Evaluation of small and medium hydropower in Turkey in consideration of economical aspects

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Turkey has a considerable economical growth rate which in return results in growing energy demand. In order to guarantee energy supply, the energy market was privatized several years ago. Since this time more and more private companies are investing in hydropower plants. Especially a great number of small and medium hydropower plants are studied by foreign investors. Hence this paper provides a short introduction particular for interested investors, which covers the legal permission process, the technical boundary conditions, risks and an economical evaluation.

Derzeit weist die Türkei ein hohes wirtschaftliches Wachstum auf, was auch einen bemerkenswerten Zuwachs beim Energiebedarf nach sich zieht. Um die Energieversorgung sicherzustellen, wurde vor einigen Jahren der Energiemarkt privatisiert. Seitdem investieren zunehmend private Firmen in Wasserkraftanlagen. Besonders eine große Anzahl kleiner und mittlerer Wasserkraftanlagen stehen im Fokus von ausländischen Investoren. Der vorliegende Beitrag bietet deshalb speziell für derartig interessierte Investoren eine kurze Einleitung zu diesem Thema, der vom Genehmigungsprozess, über die technischen Randbedingungen und Risiken bis hin zur Wirtschaftlichkeitsbetrachtung führt.

1 Introduction

Turkey has the second largest hydropower potential of all European countries, although geographically the major part of Turkey is located on the Asian continent. The socio-economical development of Turkey is dominated by a strong growth of population and simultaneously by a steady, remarkable increase of energy demand and consumption. The population of Turkey is approximately 73 million per the 2008 census. In the year 1983 the population comprised 50 million people, an increase of 50 % in only 25 years. A current prognosis predicts an energy supply deficit for the years 2015 to 2020. Furthermore, energy supply is currently particularly based on imports of gas from the Black Sea area and coal imports from Australia or Russia (Kuzu & Ercin, 2004). These circumstances make the Turkish energy market critically sensitive to the global development of energy politics and prices and also vulnerable.

One way out of this threatening situation may be the utilization of the remaining hydropower potential of Turkey. In order to accelerate the utilization of energy resources, including the huge potential of renewable hydropower, the energy market was privatized and private investors are now allowed to own and operate hydropower plants, particularly of small and medium size. Singularly, also huge hydropower are developed by private companies, both run-of-river and storage plants.

With the presented paper, actual tendencies and problems of small and medium hydropower plants in Turkey are described and discussed, particularly addressing potential foreign investors who consider entering the Turkish hydropower market. Special attention is paid to economical issues and major related issues such as existing risks, permission procedure, costs and revenues. Of course some basics about the Turkish energy market are also included.

2 Turkish Hydropower Potential, Development and Future Aspects

2.1 Energy Demand in Turkey

Turkey's energy demand is increasing with the growth of population. The actual population growth rate is 1.0 – 1.5 %. Turkey's economy is among the world's 20 largest with a GDP of around US$ 400 Billion (The World Bank Country Brief 2007). The country's economical growth is ranked on 16th place worldwide (Yüksek, 2008). The energy demand in the year 2005 was $160 \cdot 10^3$ GWh/a (in 2000: $128 \cdot 10^3$ GWh) and it is expected to be $242 \cdot 10^3$ GWh/a in 2010 (+ 51 %) and $356 \cdot 10^3$ GWh/a in 2020 (+ 122 %). This also describes an increased demand of almost 50 % in seven years considering the period from 2000 to 2007 which corresponds to an average annual increase of 7 % (in 2007: 8.5 %). These values differ in literature but indicate almost the same range. Some authors are expecting an increase up to 302 to $356 \cdot 10^3$ GWh/a already for the year 2015. For 2020 a demand of average $476 \cdot 10^3$ GWh/a is predicted (Yüksek, 2008). Since the last thirty years the energy demand has tripled (Kuzu & Ercin, 2004) and the development will continue this way according to future forecasts which consider also a permanently and quickly increasing industrialization of Turkey.

Due to the remarkable hydroelectrical potential in Turkey, which is approximately $125 \cdot 10^3$ GWh/a (Bayazit & Avci, 1997), many HEPP were constructed in the past and are actually in design stage or under construction. In the year 1997 about 30 % of the hydroelectrical potential were utilized. To be more accurate, about 36 % are utilized, 8 % are under construction and 44 % are untapped (Source: Water Hydraulic Works DSI, Turkey). The number of hydroelectrical projects planned or under constructions actually exceeds the number of 1,200 with increasing trend.

Forecasts predict a serious lack of electricity supply for the years 2015 to 2020, some pessimistic forecasts are predicting this deficit already for the year 2012. The present electric power generation capacity is 40,761 MW. In order to meet the demand in the year 2020, the “worst case” scenario requires approximately 96,000 MW installed capacity whereas other scenarios require 80,000 MW of the installed capacity. This means that for the next 13 years, new additional power generation plants have to be realized to increase the capacity of 39,500 to 55,500 MW. This also means that Turkey needs huge investments of approximately 50,000 Mio. € over the next 13 years. Some of these funds will be used for building new hydropower plants. And these funds are considerably raised by private investors.

As described in Kuzu & Ercin (2004) the primary energy consumption is mainly spread equally among industry, private households, transportation and energy production. In the year 2000 industry is taking over the main part of 23.6 %, closely followed by households (19.6 %) and energy production (20.7 %). Prognoses forecast a growth of the industry sector up to 42.6 % in the year 2025. The energy demand and consumption worldwide is increasing 1.4 % annually, which confirms that Turkey is one of the strongly growing countries in terms of demand and consumption, increasing 6 % to 8 % annually. It should be noted that energy consumption of Turkey is 0.8 % of the energy consumption world-wide, Turkey is a gnome compared to other growing countries, particularly China (Konukiewitz, 2007).

Kuzu & Ercin (2004) recommend an increase of renewable energy resources up to 60 % of the whole production which is only possible by focusing on hydropower, wind and solar energy. Nuclear energy is in Turkey’s agenda for some time and a nuclear power plant tender took place in September 2008. The tender has not been finalized, while civil society organizations object nuclear power plants. Since Turkey is one of the countries with the highest energy prices, the realization of nuclear power plants would be one possibility to lower the energy price by provision of energy for a price 4.0 to 4.5 €-Cent/kWh.

2.2 Liberalization

Turkey has been in the process of liberalization of the electricity market within the context of “Energy Sector Reform” since early 1980s. Following the legal developments allowing private participation in the electricity market, the Turkish Electricity Authority (TEK), a state owned monopoly entity in the electricity sector was restructured as Turkish Electricity Generation Transmission Company (TEAŞ) to perform electricity transmission and generation activities, and Turkish Electricity Distribution Company (TEDAŞ) to perform electricity distribution activities in 1993.

The Electricity Market Law No. 4628 (Law) which determines the legal framework of the electricity market was enacted March 3, 2001. TEAŞ, which performed generation, transmission and wholesale was legally unbundled and within this legal separation, three state owned entities were formed. In this respect, new companies were established. Here, the Electricity Generation Company (EÜAŞ) performs electricity generation activities, the Turkish Electricity Transmission Company (TEİAŞ) cares for the electricity transmission activity, and the Turkish Electricity Transmission Company (TETAŞ) organizes the energy transmission. With this legal framework it is intended that the sub sectors except for the transmission activity are open to competition under the supervision of Energy Market Regulatory Authority (EMRA).

