5. COST–BENEFIT ANALYSIS OF ADAPTATION OPTIONS

5.1 OBJECTIVE OF THE COST–BENEFIT ANALYSIS

Based on discussions with stakeholders it was agreed that a high-level economic cost–benefit analysis would be an appropriate method of examining options to manage the risks and vulnerabilities to Albania's energy security in the face of climate change. Having subsequently considered the impacts of climate change on energy security further, and given that diversification of power generation assets was identified as a key adaptation option, stakeholders agreed that the objective for the cost–benefit analysis be refined to address the following question:

> "What is the optimal technology (power generation asset) to supply the shortfall in electricity that is directly caused by climate change?"

Implicit in the word *optimal* in this question is the delivery of sustainable development. Also implicit is the time period over which options should be considered. During discussions with stakeholders, it was suggested that a 30-year period should be considered, however this was later refined to 40 years (up to 2050) to tie in with climate modeling timeframes and a notable threshold date.

5.2 ASSESSMENT OF SHORTFALL IN FUTURE POWER GENERATION DUE TO CLIMATE CHANGE

To assess the range of energy generation technologies that could be used, it is first necessary to identify what shortfall in power generation may result from climate change in Albania. The calculations and projections below use as their starting point the most recent draft National Energy Strategy (NES, Government of Albania, 2007). The draft National Energy Strategy presents two scenarios, passive and active (described in Box 8 overleaf), and considers the medium-term period out to the year 2019. Since the present assessment has a longer time horizon than the draft NES, extending out to 2050, a number of assumptions have been made to build supply and demand projections beyond the timescales of the NES. These assumptions are detailed in Annex 8.

Step 1. Supply–Demand Projections Excluding Climate Change

In discussions undertaken during the workshops and subsequent meetings, stakeholders highlighted that it was important to assess the impacts of climate change over a long planning horizon; therefore, a time period from 2010 to 2050 was selected. But the draft NES for Albania only provides projections for power supply and demand for the medium-term, from 2003 to 2019.

Therefore, as part of this assessment, the projected power demand described in the draft NES was extrapolated beyond 2019 for each of the two demand-side scenarios that the draft NES presents:

- The passive scenario, which involves no energy demand control or energy efficiency measures)
- The active scenario, which includes implementation of energy efficiency measures such as residential property insulation standards and installation of domestic solar water heating

The extrapolation of demand projections beyond the timeframe of the draft NES was based on Albanian energy-expert opinion (Islami, 2009) and corresponds to annual growth rates in demand of 2.8 percent initially, declining to 2.1 percent by 2050, in the passive projections; and 2.2 percent declining to 1.8 percent in the active projections. These demand growth projections are illustrated in Figure 19 and are detailed in full in Annex 8.

From these demand projections, potential energy supply curves were generated that would meet demand. Electricity typically cannot be stored but, rather, is produced instantaneously; in that sense, supply and demand projections are the same line. Reconciliation is achieved as follows: detailed supply projections are based on known potential energy assets included within the draft NES, plus additional energy assets known to be under discussion within the Albanian energy sector, plus energy imports at the level that achieves demand–supply balance without load shedding (after 2013, when the draft NES predicts load shedding will cease). The use of imported energy represents the demand that cannot be addressed with domestic sources.

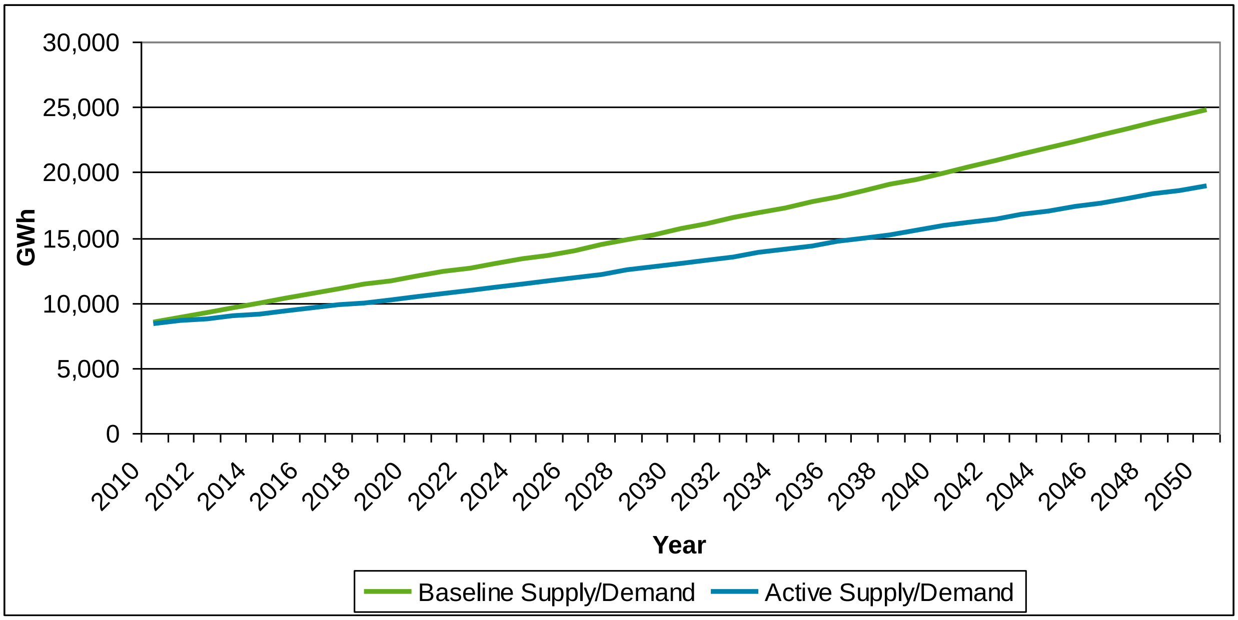

Figure 19: Projected electricity supply/demand for Albania from 2010 to 2050

Step 2. Superimposing the Impacts of Climate Change on Supply–Demand Projections

Based on the climate change risks identified for Albania (see Section 3, Annex 8 and Annex 9), the active-scenario projections of supply and demand were modified. Section 3 highlighted the anticipated impacts of climate change:

- Demand side:
  - Summer cooling of residential and commercial properties will increase due to rising summer temperatures.
  - Winter heating of residential and commercial properties will decrease as winter temperatures rise.
  - Based on analysis of the above effects and combining these two phenomena results in an estimated net effect of a reduction in annual demand of approximately 0.1 percent per year. It is noted that this annual decrease may disguise a more significant impact on energy security due to changing seasonal demand, with the summer peak demand increasing and potentially becoming a greater controlling factor than current winter peak demand (see Section 5.7 for more information on seasonality of impacts).

Box 8: Active and passive scenarios in the draft National Energy Strategy, 2007

The draft National Energy Strategy uses two future scenarios (passive and active) to project Albania's electricity supply and demand up until 2019. Both projections are based on economic growth in Albania of +5 percent GDP per year.

The passive-scenario projection assumes the preservation and development of the present situation in terms of supply and demand for energy in all sectors of the local economy. It projects continuation of electrical power consumption as the dominating source of energy for space heating and water heating in the households and services sector. This projection assumes that a considerable part of the future demand for electrical power shall be covered by extension of the thermal generating capacities (based on marine petroleum, solar, fuel oil, and imported natural gas) and hydropower energy.

