Energy Cost Escalation Rate	User-defined	Annual average rate of increase for the avoided cost of energy over the life of the project.

Table A.11. Continued

Item	Data Type	Remarks
Inflation	User-defined	Annual average rate of inflation over the life of the project.
Discount Rate	User-defined	An organization's weighted average cost of capital.
Project Life	User-defined	
Debt Ratio	User-defined	The ratio of debt over the sum of the debt and the equity of a project, the higher the debt ratio, and the larger the financial leverage.
Debt Interest Rate	User-defined	The annual rate of interest paid to the debt holder at the end of each year of the term of the debt.
Debt Term	User-defined	Number of years over which the debt is repaid, the longer the term, the more the financial viability of an energy project improves.
Income Tax Analysis?	User-defined	Calculate after-tax cash flows and after-tax financial indicators. In all cases, the model assumes a single income tax rate valid throughout the project life and applied to net income.
Effective Income Tax Rate	User-defined	Net income derived from the project is taxed. The effective income tax rate is assumed to be constant throughout the project life.

Table A.11. Continued

Item	Data Type	Remarks
Loss Carry Forward?	User-defined	If the user selects "Yes," losses are carried forward and applied against taxable income in the following years, thereby reducing the income tax owed up to the accumulated losses, years after the losses occur. If the user selects "No," losses are not carried forward but rather lost and thereby never used to offset any other year taxable income. If the user selects "Flow-through," losses are not carried forward but rather used in the year in which they occur and applied against profits from sources other than the Project.
Depreciation Method	User-defined from three options	"None," "Declining balance" and "Straight-line."
Depreciation Tax Basis	User-defined	Portion of the initial costs are capitalized and can be depreciated for tax purposes.
Depreciation Rate	User-defined	Rate at which the undercoated capital cost of the project is depreciated each year.
Depreciation Period	User-defined	Period over which the project capital costs are depreciated using a constant rate.
Tax Holiday Available?	User-defined	
Tax Holiday Duration	User-defined	

A.5.3. Project Costs and Savings

Table A.12. Items Related with Project Costs and Savings

Item	Data Type	Remarks
Initial Costs	Calculated by Model	Copied from Cost Analysis
Feasibility Study	Calculated by Model	Copied from Cost Analysis
Development	Calculated by Model	Copied from Cost Analysis
Engineering	Calculated by Model	Copied from Cost Analysis
Energy Equipment	Calculated by Model	Copied from Cost Analysis
Balance of Plant	Calculated by Model	Copied from Cost Analysis
Miscellaneous	Calculated by Model	Copied from Cost Analysis
Incentives/Grants	User-defined	Any contribution, grant, subsidy, etc. that is paid for the initial cost of the project. The incentive is deemed not to be refundable and is treated as income during the development/construction year, year 0, for income tax purposes.

Table A.12. Continued

Item	Data Type	Remarks
Annual Costs and Debt	Calculated by Model	Represent the yearly costs incurred to operate, maintain and finance the project. It is the sum of the O&M costs and debt payments. Note that the total annual costs include the reimbursement of the "principal" portion of the debt which is not, strictly speaking, a cost but rather an outflow of cash.
O&M	Calculated by Model	Copied from Cost Analysis
Debt Payments - Debt Term	Calculated by the model	Copied from Cost Analysis
Annual Savings or Income	Calculated by the model	Copied from Cost Analysis
Energy Savings/Income	Calculated by the model	Copied from Cost Analysis
Capacity Savings/Income	Calculated by the model	Copied from Cost Analysis
RE Production Credit Income – Duration	Calculated by the model	Copied from Cost Analysis
Periodic Costs (Credits)	User-defined	The model escalates the periodic costs and credits yearly according to the inflation rate starting from year 1 and throughout the project life.
End of Project Life - Cost/Credit	User-defined	Copied from Cost Analysis