Several incentives are in force to stimulate investment in renewable energy, some of them being: paying only 1 % of the total licensing fee, exemption from annual license fees for 8 years after facility completion date, priority for system connection, and purchase guarantee.

The Turkish Ministry for Energy and Resources also introduced several implementation models including hydropower plants to attract private investors for the Turkish energy market. Here, BOT, BOO and TOR models play the decisive roles. Further, the role of autoproducers has become important in order to provide additional energy production for self suppliers in industry (Kuzu & Ercin, 2004).

2.3 Hydropower in Turkey

The hydropower sector in Turkey has an installed capacity of 10,538 MW (≈ 40 % of the whole installed capacity) and produced $36.7 \cdot 10^3$ GWh/a (≈ 30 % of the whole produced energy) in the year 2000. In 2005, 12,941 MW (≈ 30 %) were installed and $42.0 \cdot 10^3$ GWh/a (≈ 27 %) were produced (Eroglu, 2006). For comparison, German hydropower production reached $26.9 \cdot 10^3$ GWh/a (≈ 4.6 %) in the year 2005 (Winkler, 2007) and $25.1 \cdot 10^3$ GWh/a in 2000 (Heimerl & Giesecke, 2004) that is about 58 % (2005) and 68 % (2000) of the Turkish production.

As mentioned above, the economically feasible electric energy potential (EFEP) of Turkey is approximately 125 to $130 \cdot 10^3$ GWh/a (Yüksek, 2008; Bayazit &

Avci, 1997; Eroglu, 2006) that is nearly 60 % of the technical feasible hydropower potential. A reevaluation of the EFEP showed that the EFEP is likely to be much higher than common expectations reaching $188 \cdot 10^3$ GWh/a. This figure is 40-50 % higher than conservative estimates, resulting in the above mentioned $125 \cdot 10^3$ GWh/a. In the year 2000 only a third of this potential was utilized, in 2005 the percentage increased up to 38 %. Hydroelectric power production provided 27 % of the whole production in 2005 (Eroglu, 2006). Future prognoses predict a realistic percentage taken over by hydropower in Turkey of 40 % for the year 2010 which will decrease to 25 to 35 % for the year 2020 (Yüksek, 2008) in case of realization of sufficient hydropower plants. As mentioned, renewable energy shall take over 60 % of the whole production (Kuzu & Ercin, 2004).

Hydropower in Turkey is and will be more and more used for generating peak electricity. Therefore, also a major part of the private developed small and medium hydropower plants are operated with reservoirs that are usually relatively small, representing daily or monthly reservoir capacities. For the future, especially the realization of many small hydropower plants (< 5 MW) will contribute to the hydroelectric energy production.

2.4 Turkey and the EU

The more developed and prosperous regions of Turkey are located in the western parts of Asia Minor. The eastern part of Turkey is less developed, because of lack of natural resources, harsh weather conditions, and small number of industrial facilities which could contribute to the development of the area. The governments over the last 30 years have classified certain regions of east and-south east Turkey as priority provinces to be developed. Socio-economical programs have been started and almost completed (e. g. the GAP-project), but poverty prevails in the eastern part of Turkey. Turkey is an official candidate of the EU but the actual access is not expected to take place before 2015. Since 2000 reforms have been implemented and harmonization with the Copenhagen criteria is in progress. (Bahcheli, 2005).

One aspect has to be considered by potential investors of hydropower. Although Turkey has made considerable progress in environmental regulations during the EU harmonization process, the European environmental regulations and laws will become effective once Turkey joins the EU and respective measures will come into force, e. g. in terms of a required ecological discharge. However, then the Turkish government and laws will guarantee the existing water rights, so that the losses will be limited for a certain period. For long-term perspectives and new hydropower plants the circumstances will change in terms of environmental considerations and economical figures which will be decisive for EPC and other investors.

Turkey's EU access will depend on several unpredictable circumstances which are related to world policy and economics. Nevertheless, overwhelming part of the Turkish population endorses the entry of Turkey mostly in terms of becoming a member of a prosperous and modern union. But, the level of support for the EU entry has reduced and will continue to reduce if European citizen and politicians keep on objecting to a full membership of Turkey. (Bahcheli, 2005; Gai, 2004).

A detailed discussion about Turkey and its relationship to the EU is presented by Akçakoca (2006).

3 Layout of Small and Medium Hydropower Plants in Turkey and relates Risks

3.1 General Layout and Design Criteria

The usual applied layout of small and medium HEPP in Turkey contain following structures:

- Diversion weir or dam with spillway (and reservoir)
- Sedimentation basin / facilities
- Conveyance channels and tunnels
- Inlet structure to penstock and surge tank
- Penstock
- Powerhouse
- Downstream channel

When circumstances are suitable, reservoirs are created by placing dam structures near the diversion structures. Normally the reservoir volumes of the related HEPP are relatively small, daily to monthly reservoirs. Most of the reservoirs shall enable the owner to produce peak electricity. If an annual reservoir is located upstream of a HEPP the operation scheme is dominated by the operation management of the reservoir which usually leads to a considerable increase of the energy revenues.

The common used design discharge in Turkey is derived from load factors of 10-20 [%] (about 35-70 days). Compared to European practice where load factors of about 25 % (about 90 days per year) are usually taken, these factors appear to lead to an uneconomical layout of the turbines and the whole powerhouse. But due to low construction and O&M costs in Turkey and the application of Chinese electromechanical equipment, this design approach is absolutely adequate and leads to the optimum solution.

Flood discharges are usually fixed on a reoccurrence period of T = 100 a for weir structures and T = 1,000 a or T = 10,000 a for reservoir dam structures. This is compared to international standards a reasonable approach. If safety concerns forces a higher safety level, the reoccurrence periods should be increased and/or the Probable Maximum Flood (PMF) has to be and is applied.

The design of the mentioned structures is focused on cost saving in terms of construction. The construction process itself is realized “as you go” which means that geological investigations and design work before construction are also limited to a minimum in order to keep the deadlines and to speed up the project realization.

Due to rapid construction and sometimes lack of supervision and quality control including safety standards during construction, the durability of the construction is different from European standards. However, license periods are usually 49 years, most companies consider shorter return periods for their investment. For the considered return periods also the OPEX (operation expenditures) is minimized applying a “in damage case”-concept for operation and maintenance.

3.2 Mechanical and (Hydro)Electrical Equipment

Since the beginning of 1990 Turkish hydropower owners and developers contracted Chinese manufacturers for the E&M-equipment. Although first orders were limited to turbines, the generator was still delivered from western companies. But the trend is heading to order all E&M-equipment from Chinese providers including sometimes also the design of the powerhouse. In the past decade Turkey mainly ordered Kaplan and Francise turbines from the Chinese market since the Chinese performance with Pelton types were poor. But also this is changing, so that actually also several Pelton turbines are ordered from China.

The switching facilities and other electrical items and the control and communication system as well as the transformators are usually ordered and produced in Turkey. Here, it has to be mentioned that Turkish companies usually apply European technology and high standard material bought from some well-known manufacturers mainly located in Europe.