The active-scenario projection assumes efforts to address the supply–demand imbalance that is expected to arise under a passive scenario. It assumes the following objectives:

- Improving supply security
- Improving energy efficiency
- Diversification of energy resources
- Use of renewable resources
- Real pricing of electrical power
- Implementation of the regional electricity market
- Environment protection

The active-scenario projection assumes a focus on improving energy efficiency through:

- Greater use of domestic solar water heating
- Improved building standards (insulation, windows etc.)
- Lower energy appliances
- Alternative heating sources other than use of electricity

Although the active scenario envisions efforts intended to address current energy security concerns, many of the actions included in the active scenario would also help to build resilience to the impacts of climate change. The projections made under the active scenario are dependent on the successful implementation of the measures outlined above, which will be challenging. For the elements of the cost–benefit analysis involving the active-scenario projections, it has been assumed that these measures are implemented as described in the draft

- Supply side:
    - Reduce annual precipitation and increases in temperature, leading to lower runoff and less hydropower generation. As outlined in Section 3, the impact of climate change on large hydropower plants is estimated as reduction of their generation by 15 percent by 2050. For small hydropower plans, the reduction is estimated as 20 percent by 2050.
    - Reduce efficiency of thermal power plants and also transmission and distribution networks. The efficiency reduction has been estimated as 1 percent for TPPs by 2050, associated with rising temperatures. This estimate does not take into account any impact on efficiency of thermal power plant operations due to environmental management associated with cooling water discharge. Vlore TPP will be cooled using

seawater, and it is considered unlikely that its operations would need to change for discharge to the marine environment. (However, if Albania develops river- or lake-cooled TPPs in the future, these risks could be significant.) Losses from transmission and distribution networks are also estimated as 1 percent by 2050.

  - The projected reduction in cloudiness would mean that the output of solar power plants would increase in the future. As outlined in Section 3, it is estimated that an increase of 5 percent would occur by 2050.

The resulting predicted net reductions in supply (shortfall in power generation) due to climate change are on the order of 580 to 740 GWhrs/annum (2 percent to 3 percent of total power demand) by 2050, based on the extrapolated passive- and active-scenario projections respectively. Interestingly, the shortfall caused by climate change in the active-scenario projection is greater than that in the passive-scenario projection. This is because the active-scenario projection assumes greater demand-side efficiency measures, less reliance on GHG-emitting thermal plants, and a greater share of generation burden placed on hydropower plants, which are more affected by climate change than other sources of electricity. However, an aspect that should not be overlooked is the fact that many of the actions proposed as part of the active scenario represent adaptation options: energy efficiency measures, diversification of assets, and regulatory reform. Ensuring implementation of these measures would be an important part of a strategy for Albania to manage climate-related risks and vulnerabilities to the energy sector. As climate change impacts take effect in Albania, these “adaptive-active” scenario options will have increasing value. However, the benefits evident in the active-scenario projection are predicated on successful implementation of energy efficiency measures, asset diversification, and other measures mentioned in the draft NES.

As can be seen in Figure 20, the active- and passive-scenario projections track together over the time period considered, with the energy shortage due to climate change slightly higher in the active scenario than that in the passive scenario. As already mentioned, the draft National Energy Strategy projections end at 2019. From 2020 onward, the shortage is projected using a different methodology and a number of technologies are assumed either to come online or increase output. This is the reason for the inflection in the active scenario line at 2020. (See Annex 7 for further details.)

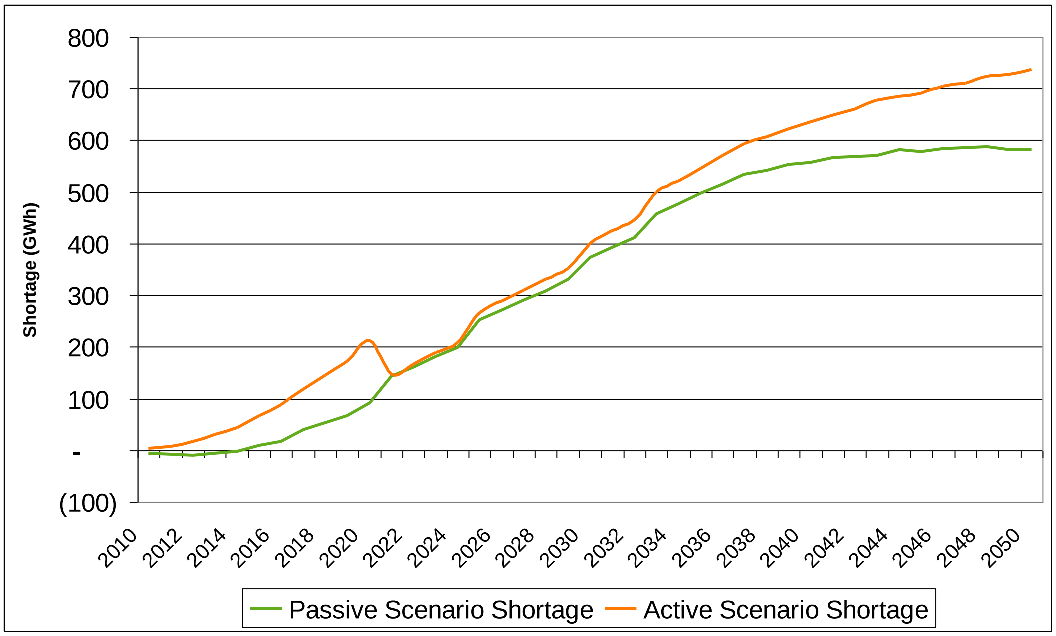

Figure 20: Electricity shortage due to climate change

Superimposing the impacts of climate change on the annual supply–demand projections reflects only part of the potential threat that Albania's energy sector faces from climate change. There is a question regarding how the energy system will work during critical periods (very hot or dry periods) and whether more-significant impacts may emerge under some circumstances that are beyond the annual-average shortfall projected in Figure 20. For example, the shortfall projected does not take account of the limited capacity for storage of water in reservoirs that serve LHPP assets. If, due to climate change, runoff that fills the reservoirs comes in shorter, more-extreme periods of wet weather that requires water to be spilled, followed by long dry periods and shortage of water, the power generation from LHPPs could be less than projected above. This issue is discussed further in Section 5.7. A recent study in Brazil indicated that where power production was calculated based on projected annual-average rainfall/runoff data, climate change would result in a 3 percent drop in power generation. When the same analysis was conducted using more detailed seasonal data, it was projected that the drop in firm power production could be as much as 30 percent (Schaeffer *et al*., 2009). At this stage, there are insufficient hydrometeorological and climatological data available for Albania to enable an estimate of future subannual rainfall and power-generation relationships. However, this could be researched further by policy makers and technical managers.

5.3 OPTIONS TO MEET THE PROJECTED POWER SHORTFALL DUE TO CLIMATE CHANGE IMPACTS

Having identified potential future shortfall in electricity supply due to climate change, and noting that some measures that contribute to building climate resilience are already contained within the active-scenario projection, this assessment looks at the costs and benefits of options for diversification of Albania's electricity supply.

Before discussing these options, it is worth noting briefly the significant benefits of improving energy efficiency. The Asian Development Bank estimates that if 1 million incandescent light bulbs were replaced with compact fluorescent lamps (CFLs) at a cost of about $1.5 million, electricity demand would be reduced by about 50 MW. It estimates that the cost of building a new 50 MW power station would be at least $50 million, and that operating costs would add another $2 million to $3 million per year. This demonstrates how cost-effective energy efficiency measures can be, and further strengthens the argument for ensuring that the energy efficiency measures in the draft NES are implemented.