A.5.4. Financial Feasibility

Table A.13. Items Related with Financial Feasibility

Item	Data Type	Remarks
Pre-tax Internal Rate of Return and Return on Investment	Calculated by Model	Represents the true interest yield of the project equity over its life before income tax.
After-tax Internal Rate of Return and Return on Investment	Calculated by Model	Represents the true interest yield of the project equity over its life
Simple Payback	Calculated by Model	Represents the length of time that it takes for an investment project to recoup its own initial cost
Year-to-positive Cash Flow	Calculated by Model	Represents the length of time that it takes for the owner of a project to recoup its own initial investment
Net Present Value – NPV	Calculated by Model	Value of all future cash flows, discounted at the discount rate, in today's currency.
Annual Life Cycle Savings	Calculated by Model	Is the levelized nominal yearly savings having exactly the same life and net present value as the project.
Benefit-Cost (B-C) Ratio	Calculated by Model	Is the ratio of the net benefits to costs of the project.
Calculate Energy Production Cost?	User-defined	
Energy Production Cost	Calculated by Model	
Project Equity	Calculated by Model	
Project Debt	Calculated by Model	Is the portion of the total investment required to implement the project and that is financed by a loan.
Debt Payments	Calculated by Model	Is the sum of the principal and interest paid yearly to service the debt.
Debt Service Coverage	Calculated by Model	Is the ratio of the operating benefits of the project over the debt payments.

A.5.5. Yearly Cash Flows

Table A.14. Items Related with Yearly Cash Flows

Item	Data Type	Remarks
Pre-tax	Calculated by Model	The net pre-tax cash flows are the yearly net flows of cash for the project before income tax.
After-tax	Calculated by Model	The net after-tax cash flows are the yearly net flows of cash for the project after income tax.
Cumulative	Calculated by Model	Represent the net after-tax flows accumulated from year 0. It uses the net flows to calculate the cumulative flows.

APPENDIX B

TURBINE EFFICIENCY FORMULA OF FRANCIS TURBINES

The formulae used by RETScreen-Small Hydro Project Software to calculate the efficiency of Francis turbines is given below (RETScreen, 2004-b);

$$d = k_1 Q_d^{0,473} \quad \text{(B.1)}$$

where; d = runner diameter in m.

k_1 = 0,46 for d < 1,8 m

= 0,41 for d ≥ 1,8 m

Qd = design flow

$$n_q = k_2 H_n^{-0,52} \quad \text{(B.2)}$$

where; n_q = specific speed based on flow

k_2 = 600 for Francis turbines

H_n = net head on turbine (m)

$$\hat{}e_{nq} = \{(n_q - 56)/256\}^2 \quad \text{(B.3)}$$

where; $\hat{}e_{nq}$ = Specific speed adjustment to peak efficiency

$$\hat{}e_d = (\hat{}e_{nq} + 0{,}081)(1 - 0{,}789d^{-0,2}) \quad \text{(B.4)}$$

where; $\hat{}e_d$ = Runner size adjustment to peak efficiency

$$e_p = \left(0{,}919 - \hat{}e_{nq} + \hat{}e_d\right) - 0{,}0305 + 0{,}005R_m \qquad \text{(B.5)}$$

where; e_p = Turbine peak efficiency

R_m = Turbine manufacture/design coefficient (default 4,5)

$$Q_p = 0{,}65Q_d n_q^{0{,}05} \qquad \text{(B.6)}$$

where; Q_p = Peak efficiency flow

$$e_q = \{1 - \left[1{,}25\left(\frac{(Q_p - Q)}{Q_p}\right)^{(3{,}94 - 0{,}0195n_q)}\right]\}e_p \qquad \text{(B.7)}$$

where; e_q = Efficiencies at flows below peak efficiency flow

$$\hat{}e_p = 0{,}0072n_q^{0{,}4} \qquad \text{(B.8)}$$

where; $\hat{}e_p$ = Drop in efficiency at full load

$$e_r = (1 - \hat{}e_p)e_p \qquad \text{(B.9)}$$

where; e_r = Drop in efficiency at full load

$$e_q = e_p - \left[\left(\frac{(Q_p - Q)}{(Q_d - Q_p)}\right)^2 (e_p - e_r)\right] \qquad \text{(B.10)}$$