However, the equipment produced in China is “old fashioned”, it is reliable and easy to maintain and repair. A disadvantage is that full remote control systems are currently not available and that spare parts have to be ordered also from

China. In respect to economical advantages the Chinese technology is more than acceptable since the price is only half or a third of the competing manufacturers with respect to western companies.

In China several major manufacturing companies are spread over the whole country. But, in most cases Chinese trading companies are organizing the whole business including order, deliver, quality control and the negotiations with Turkish clients and Chinese manufacturers.

The books of the manufacturers, particularly in China, are fully booked. Therefore, the deliverance of E&Q-equipment in time according to the fixed quality standards have to be guaranteed, also regarding deliver periods of 12 to 24 months for orders during the years 2007 and 2008. Here also, a local quality control can contribute to risk mitigation. Nevertheless, penalties are still a suitable tool to “motivate” the manufacturers to deliver in time and in the contracted quality. Usually, the sum of the penalties are limited to 10% of the contract sum or related to the daily revenues. The penalty sums can be charged daily in regard of the lost daily revenues, e. g. 50 % of the daily revenues. Another method is to foresee a certain delay period, e. g. 3 months, and intensify the daily penalties leading to a certain penalty sum for each month, e. g. 20 % in the first month, 30 % in the second month and 50 % in the third month. A concept like this will also grant additional time for the manufacturer for completion and moreover will give a motivation for speeding up. However, if precautious measures (quality control, penalties, choice of provider …) are taken and since experiences with Chinese products are satisfactory, actually no argument objects to orders from China.

3.3 Major Risks

Precipitation and discharge measurement facilities are usually widely spread across Turkey, mainly concentrating on major river regimes. The measured data reach back to 50 a and more. In areas where small and medium hydropower plants will be built or are in the feasibility stage, sometimes no reliable hydrological data is available so that new data has to be collected and the hydrological necessary data for preparing load duration curves are derived from similar hydrological regions in Turkey. Of course, this represents an uncertainty. Here, conservative estimates should be dominating in order not to overestimate the run-of-river potential and, therefore, the revenues. Poor hydrological data cause similar problems for the determination of the design flood discharges. Here, also a conservative approach should be applied both in estimating the critical discharges and in design, e. g. of the spillway capacity.

Hydropower projects in Turkey, particularly small and medium HEPP, are located in mountainous areas that are located in high danger earthquake zones.

Consequences are additional loads on static structures such as channel, dams, powerhouses, weirs, etc. and the threat of landslides and rock falls near structures and in the reservoir area. Also, the earthquake threat is high, usually small hydropower plants represent only a minor risk for downstream areas since only small weirs are necessary for diversion, but operation stops can occur due to earthquake impacts. If huge reservoir dams are applied the situation is completely different. Here, a complete and duly earthquake risk assessment is necessary due to the major risks and the threat to human life. Therefore, mostly the reservoir dams are designed as rockfill dams. However, Turkey has a huge number of dams in high danger earthquake areas and, therefore, a lot of experience with such kind of design and construction work (Tosun et al., 2007).

In general, the geotechnical investigations are relatively limited, so that construction processes can meet unexpected soil, rock and foundation conditions. This has an impact on the stability and the construction process of structures, especially regarding tunnels and conveyance channels. Anyhow, the concept "build as you go" is international practice, but bears a factual uncertainty in costs and time schedule.

Also bed and suspended loads play a major role so that usually sedimentation reservoir or basins are foreseen at the entrance of water conveyance channels or tunnels or upstream of the penstock. Here, abrasion and sedimentation may endanger the functionality of structures in terms of stability and serviceability. Also, suspended loads can cause critical cavitation damages of blades of turbines. Experiences show that runner blades had to be refurbished or renewed every two years at some existing HEPP. Existing sediment studies for small and medium HEPP are missing or are quite short and superficial, so that also sedimentation structures cannot be designed properly in terms of the expected sedimentation loads. All in all, the sedimentation problem can increase the maintenance costs and it may also cause some operation stops e. g. if the runners have to be renewed more often than expected. Moreover, the construction of sufficient sedimentation structures will increase also the investment costs.

Environmental aspects are becoming more and more important in Turkey. Ecological discharges and the impact of reservoirs have to be assessed and the effects have to be mitigated according to laws. However, the need for energy production is decisive, environmental aspects may have to be reevaluated in the future if environmental requirements change. This may cause a decrease of revenues and an increase of costs also for small and medium hydropower plants.

Actually, social aspects play a minor role for small and medium HEPP since the impact is anyway limited compared to large HEPP and positive aspects are provided by employment, work and infrastructural structures. Also land owners receive good prices for affected private land property. Besides, Turkish laws enable expropriation, and legal permits are obtained relatively easily.

Beside these risks referring to the design and construction, the use of water for irrigation purposes has to be kept in mind. Since for most regions in Turkey agriculture plays a major role and the amount of irrigation water is yearly negotiated between DSI and the local rural communities, this issue bears a certain risks regarding energy production also in terms of drought periods.

Other risk related aspects, e. g. the application of Chinese E&M-equipment, energy selling price, political conditions and legal procedures are discussed within the according sections of this paper.

4 Commissioning, Licensing, Permission Procedures

According to the different constellations and aims of private investors several different license types are available: generation, autoproducer, transmission licenses distribution, wholesale and retail licenses.

The head authority in Turkey responsible for the energy market is the EMRA. All applying companies have to submit a full compilation of the necessary documents to EMRA. The companies are required to be established as joint stock or limited liability companies in accordance with the provisions of the Turkish Commercial Code No. 6762.

The licensing and implementation procedures can be subdivided into three groups of projects for which private companies can apply:

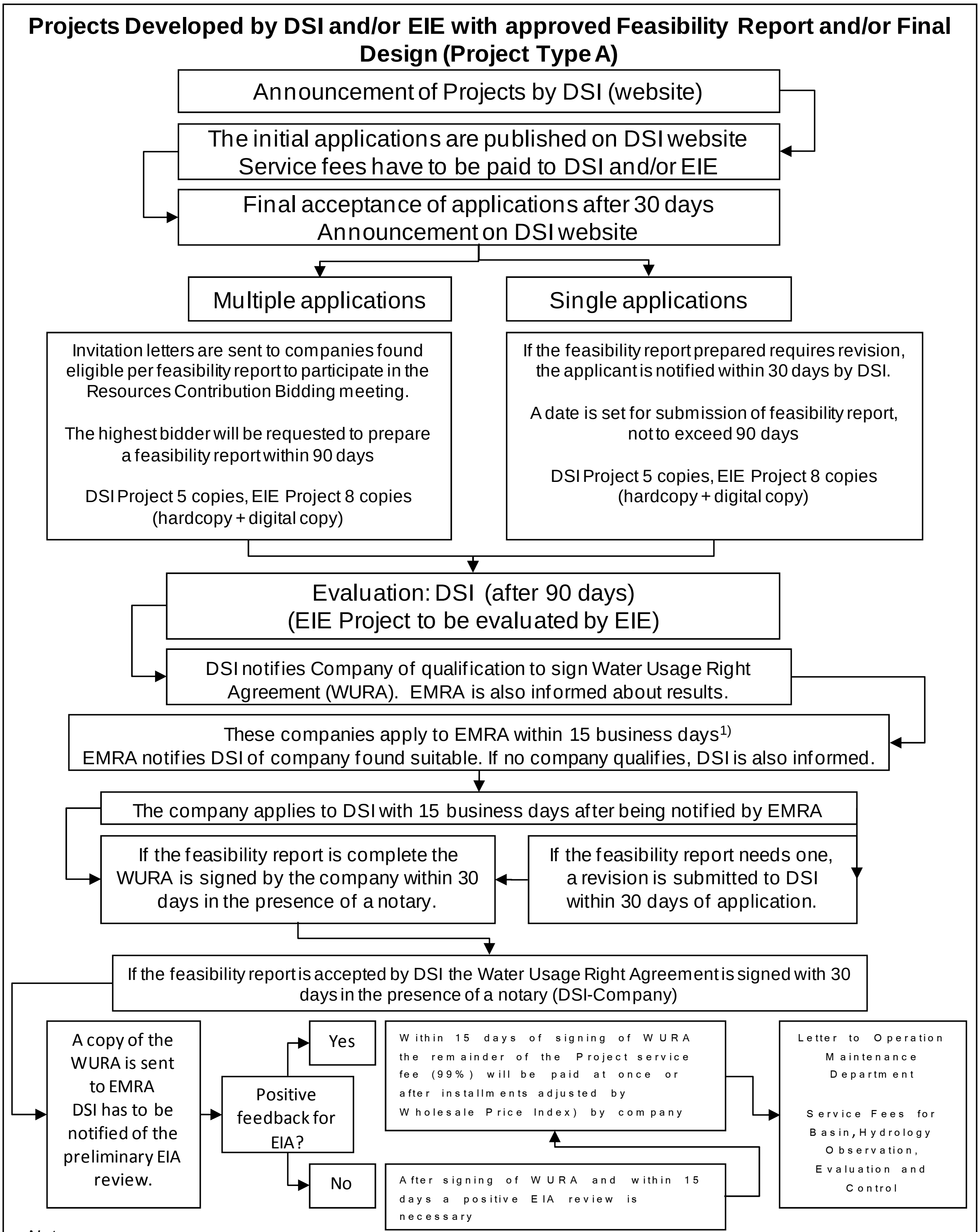
- Type A: Projects developed by DSI and/or EIE and which already have a feasibility and/or detail/final design
- Type B: Projects which have a master plan, preliminary study and pre-feasibility report
- Type C: Projects developed by legal entities

For project type A the procedure of the licensing process is given in Figure 1. In general the technical items are handled first. The EIA is prepared after signing the WURA and EIA is contributing to the maintenance and operation evaluation and program. The main steps of the EIA procedure are given in Figure 2 below.

The whole legal processes and requirements are strictly controlled by the authorities and clearly described by the according laws, technical requirements and specifications. However, the process and the contents of all outlined processes are comparable to German or European standards. Practice often looks different due to the need of the Turkish government to attract private investors in order to meet the rising energy demand. Also, detailed EIA are required for the larger projects, the importance of ecological aspects is often considered to be less than the need of power supply.

Therefore, in areas where diversion hydropower plants are or have been constructed, often dry river beds can be observed. But, especially for small hydropower plants the requirement of an ecological discharge may be an economical k.o.-criterion for the whole project. As mentioned above, the whole ecological topic have to be reassessed if Turkey shall join the EU and, therefore, also represents one more risk for owners and investors in the future.

Subsequently the company signs a contract with the Energy Market Regulatory Authority (EPDK) and takes license for 49 years.



Notes:

1) If deadline is missed, the company is automatically excluded from the permission process.

2) All the timeframes for pre-feasibility study, feasibility study, application and evaluation may be extended only once depending on the specifics of each Project. Companies will be informed of these decisions concurrently.

3) Planning period for companies is usually 2-3 months

4) The duration of six months might be reduced to 3 months. In sum 6 a 6 month period is foreseen for the whole process.

Figure 1 Implementation process for Project Type A

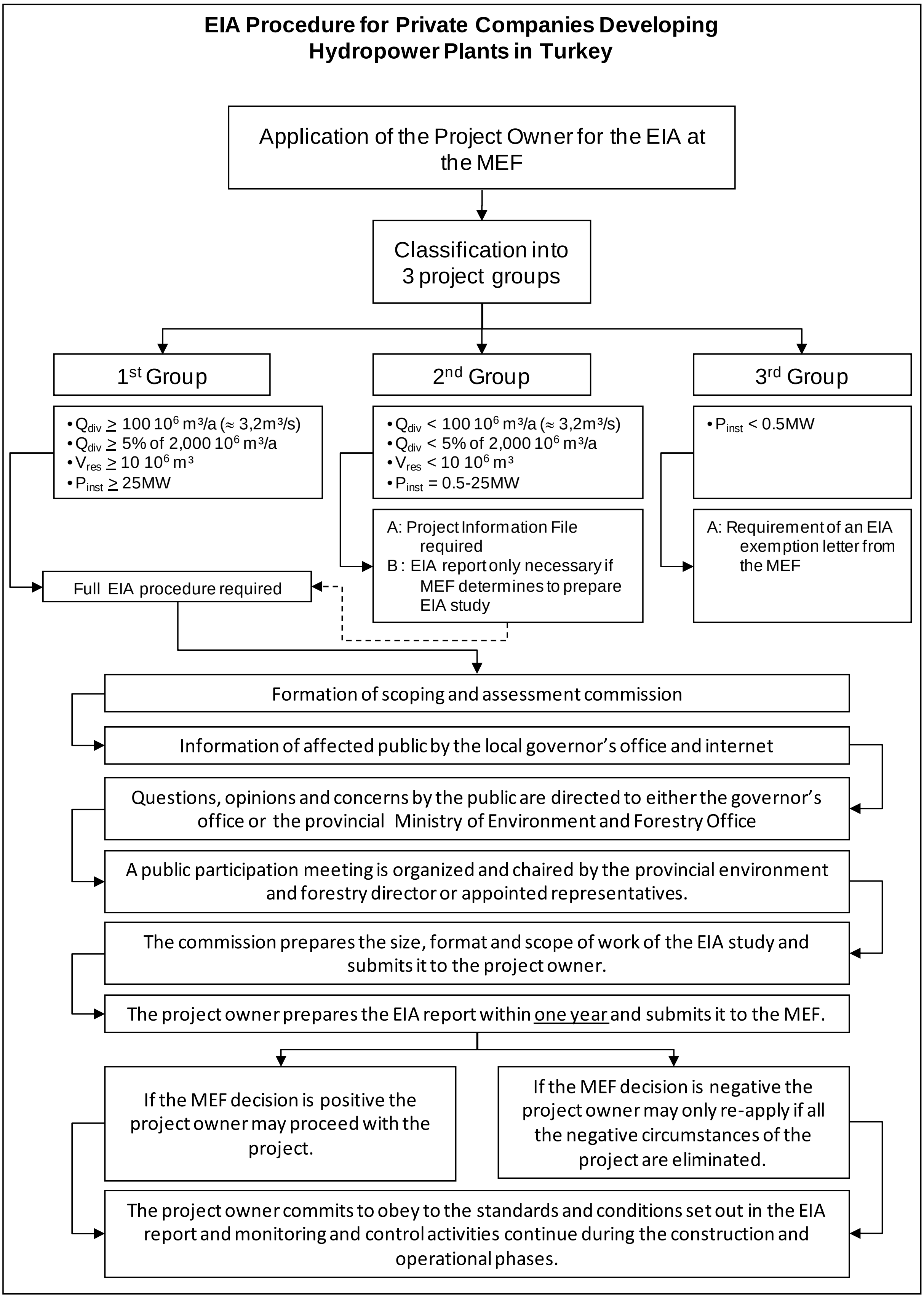


Figure 2 EIA procedure for private Hydropower Projects in Turkey

5 CAPEX, OPEX, Revenues

5.1 Investment costs, CAPEX

The total investment costs or capital expenditures (CAPEX) are comprising the construction costs including also license fees and other directly with the construction and implementation related costs such as costs for expropriation. Funding of the investment costs and, therefore, any interests are not considered in the following considerations.