For the cost–benefit analysis, eight reasonable and practicable technology-based options (asset types) for filling the electricity shortfall were identified during the workshops. These selected options are described in order of increasing estimated capital cost. Assumptions relating to the parameters that were used to assess each option in the CBA are also outlined:

1. **Import.** The import of electricity from neighboring countries is considered to be a realistic potential option. There is a premium associated with the cost of this power and prices fluctuate on a daily basis. To assess the environmental and social effects associated with this option in the CBA, only those global impacts that could potentially affect Albania were considered. Water usage and emissions for this option were considered to be the same as for the combined cycle gas turbine option. Impacts on ecosystems and disturbances to people and property were not considered, as it was assumed that the regulatory authority in the generating country has already taken these into account. It has been assumed that all imported electricity is produced using combined cycle gas turbine (CCGT) technology, although it is recognized that a range of electricity generation technologies are used in South Eastern Europe (see Box 2, Section 2.1), including nuclear power, hydropower, other renewables, and GHG-emitting thermal plants fueled by coal.
2. **Use combined cycle gas turbine (CCGT) technology.** A new-build CCGT-based power plant would use natural gas, which is cleaner than coal but has several disadvantages, such as dependence on foreign sources of fuel and relatively high GHG emissions in comparison with renewable technologies such as hydropower. Supercritical pulverized coal technology was not considered in detail in the CBA, but if supercritical pulverized coal technology were used instead of a gas-fired CCGT, it would have different environmental costs: it has approximately 200 percent of the water usage and 220 percent of the GHG emissions of CCGT. CCGT is clearly the more sustainable thermal option in spite of costing approximately 10 percent more than coal on a levelized basis.
3. **Improve/update existing large hydropower plants (LHPPs).** There is some capacity for improvement in existing large hydropower assets, including actions such as optimizing data collection and usage, reservoir/dam maintenance and reservoir management.
4. **Improve/update existing small hydropower plants (SHPPs).** Many of the small hydropower assets in Albania are old, and technology and design have improved considerably since they were installed. In many cases, improvements such as optimizing turbine operation with respect to varying river flow regimes, widening intake and outfall channels, resizing turbines/plant, and improving connections to the transmission network are possible.

5. **Install new small hydropower plants (SHPPs).** There are a number of unexploited sites where new run-of-river hydropower plants could be sited. These smaller plants generally serve smaller communities and could be connected to local distribution networks as well as the national transmission grid.
6. **Develop wind power.** At this stage, there is no wind-power electricity generation in Albania, although, as outlined in Section 2, a number of potential projects are currently under consideration in Albania's coastal areas.
7. **Use concentrated solar power.** Concentrated solar power (CSP) captures solar energy through a large array of mirrors, directing light toward a brine solution or other thermal receptor that converts the solar energy into electricity. There are currently no CSP plants in Albania. However, there are several located in the Mediterranean region in areas with similar solar characteristics to those of Albania.
8. **Install new large hydropower plant (LHPP).** This option represents the building of a completely new dam and reservoir to exploit the remaining generation potential in Albania's hydrological system.

In undertaking the CBA, potential constraints on the implementation of technologies have been considered:

- It is considered that, subject to approval, there are no physical constraints on the number of thermal power plants that could be installed.
- With respect to wind power, there are insufficient data at present on wind speeds in Albania at turbine operating heights. However, it is assumed that there is adequate wind potential for the purposes of the CBA.
- In the case of CSP, technology is developing in this area and a number of stakeholders felt that this technology might become more feasible in the future, perhaps by 2040 and beyond. Aspects considered in relation to current use of CSP were:
    I. The technology is relatively new.
    II. The capital costs are higher compared to other technologies.
    III. There is not enough operating experience accrued worldwide to provide real data for operating and maintenance costs.
    IV. It involves higher technological, schedule and financial risks.

  It is expected that by 2040 the capital costs for CSP would be comparable with other technologies and sufficient experience worldwide would be developed that would reduce the current risks associated with CSP. For the purposes of the CBA, best estimates of technology costs (CAPEX and OPEX) have been used in the analysis, though it is recognized these may be reduced if/when the technology advances.
- With respect to hydropower, much more data are available. METE stated during meetings that the current estimate of Albania's hydropower generation capacity is 3,200MW total for LHPP and SHPP (Tugu, 2009). Of this, there is currently 1,445MW of LHPP and 15MW SHPP installed capacity. The future supply projections developed in this assessment are based on

> development of a further 1,150MW LHPP and 390MW SHPP, thus giving a total installed capacity of 3,000MW by 2050. These values are estimated before the impact of climate change has been taken into account, which it is predicted would reduce hydropower potential in Albania. Therefore, there may be a significant physical constraint on further potential capacity for hydropower generation, beyond those facilities already included in the future projections. However, given the uncertainty surrounding total potential for hydropower generation in Albania, and that estimates may be substantially modified if additional basin hydrometeorological data and modeling were available, further development of both LHPPs and SHPPs have been considered for the purposes of the CBA.

Importantly, to compare the costs and benefits of all the different assets on a like-for-like basis, a quantity of power was chosen, 350 GWh, which could meet the estimated climate change-induced shortage for 20 years. All of the generation capacity is not required at once, but rather the need increases over the assessment period. Some assets would probably not be able to fill the entire gap from beginning to end. Additionally, the assets under study have different expected periods of service. Twenty years represents a period of time for which energy needs could be met by the technologies under consideration. For the second 20 years to 2050 (the timescale under consideration for climate change risks in this assessment), the additional generation needs could be reexamined. This analysis thus considers what could be done in the immediate future, providing guidance as to what may be good options.

It is important to note that the use of a normalized quantum of a particular asset that could provide 350 GWh per year is hypothetical and a simplification, in the sense that installing this amount of capacity may be unrealistic in most cases. For instance, economies of scale dictate that a 50 MW thermal plant (which would provide about 350 GWh) would generally be less feasible on a financial basis than a larger unit. Furthermore, to complete a high-level CBA, it has been necessary to make broad assumptions about the specific locations where future assets may be sited and also of the various options, their costs, and their impacts on society and the environment. In addition, it should be noted that the options would themselves be susceptible to climate change. The most notable impacts would be on the SHPP and LHPP options, as these are most sensitive to climate change (see Sections 3.3 and 3.2), though the efficiency of TPP is also slightly reduced as temperatures rise (see Section 3.4). In contrast, there may be benefits for future solar power production due to reduced cloud cover in summer in the future (see Section 2.2). Since the available cost and benefit data are relatively high-level, further analysis of these impacts on the options is not included in the scope of the CBA. Thus, the options considered in this assessment are generic and indicative rather than definitive. However, it is considered useful and informative to undertake a high-level CBA for these technologies, to provide an indication of what the key issues are, and to identify where further data could be used to reduce uncertainty or confirm a chosen course of action.

The eight power technology options were evaluated on the basis of eight parameters that were determined based on the outcome of workshops and discussions with stakeholders. Parameters were chosen that reflect sustainable-development performance aspects—that is, financial, social, and environmental aspects of the different options. The parameters selected are detailed next.

5.4 BENEFIT CATEGORIES/PARAMETERS USED IN THE COST–BENEFIT ANALYSIS

In a complete economic analysis, the benefits of a given course of action are compared to the cost. Actions that result in a net overall positive benefit to society as a whole are deemed *economic* and sustainable.

The approach for this analysis is to attempt to capture the maximum likely benefits and dis-benefits (i.e., costs) that would accrue to both the power producers (private benefits/dis-benefits) and to society (external benefits/dis-benefits), for each of the various alternatives being assessed. To do this, a conservative approach (from the economic point of view) has been adopted, with each external (societal) monetizable benefit valued using a method that would tend to overstate (rather than understate) the benefits. In addition, a qualitative examination of some likely nonmonetizable benefits is also included. Thus, in the CBA, likely costs are compared with conservatively high benefits, or disbenefits, as the case may be. In adopting this approach, the report is biasing the economic analysis toward the societal position. This is advantageous because it assures that the external perspective is fully considered and valued, and helps to deflect any possible criticism that the analysis favours the proponent.