In terms of a first estimation of investment costs of hydropower plants in Turkey in Figure 3 provides a graph showing the relation of installed power capacity and investment costs regarding 36 HEPP of small to large size. Roughly, the investment costs can be estimated by following *Formula 1*:

$$C_{Total}\,[Mio.\,€] \approx 1.00 \cdot P_{Inst}\,[MW] \qquad \textit{Formula 1}$$

This relation also confirms that investments in Turkish hydropower is actually quite profitable in terms of investing one Million € for one installed MW.

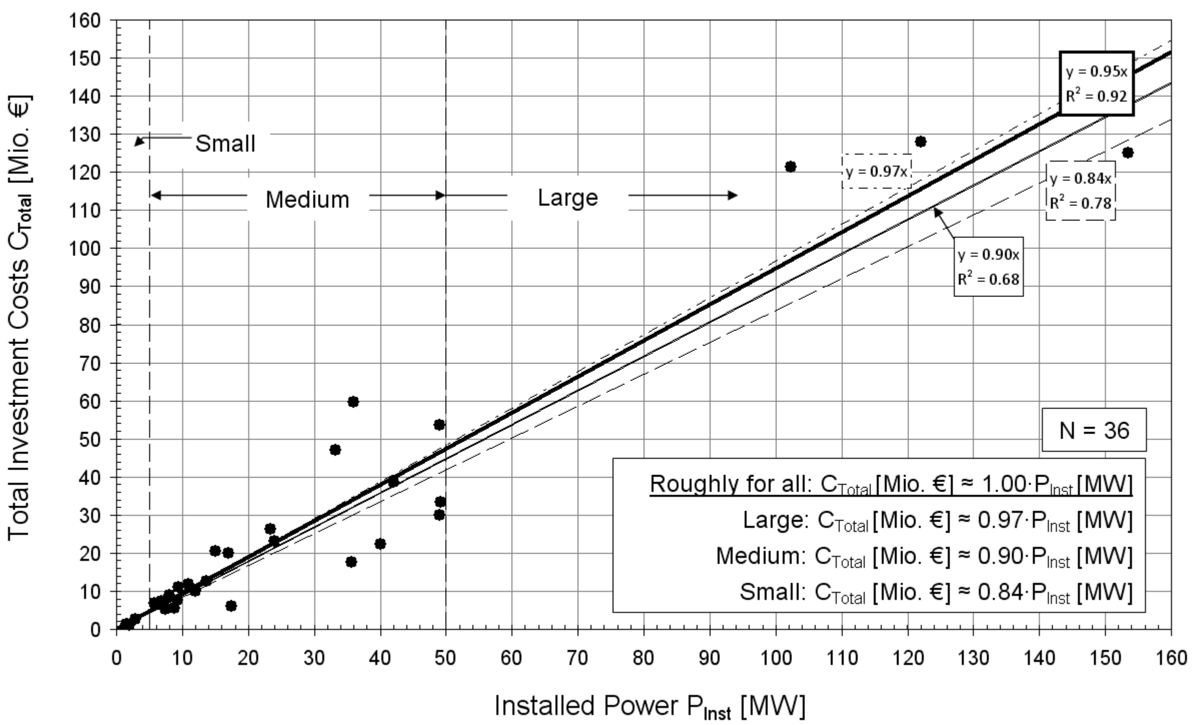


Figure 3 Investment costs of 36 hydropower plants in Turkey related to installed power

Similar to Figure 3, Figure 4 enables an estimation of the total investment costs with regard to the predicted annual power production. Herewith following

Formula 2 can be applied for checking the investment costs when hydrological data are available.

$$C_{Total}\ [Mio.\,€] \approx 0.25 \cdot W_{Annual}\ [GWh/a] \qquad \textit{Formula 2}$$

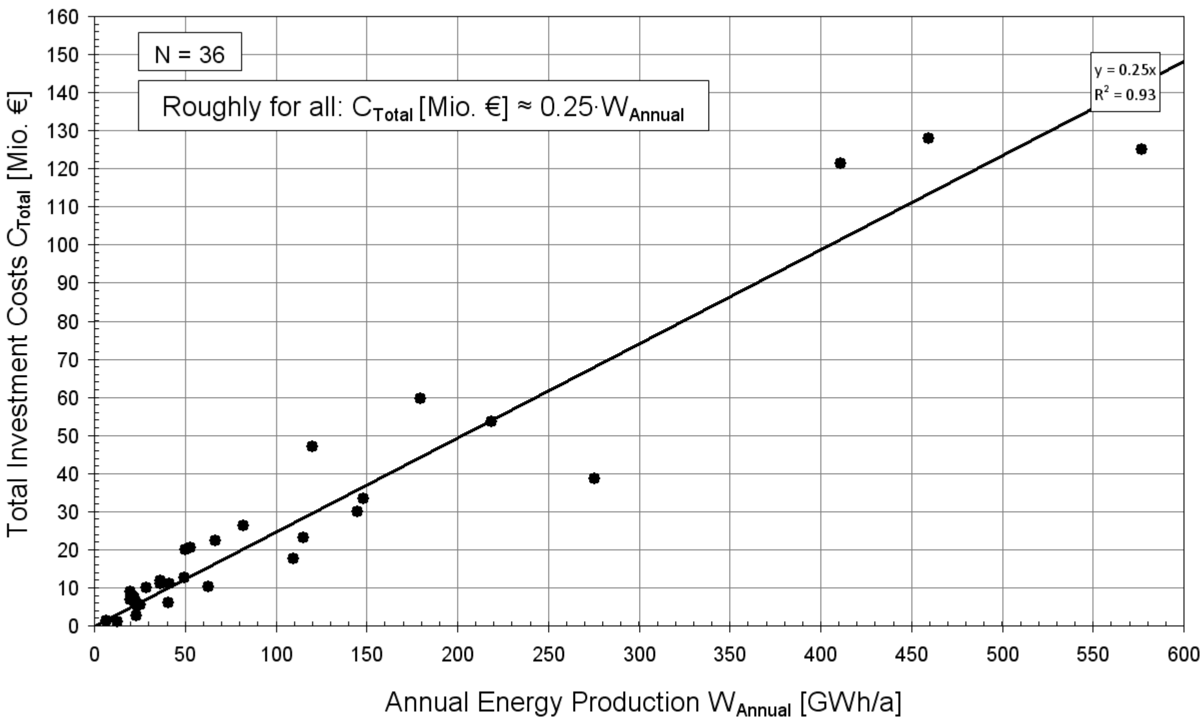


Figure 4 Investment costs of 36 hydropower plants in Turkey related to predicted annual power production

Of course, the given relations reflect only a rough, average estimate, but in case of investing in not only a single plant but a bundle of several it may produce quite precise overall investment costs. Whereas, single hydropower plants can reach investment costs lower than 0.5 Mio. € per installed MW. But since Turkish developers or owners often only offer a share of several plants or purchase a bundle of plants, more cost intensive plants are also included in offered numbers so that in average the given estimate will most probably meet a realistic cost figure.

The unit prices for the basic calculation work are given by DSI and have to be applied for the required project studies. Depending on the size of the project, these calculations are resulting in overall investment costs that are up to 10% higher or even more than the market price for small and medium hydropower plants. In case of large hydropower the cost calculation meets the final investment costs are too low due to logistical, financial and geological uncertainties that can cause a cost increase. Therefore, private companies are keen on realizing the projects by self-owned construction companies in terms of meeting the market price and profiting also from the overestimate of the feasibility report. Special attention has to be paid when the developers try to sell the whole project to investors or other power supply companies in terms of quality control and management and cost control. All in all, the 10 % overestimate by using DSI prices is a welcome additional profit for the developers.

Turkish companies often only apply 5 % contingencies for cost calculation at feasibility stage that is much too low, e. g. regarding uncertainties in geology and design. Usually, contingencies achieve at least 10 % to 15 % at that project state. It is also possible to foresee contingencies for the different structures separately, e. g. tunnels, channels, powerhouse. As mentioned before during the discussion of the E&M-equipment the uncertainties regarding E&M should be quite limited if normal purchasing and quality management process are applied.

5.2 Operation and Maintenance, OPEX

The O&M-costs usually include following costs and aspects:

- staff on site and at the control centre / headquarter
- administration including engineering (general expenses, staff …)
- maintenance & operation consumables and spare parts (oil, incidentals ...)
- regular revisions of turbines, electrical equipment a. s. o. with assistance of external companies (e. g. for turbines all 5 years regular revision and all 15 years detailed revision)
- renovation / refurbishment of equipment due to abrasion and cavitation caused by sediments (turbine blade …)
- refurbishment of waterways and reservoirs due to sedimentation (excavation, dredging …)
- modernization of control equipment (normally all 10 years)
- regular checks (operation and security) for cranes a. s. o.

An increase of O&M-costs can be caused by following aspects:

- High sedimentation loads (waterways …)
- Suspended loads worsen cavitation and abrasion of concrete and steel structures
- Design contingencies may lead to some damages in operation times and especially during flood times (layout of the stilling basins, seepage flow in powerhouses …)

- Huge amount of woody debris lead to increased allocation of resources
- Some of the maintenance works has to be done by expensive outside companies (for the maintenance of the electrical equipment)
- Consumables and spare parts are relatively expensive in Turkey (fuel, material imports …)

For the economical evaluation the O&M-costs play a decisive role for investors, developers and owners, since these cost items will be much higher than the investment costs in terms of the service time of hydropower plants which is roughly estimated equal to the license period of almost 50 years. Due to the finance market's requirements, private investors are looking at much shorter time periods and much higher IRR for their investments as usually applied for hydropower projects. This will be discussed in chapter 6 "Economical Considerations".

The maintenance and operation costs of HEPP can be evaluated for rough cost calculation at the stage of pre-feasibility, feasibility and also detail design studies by different methods. One of the most common methods is using the power production revenues and foresees as percentage of around 15 % to 20 % of this revenues for O&M-costs. Another method takes the whole investment costs for the projects and takes a percentage of around 3 % to 6 % for the annual O&M-costs. These methods are based on large projects worldwide with western maintenance and operation standard. For the Turkish market this methods may lead to an overestimate of the O&M-costs due to the different concepts for operation and maintenance which results in very low costs.

A reliable approach of estimating the operation and maintenance costs can be derived from a reasonable separation of the costs into following three items:

- O&M for the E&M-Equipment
- O&M for the Civil Works
- Staff costs

The maintenance concept in Turkey is generally a "in case", reactive concept. Here, only if a damage occurs measures are taken which will enable the plant to continue operation, not more or less. This bears certain dangers but reduces the running costs to a minimum regarding annual costs and short term operation periods. Here also, a renewal of the whole E&M-equipment may be necessary after a relatively short operation period. Generally, renewal is assumed to be necessary after 30 a to 35 a.

E&M-equipment usually requires a higher cost percentage for maintenance and operation than civil works. Since the total investment costs are dominated by the

E&M-equipment and the civil works, the O&M-costs can be calculated applying fixed percentages of the total investment separately for civil works and E&M-equipment. Here, some common known values can be applied. Different to other worldwide realized projects, the E&M-equipment of Turkish hydropower plants only reflects a low percentage of the investment costs. Experiences confirmed that the costs for E&M-equipment "only" comprise roughly 10 % to 30 % of the total investment regarding the cost composition of 10 hydropower plants.

Thus, a separated look at the O&M-costs of the E&M-equipment is necessary applying also different cost percentages of the whole investment for both items. For the E&M-equipment O&M-costs can be derived from taking 2.5 % to 3.5 % of the E&M-investment costs. For civil works 0.5 % to 1.0 % of the civil works investment can be applied. Herewith an average of 2.6 % of the investment costs is achieved after evaluation of 10 HEPP. Nevertheless, a conservative approach should head for 3.0 %, what was also confirmed by Turkish owners.