The parameters/potential benefits considered are summarized next and described in more detail in Annex 5.

Financial Parameters

Financial parameters reflect a number of key issues identified at the workshops. An obvious issue is the cost per unit of electricity produced. Although social and environmental aspects are also important, the cost of producing electricity plays heavily on the viability of a given asset type. Loss of production is also reflected in the financial parameters, specifically revenue from electricity sold. The possibility that an asset type may not be able to fill the electricity shortage is included in the model by virtue that it would have lower associated electricity revenue.

1. **Capital Expenditure.** Capital expenditure is the financial expense required during the construction of the plant. It represents investment in the fixed assets that are used to generate electricity. The value of land is also included in capital expenditure figures.
2. **Operating Expenditure.** Once the plant has been built, ongoing expenditure is required to keep the plant operating. These costs comprise spares, maintenance, fuel, and other ongoing costs required to keep the plant operating. Operating expenses vary depending on asset type and depend on factors such as the location of the asset (more isolated assets are more expensive to supply) and the age of the technology (newer technologies are often more expensive to maintain).
3. **Electricity Revenue.** The revenue received through the sale of produced electricity represents both the value of the production of the electricity and its contribution to macroeconomic activity. Electricity revenue is based on the stated market price of 8.23 Lek per kWh (USD 0.085 per kWh) (Tugu, 200). This parameter also represents a portion of the benefits to the economy through a contribution to GDP.

Environmental Parameters

In the workshops environmental parameters were also identified as high priority issues to be taken into account when deciding which type of power assets to build. Greenhouse gases, other emissions, water and ecosystems were included as parameters in the CBA. In addition to determining a base case monetary value for these parameters, a potentially realistic maximum (high case) monetary value for these parameters was also determined, as shown in Table 6.

1. **Value of water.** Water in many forms (as a resource, in precipitation, in storms) is a key factor in the risks associated with climate change. In Albania especially, where a large proportion of electricity generation is based on water flows, it is important to account for water usage and availability when looking at the different generation options. In this economic CBA, the base value of water was based on the rate charged to an enterprise consumer in Albania, 90 Lek per m^3 (USD 0.93 per m^3). This price is based on information from Tirana Municipality (2006). It is noted that, other than for concession costs for new small hydropower plants, hydropower generators do not currently have to pay for water that they use. However, inclusion of this value in the analysis takes account of the fact that there may be cost in the future, as water becomes more highly valued by society.
2. **Carbon dioxide and other greenhouse gases (GHGs).** CO_2 is the well-known greenhouse gas that is traded in markets around the world. The base value used in this analysis was based on the European Trading Scheme market spot price, €15.80 per tonne (USD 21.55 per tonne) (11 May 2009). Other studies, such as the Stern Review (Stern, 2006), use detailed models to project the cumulative economic impact of additional units of GHG, called the social cost of carbon (SCC), estimated at approximately USD 75 per tonne $CO_{2\text{-}e}$. This value was used in the evaluation of the high case (see Table 6). Other emissions that were considered were particulate emissions and NO_x. After research, none of the generation asset types were determined to have significant emissions of particulate matter, so it was not monetized or explicitly included in the model. There are limited emissions of NO_x from the CCGT plant option, and these emissions were valued at USD 62 per tonne based on the U.S. EPA auction of NO_x emissions permits. Due to the limited scope of the study, some GHG emissions were not included. The GHG emissions caused by the decomposition of organic matter during the creation of a reservoir for a large hydropower plant and emissions during transportation of materials for construction of the various generation assets are two examples.
3. **Value of ecosystems (loss of ecological services).** Building a power plant on a greenfield site destroys or converts ecosystems to other uses. For the CBA, it was assumed that hydropower plants were built in mountainous ecosystems and all other asset types were constructed in coastal ecosystems. Based on published studies, the ecosystem services for the mountains were valued at USD 30 per hectare (UNEP, 2001) and coastal ecosystems were valued at USD 117 per hectare (Department of Natural Resources, 2004). The analysis included loss of ecological resources, specifically the loss of mountainous or coastal

ecosystems, due to clearing associated with activities directly related to the power generation options being considered.

Social Parameters

The economic CBA takes into account an aspect of social concerns through a parameter that describes the overall disturbance to people and property caused by new constructions. There were several other social aspects identified as important in the workshops that could not be generalized and therefore were not included within the scope of this high level analysis; examples are impacts on tourism, recreational benefits of some asset types (e.g., reservoirs) and political implications of constructing a new power asset in a region or area where public dissatisfaction is high.

1. **Disturbance of people and property.** This aspect has been valued using an approach that has been previously widely used for assessing the disturbance from wind farms (Ladenberg, 2001). This value was pro-rated for the other asset types based on the population density of the area and the footprint of the asset at hand. It is clear that there are other disturbances, such as recreational benefits, and importantly for Albania, impacts on tourism. This is an area for further study when more information about specific proposals is available. Other important aspects are mentioned below.
2. **Discount rate.** In economics, it is common to assume that having something now is worth more than getting it in the future. This is the basis for interest on bank accounts. To account for the fact that expenditure today precludes other uses of the money, a discount is applied to future cash flows. The amount of this discount rate has an effect on the present value of future cash flows. In this assessment, a base discount rate of 4.5 percent has been used. This discount rate has been adopted as the base value following discussion with the World Bank's energy economist in Albania. The value is higher than the social discount rate used in other developed European economies (e.g., the United Kingdom uses 3.5 percent) and reflects the higher potential growth rates that a developing economy, such as Albania's, may experience. The choice of discount rate can be contentious, especially in the context of environmental and social benefits that occur many years in the future. Whereas environmental benefits for future generations may not be considered as less valuable than the same benefits for the current generation, in the context of purely financial investments, such as savings accounts, benefits now are much more highly valued than later benefits. This causes a divide between the discount rate used for public projects and the private discount rate used by investors when making investment choices. The power sector necessarily combines a number of stakeholders with interests in both the private financial and the public social/environmental performance of investments. A project that is attractive from a purely private financial point of view may not be interesting from a public point of view (or vice versa). Therefore, for this assessment the impact of discount rate on the outcome of the CBA is explored through sensitivity analysis, to understand the effects that discount rate assumptions may have on the relative performance of different options.

Important Aspects for Further Study

As many parameters as feasible have been included within the scope of the high-level CBA assessment. However, it is important to note that there are several important aspects that either could not be included or were not included to the full extent possible in principle.

Water, by nature of its multiple forms and uses, is a particularly complicated aspect to consider in policy decision making. In future studies, the alternative possible uses of water (e.g., irrigation) should be considered. There are also nonuse and ecological values to consider. Not every use of water accrues all of these values. For instance, using water to cool a turbine through evaporation precludes its use for irrigation, whereas water that has passed through a hydropower turbine may still be available of downstream irrigation.

Each asset type will have a different impact on the surrounding ecosystems. Furthermore, different locations will have different types of ecosystems of different values. Outside a highly-general study, greater ecosystem impact information is required to consider properly the full costs and benefits of various options.

Broader economic impacts are also important. Again, across various assets, the exact impact that constructing a given facility will have on gross domestic product and employment will depend on the number of people that particular facility takes to operate, the type of training required and the legal structure of the operating company. Although these effects could only be superficially covered in this assessment, they are suited for inclusion in a more detailed and specific future study.

Vulnerability to natural disasters and increased climatic vulnerabilities is another parameter that was identified as important at the workshops, but has only been incorporated in the CBA through sensitivity testing (see Section 5.6). Further study could expose potentially-critical hidden vulnerabilities that would need to be incorporated into policy decisions.