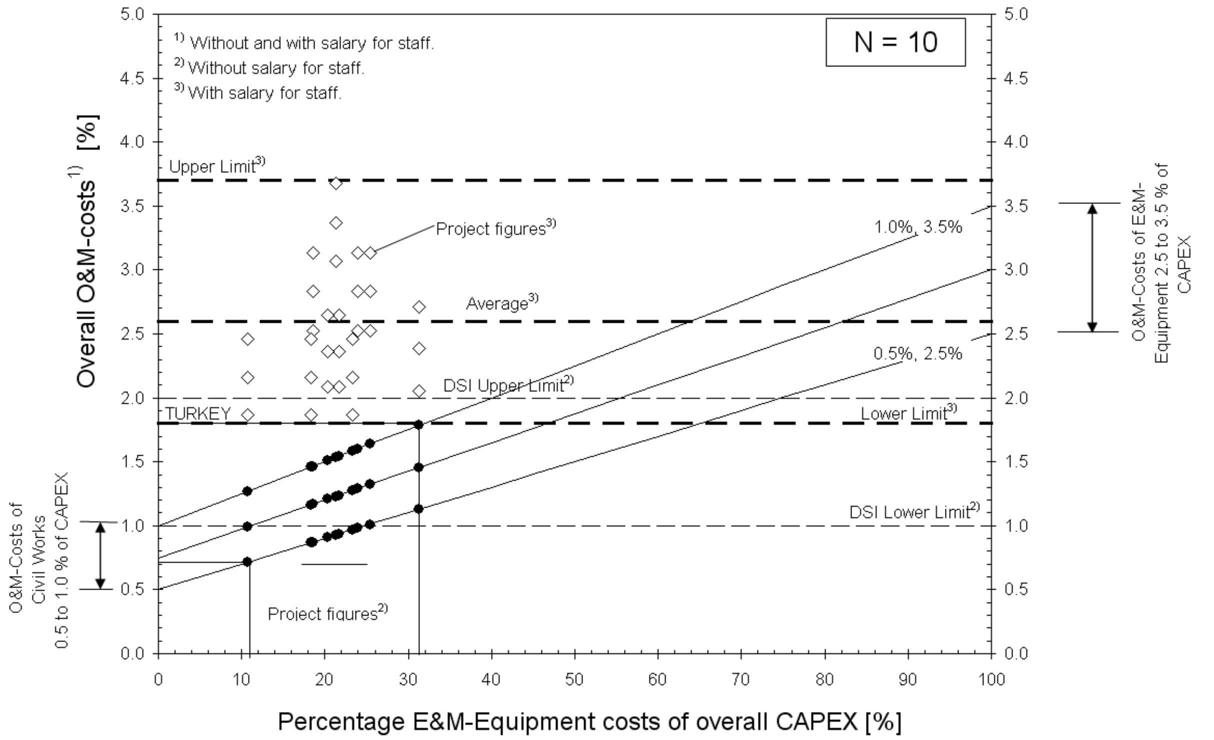


Figure 5 O&M-costs with and without salary for 10 HEPP in Turkey regarding the E&M-equipment cost percentage

As commonly known, the O&M-costs have a relatively strong influence on the economical evaluation of small and medium hydropower plants.

The average income of the craftsman that are employed at the HEPP is roughly 8,000 €/year. An average income of the O&M- staff is assumed to be approximately 10,000 €/year regarding the different wages for technicians, security personal and engineers. The average number of staff members is 15, so that annual costs of roughly 150,000 €/year can be assumed for a single HEPP. However, organigrams can also easily be prepared for a more precise estimate of the annual staff costs.

As expected, the costs for staff contributes only little to the estimated overall costs. If several hydropower plants can be operated and maintained as single operation unit, the supervision, coordination and overhead costs can be reduced. Taking into consideration the staff costs for 10 hydropower plants the annual costs are approximately 0.7 % to 2.2 % of the total investment. Also here, in average a percentage of 1.5 % of the total investment can be used for preliminary staff cost calculations. An evaluation is given in Figure 5. Here, the range of the O&M-costs ranges from 1.8 % to 3.7 % of the investment.

All in all, conservatively an overall percentage of 2.5 % to 3.0 % of the total investment can be taken for the annual O&M-costs including staff salaries. The given limits of DSI for O&M-costs without salary are 1.0 % and 2.0 % and this range could be more or less confirmed by the own evaluations (see Figure 5). Also a gross check by empirical data for O&M-costs in Austria and Germany where less than 1.0 €-Cent/kWh/a are assumed for the O&M-costs is positive. The related Turkish projects reach O&M-costs of 0.6-0.7 €-Cent/kWh/a.

5.3 Energy Selling Price, Revenues

The energy revenues for a lot of HEPP studies are commonly based on average values for the selling price of the electricity that comprises a range of 6.0 to 8.0 €-Cent/kWh. Former studies were also applying lower prices. The energy selling price for 2008 was according to DSI publications (Yüksek, 2008) 6.0 $-Cent/kWh for the firm energy. For the calculation of an average selling price the value for the firm energy can be increased if peak energy can be also provided by a HEPP that is affected by a reservoir operation scheme.

Actually, TEDAS calculates with an average selling price of 8.5 €-Cent/kWh which may increase to 9.0 to 10.0 €-Cent/kWh in near future according to rising prices. This average price implies all kind of daily prices such as peak or firm energy price. Currently, new models of selling concepts for producers and other providers are introduced to the market. Moreover, energy companies aim on increasing the profit by producing more and more peak energy by the usage of reservoirs.

All in all, the approach using average selling prices seems suitable for the estimate of annual revenues as operation concepts for HEPP in Turkey are partly not existent, also due to the considerable changes within river regimes. A second aspect that supports this method is that the effects of the reservoirs under construction have to be elicited by reservoir operation simulations and assessments. In case when irrigation facilities and hydropower production are combined, the simulation and evaluation of a long-term behavior is relatively complex. Taking also the uncertainties comprised by the Turkish retail market and the development of the energy price in Turkey and also worldwide into account the application of an average selling price seems to be quite suitable.

In Figure 6 the annual energy selling revenues of 33 HEPP of small and medium size in Turkey are given related to the investment costs. Herewith it is again confirmed that the investment costs are relatively low compared to the annual revenues. In average following *Formula 3* can be applied for the estimate of the annual revenues, applying an average energy selling price of 8.0 €-Cent/kWh that is actually probably lower than the realistic market producer selling price.

$$R_E\,[€] \approx 0.3 \cdot C_{Total}\,[€] \qquad \textit{Formula 3}$$

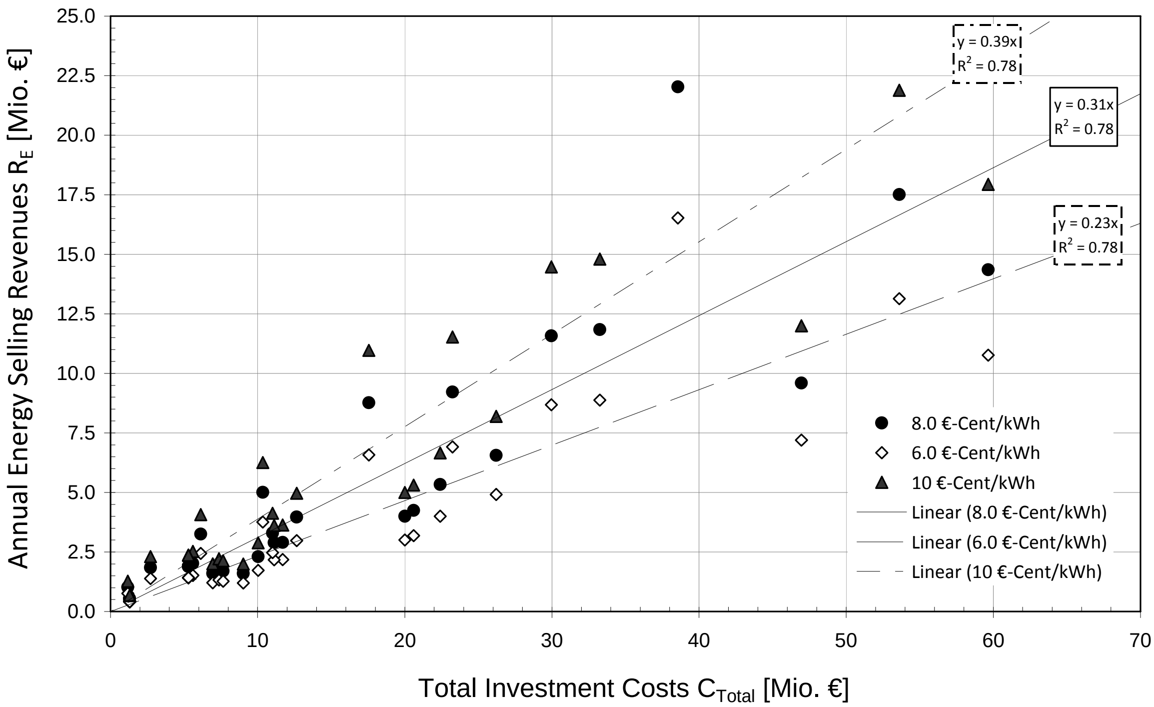


Figure 6 Predicted Energy Revenues for 33 HEPP in Turkey using an average Selling Price

Additional revenues by selling CO_2-certificates or achieving some is not feasible at the moment.