A summary of the base case and high case parameter values used in the CBA is presented in Table 6.

Table 6: Base Case and High Case Parameter Value Assumptions

Benefit Category	Units	Base (USD)	High (USD)
Value of water	m^3	0.93	3.00
Carbon dioxide and other GHG emissions	Tonne	21.55	75.00
NO_x emissions	Tonne	62.00	80
Value of ecosystem (mountain)	/ha/yr	30	200
Value of ecosystem (coastal)	/ha/yr	117	200
Disturbance of people and property	/hh/km^2/yr	1.82	5.00

5.5 RESULTS OF THE COST–BENEFIT ANALYSIS

Given the financial, environmental and social base values discussed in the previous section, the results of the CBA for the base values only are presented below. The charts (Figures 21 and 22) provide the net present value (NPV) results in current (2010) U.S. dollar terms for each of the technology options under consideration.

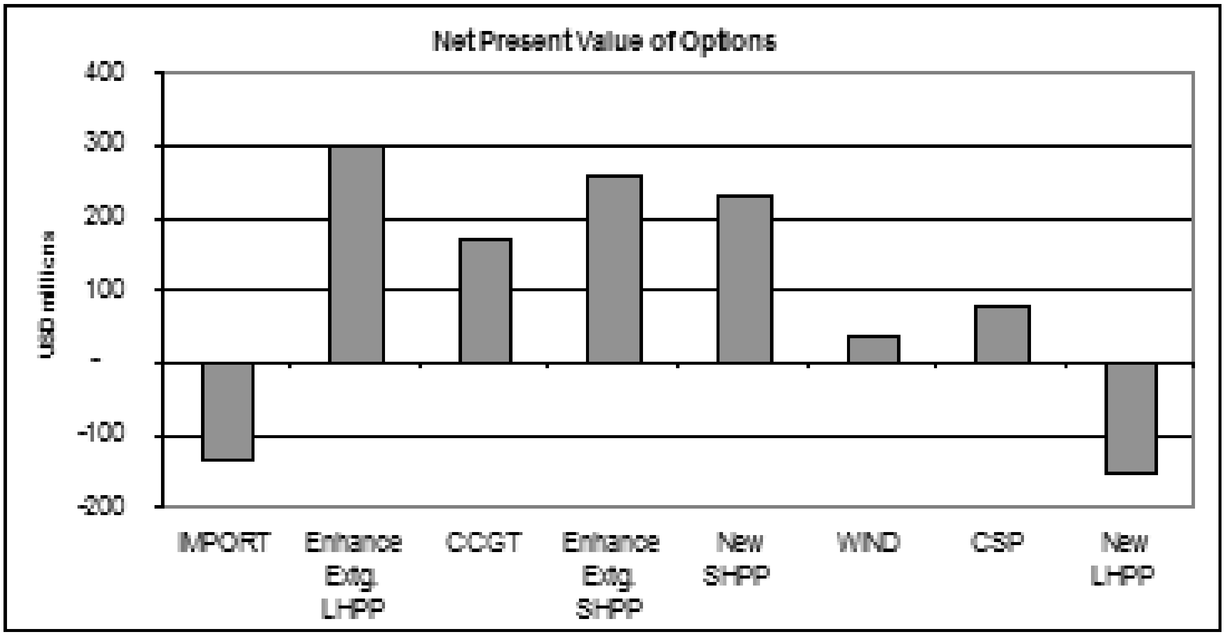

Figure 21: NPV using base case assumptions

Figure 22 illustrates the NPV results broken down by each internal and external parameter value.

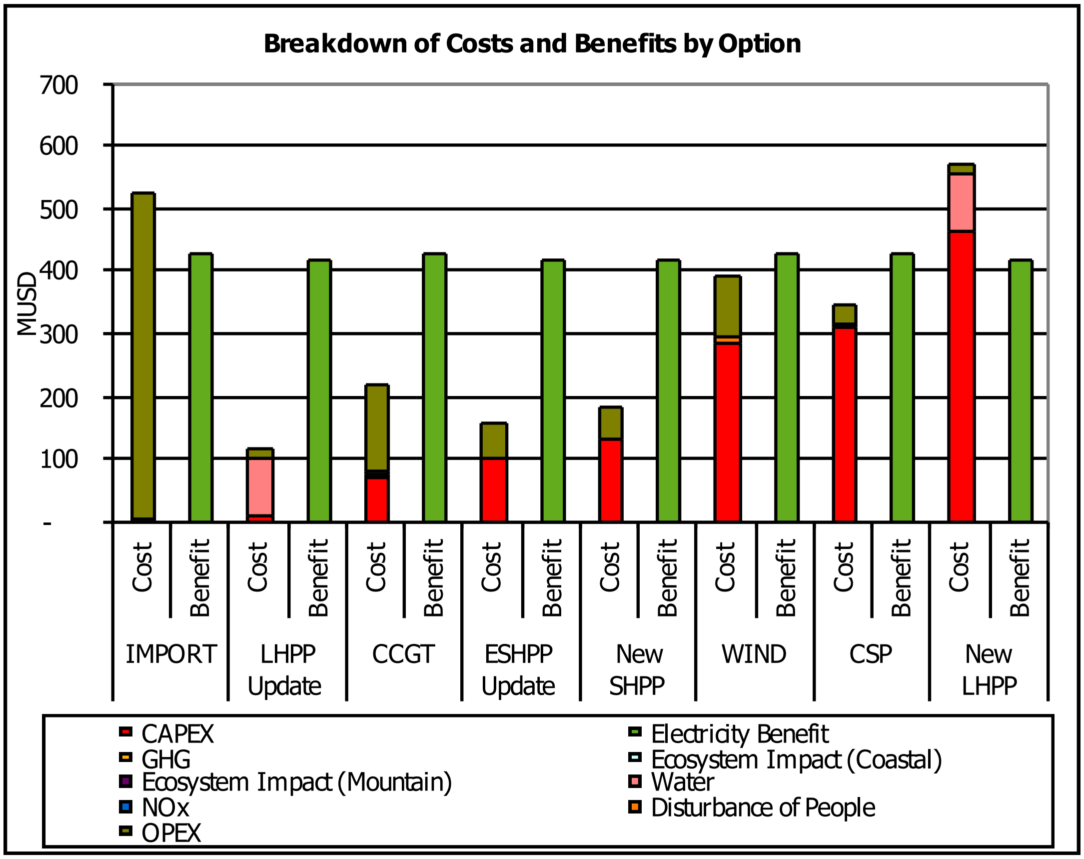

Figure 22: Breakdown of NPV of options by parameter

The options are sorted from greatest to least capital expenditure, going from left to right. In general, options with an NPV less than zero are not considered economic/sustainable. Options with an NPV greater than zero are economic/sustainable. The higher the NPV the more sustainable is the option. The three most-sustainable options identified are as follows:

1. Enhancements to existing large hydropower assets
2. Enhancements to existing small hydropower assets
3. The building of new small hydropower plants

Within the scope of this CBA, two options appear unsustainable within the context (i.e., to fill the future shortfall in electricity supply due to the impacts of climate change) and boundaries of this assessment, namely: building new large hydropower plants, and importing power. However, in this particular analysis the relative ranking of the options is more important than the specific NPV of any particular option. Due to the high-level nature of this analysis, other possible benefits that may be very relevant when considering a specific project have not been considered. In a detailed analysis phase, careful consideration of all possible benefits may well mean that the two unsustainable options may, in fact, be sustainable in certain contexts. This is especially important to note in the case of “New LHPP.” Although in the context of this analysis the net present value is below the breakeven point (zero), this should not imply that the options should never be undertaken. Nevertheless, these results provide useful information by way of illustrating a high-level comparison of the options.

The breakdown chart in Figure 22 shows that by far the biggest costs are capital expenditure (CAPEX) and operating expenditure (OPEX). This is unsurprising, as most of the options are based on renewable fuels, which have fewer external costs than traditional generation asset types such as coal-fired power plants. The nonrenewable option, CCGT, is a low-carbon source of energy and thus also has limited environmental impact.

Importing electricity has the biggest operating expenditure, because the electricity is purchased from the regional grid, and thus, the price reflects recapture of foreign capital expenditures, operating expenditures, and the profits of the other generating assets. However, this should not be taken as evidence that imports do not play an important role in Albania’s energy mix. This assessment is concentrating only on the shortage due to climate change, which is one piece of a larger energy context. Imports are sometimes necessary to fill short-term shortages and avoid load shedding. Furthermore, this analysis was based on a one-time snapshot of market prices, where import cost is higher than domestic sales revenue in Albania. In reality, there are a number of measures that could help manage the cost of imports. Financial tools such as options or long-term contracts could hedge against price movements and keep imports viable for appropriate uses. However, the results of this analysis suggest that for the gap caused by climate change, another source of electricity may be preferable.

As mentioned in Section 5.3, supercritical pulverized coal technology was not considered in detail in the CBA. A cursory analysis based on general knowledge of the relationship between the cost, GHG emissions, and water usage of supercritical coal and CCGT technologies indicates that although coal technology is less sustainable than CCGT, it ranks relatively the same amongst all the other options. That is, it would likely be the fourth most sustainable option behind the three options just identified.

5.6 SENSITIVITY ANALYSIS

Any CBA analysis of this type is inherently subject to uncertainty. Cost estimates provided are to ±30 percent accuracy, and the valuation and estimation of benefits is subject to even larger changes, as discussed in Annex 5. However, the aim of the analysis is not to reveal “absolutes” in terms of dollars, but better and worse decisions overall, when comparing the range of possible decisions that could be made.

From this perspective, sensitivity analysis is important because it allows the overall conclusions of the analysis to be tested across a wide range of parameter inputs. If a decision is favourable or economic over a wide range of parameter inputs, compared to other possible decisions, then despite the overall uncertainty in the actual dollar figures, the decision can safely be identified as superior to the alternative options. This is particularly useful when considering the sustainability of options. By definition, sustainability is concerned with the future, which is inherently uncertain. By varying key input parameters over a wide but reasonable range, the implications of a range of possible futures can be examined.

The overall sensitivities are presented in the *tornado* chart in Figure 23. The sensitivities are normalized so the most sensitive option/parameter combination is 1.0 and less-sensitive options/parameter combinations have shorter lines, with values less than 1.0.

The parameter to which every option is sensitive is the electricity benefit, which is the value to the producer and society for use of electricity. GHG and water value is significant for large hydropower options, and GHG emission costs are significant for CCGT and import options.

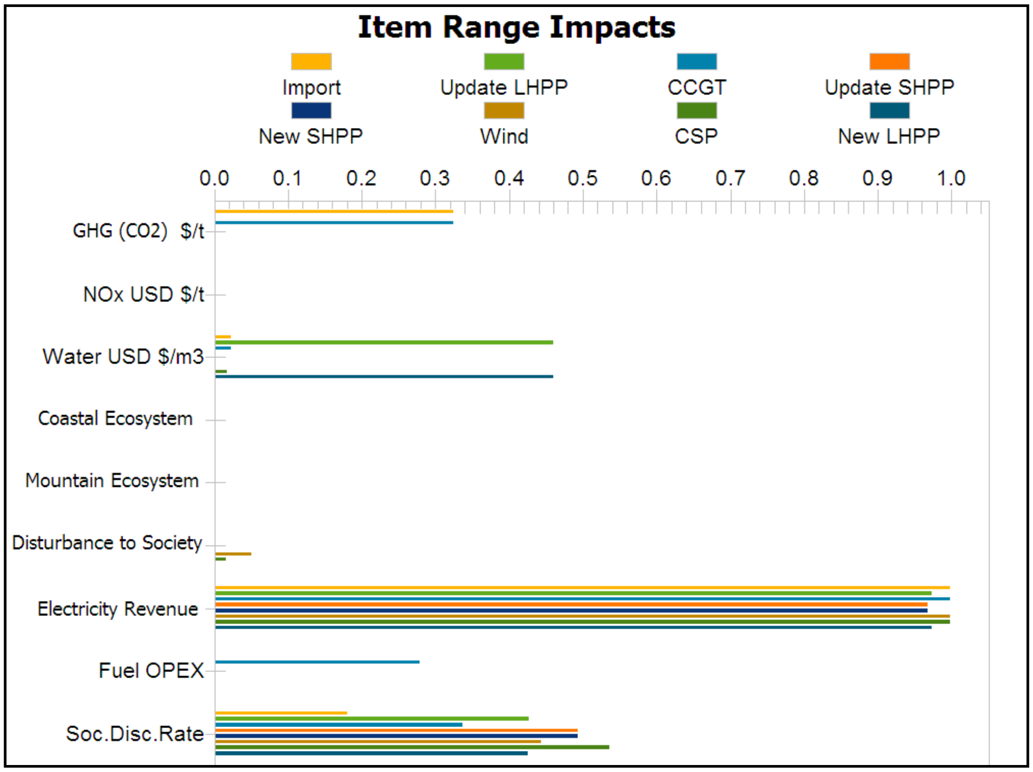

Figure 23: Tornado chart showing sensitivity of NPV for each option to variations in the values of each parameter

One possible parameter case, using the high-case values summarized in Table 6, is presented in Figures 24 and 25. In this case, the values of water, carbon dioxide and other GHGs, and fuel for the CCGT are increased to represent a high scenario under the effects of climate change.