6 Economical Considerations

As mentioned above, the cost calculation, the construction process and, therefore, the whole economical evaluation of hydropower projects in Turkey are influenced by the aims of the developers. If the developers are simultaneously the future owners and the funding will be done exclusively by themselves, the cost calculation and the projections of the revenues will be usually done as realistic as possible in order to draw a realistic future picture. If additional investors shall contribute to the funding or other shareholders are involved or the project shall be sold to a new owner all the cost calculation and the projection of revenues have to be checked very carefully within an economical reassessment. Here, costs maybe underestimated and revenues over-estimated to achieve very positive project characteristic regarding IRR and profits.

It is also relevant whether an investor will be a shareholder or the owner or a creditor that will “only” be interested in amortizing the credits including interests, fees, provisions and profit.

In Figure 7 an exemplary evaluation of the IRR for typical Turkish HEPP is given. The assumptions for this economical consideration are added on the right side in Figure 7. Losses to the net and other transmission fees are not included.

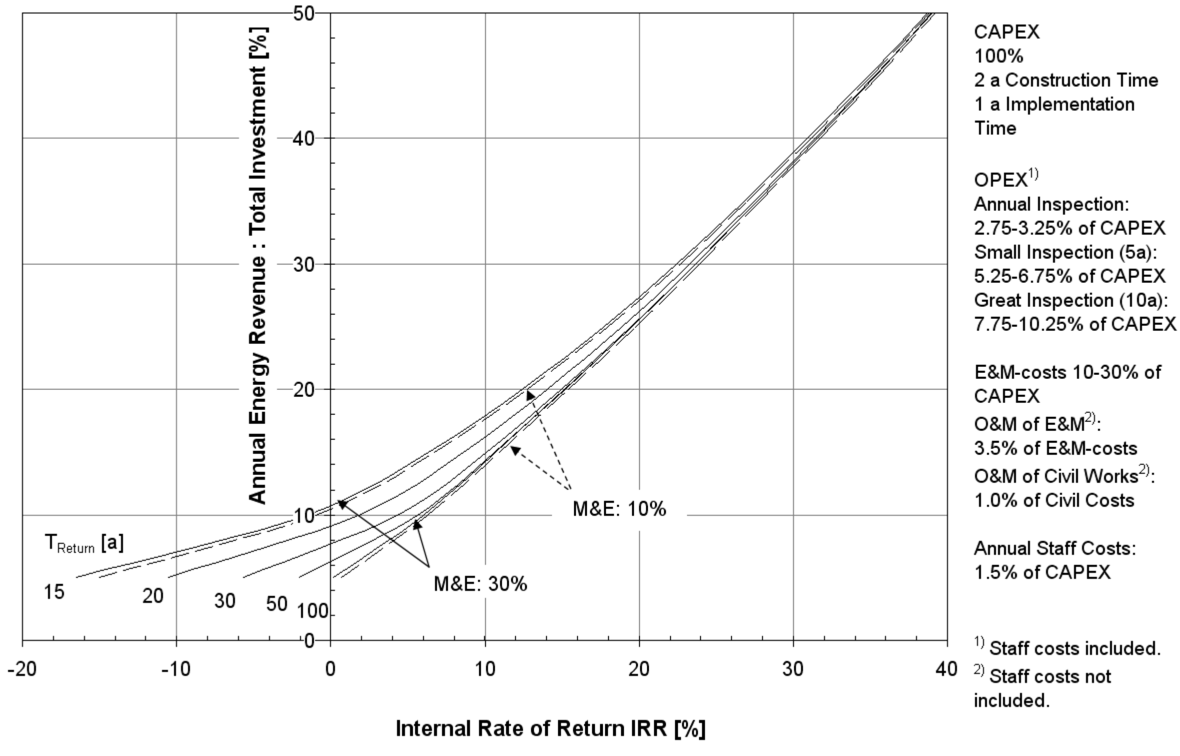


Figure 7 IRR for varying annual revenues for typical HEPP conditions in Turkey (without any interests, without profits, overhead and assuming constant selling and construction prices)

Of course, the positive results are not surprising regarding the high revenues percentages that are 30 % of the CAPEX in average (see Figure 6). The IRR reaches over 20 %, having enough buffer also for external funding and its interests expenditures or also enough buffer for unforeseen additional costs during construction or during operation.

7 Conclusion

Investing in hydropower projects in Turkey is attractive regarding both short-term or long-term perspectives due to low construction and O&M-costs. Nevertheless, inherent risks shall not be neglected. In order to mitigate the risks and production stops an early intervention by investors is required, also to find a common basis for cooperating with Turkish companies, authorities and all related and affected persons.

Whoever will participate in the “boom” of small and medium hydropower in Turkey, it shall not be forgotten that the HEPP are and will be located in Turkey and Turkey is a special country with all its particular habits, attitudes and history. A usual fact for developing countries is that risks are taken more easily without assessing all the consequences. Simultaneously, this is one major reason for the project pretending to be very profitable. Changing the construction method or the O&M concept maybe mitigates related risks but will also decrease the profits.

Finally, investors shall take care to find suitable Turkish counterparts who are used to the Turkish habits and are experienced in hydropower. This will make work easier and may also contribute to risk mitigation concerning permission processes, construction, operation and design work.

Abbreviations

BOO	Built-Operate-Own	MEF	Ministry of Environment and Forestry
BOT	Built-Operate-Transfer	MW/GW	Mega-Watt (106 W) / Giga-Watt (109 W)
CAPEX	Capital Expenditures	O&M	Operation and Maintenance
DSI	General Directorate of State Hydraulic Works	NSC	National Security Council
E&M	Electrical and Mechanical (Equipment)	OPEX	Operation Expenditures (including Maintenance)
EFEP	Economically Feasible Energy Potential	P	(installed) Power Capacity [MW]
EIA	Environmental Impact Assessment (Turkish: ÇED)	TEAŞ	Turkish Electricity Generation Transmission Company
EIE	General Directorate of Electrical Power Resources, Survey and Development Administration	TEDAŞ	Turkish Electricity Distribution Company
EPC	Energy Providing Company	TEİAŞ	Turkish Electricity Transmission Company
EPDK	Energy Market Regulatory Authority	TEK	Turkish Electricity Authority

	(Turkish: EMRA)		
EU	European Union	TETAŞ	Turkish Electricity Transmission Company
EÜAŞ	Electricity Generation Company	TOR	Transfer of Operating Rights
IRR	Internal Rate of Return	WURA	Water Utilization Right Agreement

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