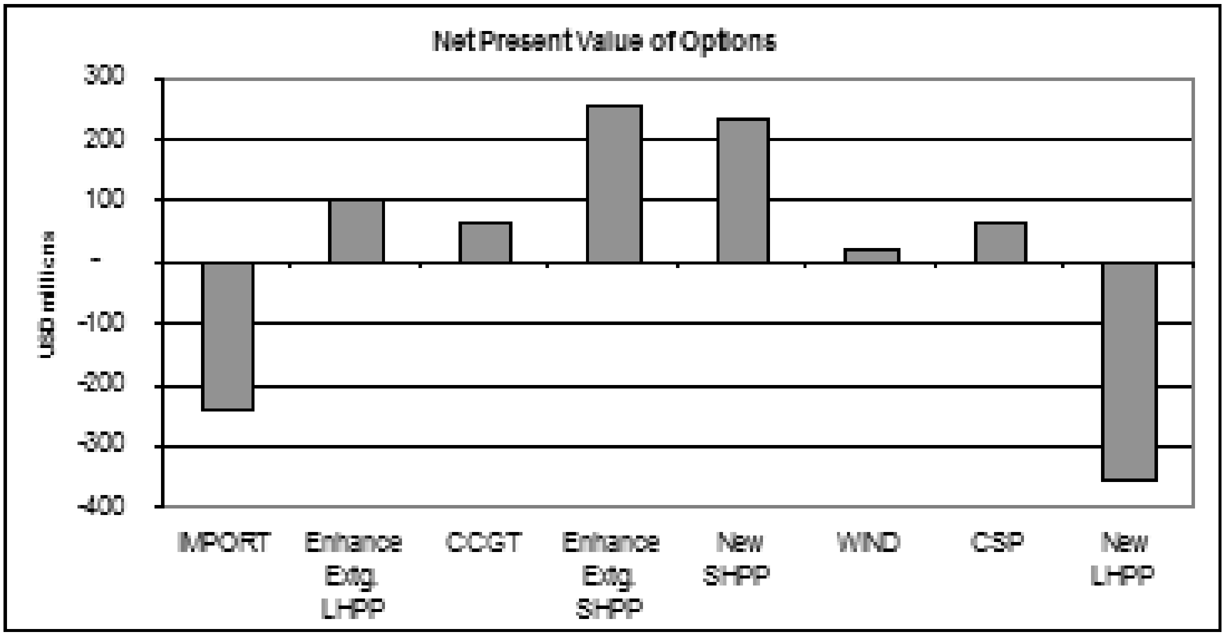

Figure 24: Net present value of options under high parameter assumptions

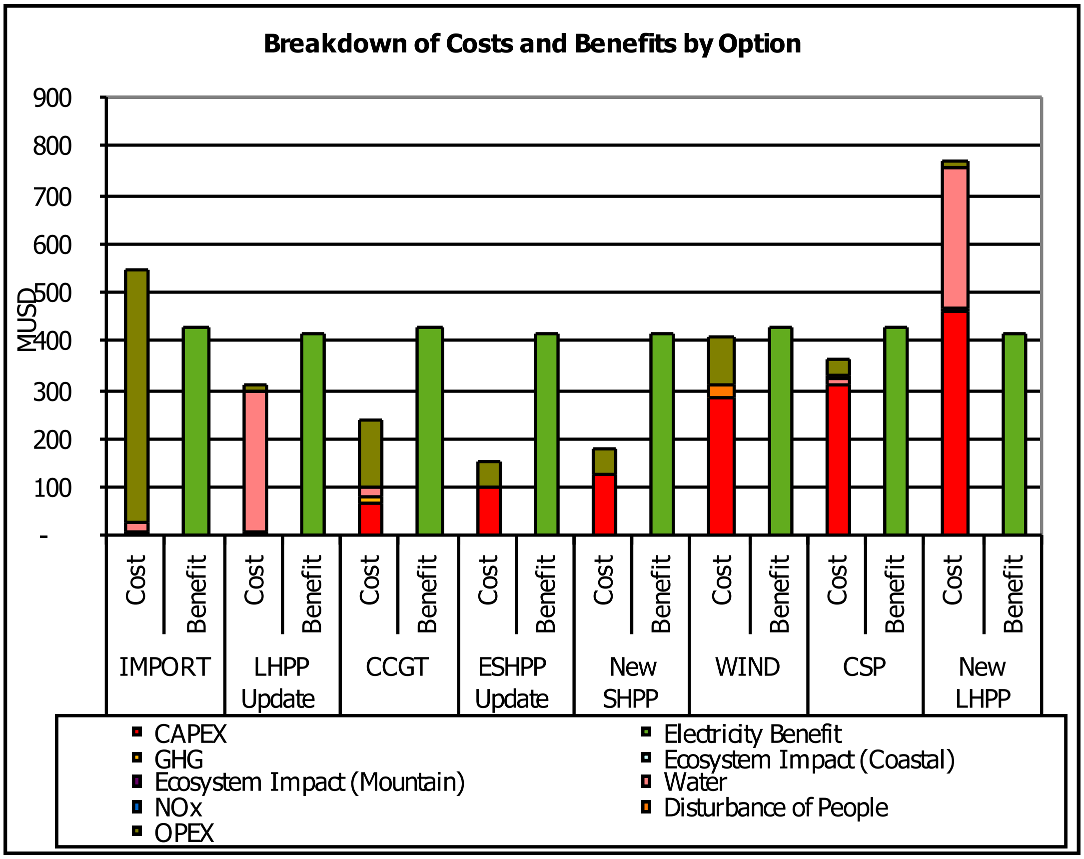

Figure 25: Breakdown of costs and benefits, high parameter case

The value of water primarily affects the large hydropower assets. Dams increase the surface area by which water can evaporate, causing water losses. With a higher value of water, the water usage of the large hydropower assets becomes a greater issue to society as a whole, and therefore this option becomes less attractive.

Increase in the value of CO_2 and other GHGs and fuel for the CCGT creates a marked decrease in the viability of the CCGT option. Increasing the value for CO_2, fuel costs, and water is akin to making the assumption that these commodities are going to be increasingly valuable in the future under climate change. It should be noted that although Albania is not yet subject to a carbon trading system such as that adopted in the European Union (EU), it is important that the pricing of carbon is taken into account now, as Albania aims for inclusion in the EU, so in the future explicit GHG emission levies may apply. The reaction of the CCGT option in this analysis to this change in parameter values suggests that further study is warranted when considering CCGT.

In this high-parameter case, small hydropower and updating existing hydropower are still viable options, and solar power begins to show relative advantages as well. These renewable options are not as vulnerable to fluctuations in fuel costs, increases in the value of CO_2 and other GHGs, or increases in the value of water.

Another set of parameters was designed to explore the effect that increasing frequency of extreme events may have on the availability of electricity from various sources. The primary source of risk is the vulnerability of power transmission assets to wind and lightning strikes. Although transmission lines are generally designed to withstand storms, repairing lines that are more remote is more difficult, meaning that assets that require longer transmission distances, such as hydropower and import, are more vulnerable. To set up this scenario, a penalty was placed on long-distance transmission assets—that is, all hydropower assets and the import option. For the base value, it was assumed that in the second 20 years of the analysis, these assets are unable to supply the needed power for one week per year, due to extreme events. By adjusting this factor up and down, the significance of this effect on the relative ranking of the options is revealed. The results of this extreme event scenario are illustrated in Figure 26.

It can be seen that the effects on the ranking of options are relatively minor, in spite of the effect having an approximately USD$8 million penalty. This indicates that in spite of the increased risk, the other parameters are more important to the relative ranking. It is important to note that this is based on the assumptions made, and that further study may reveal cases where transmission vulnerability may be an important consideration.

A more-significant effect was investigated; i.e., long transmission assets being put out of service for a month per year. Depending on the availability of resources in Albania and the remoteness of the terrain, this effect is a possibility. Figure 27 shows the results of one month of shortage for long transmission assets for every year of the final 10 years of the assessment period. However, interestingly, even when the long transmission assets are further penalized and are taken out of service for a month every year, the effect is not enough to change the conclusions of this high-level CBA analysis.

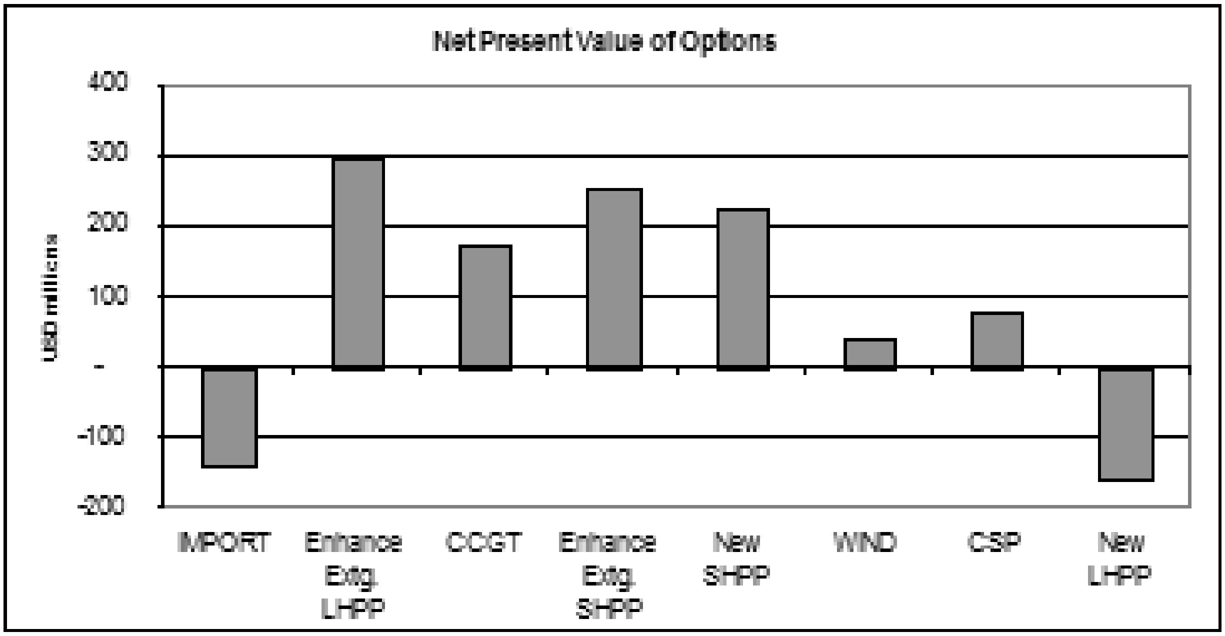

Figure 26: Costs vs. benefits for the extreme storm case (1 week per year outages)

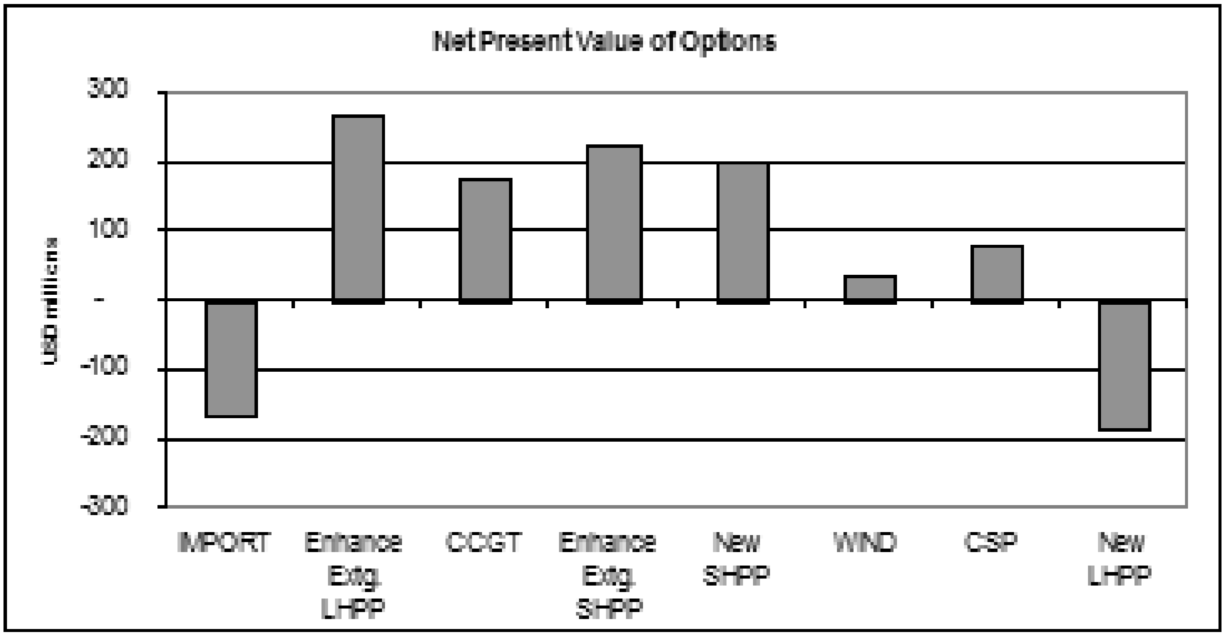

Figure 27: Costs vs. benefits for the extreme storm case (1 month per year outages)

A final case illustrates the effect that length of time can have on the analysis, whereby the timeline is extended from 20 years to 50 years (see Figure 28). All base-case parameter values are used. It should be noted that many of the assets would not last until 2050 without extensive reinvestment. However, this case illustrates the consequences of the time and discount rate assumptions.

Under this scenario, all options except import (discussed above) have greater value to society because they are providing value for a longer period of time. Eventually, the ongoing benefits outweigh the one-off investment costs.

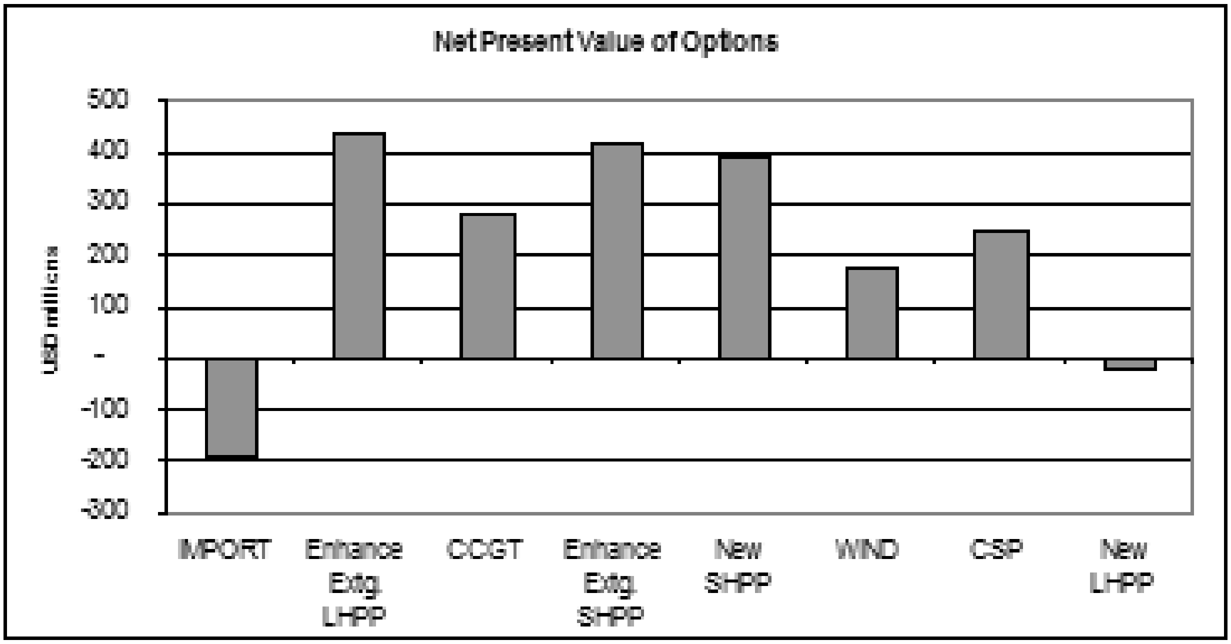

Figure 28: Costs vs. benefits for 50-year duration analysis

Figure 29 presents the sensitivity of the various options to changes in the discount rate in the range 0 percent to 20 percent. The NPV is represented by the vertical axis and the discount rate increases along the horizontal axis from left to right.

The chart illustrates that in general, over a range of different discount rates that would typically be used for public decision making, the relative ranking of the options does not change, with the “Update LHPP” option returning the greatest NPV. However, as the discount rate increases toward ranges that represent typical investment thresholds for private investors, “Import” becomes a relatively more attractive (though still NPV-negative) option. Additionally, when the discount rate is larger than 16.2 percent “CCGT” becomes marginally more attractive than “New SHPP.” “CCGT” has higher operating costs. However, the effect of the future operating costs on “CCGT" in comparison with “New SHPP” is such that NPV for “CCGT” is diminished at higher discount rates.

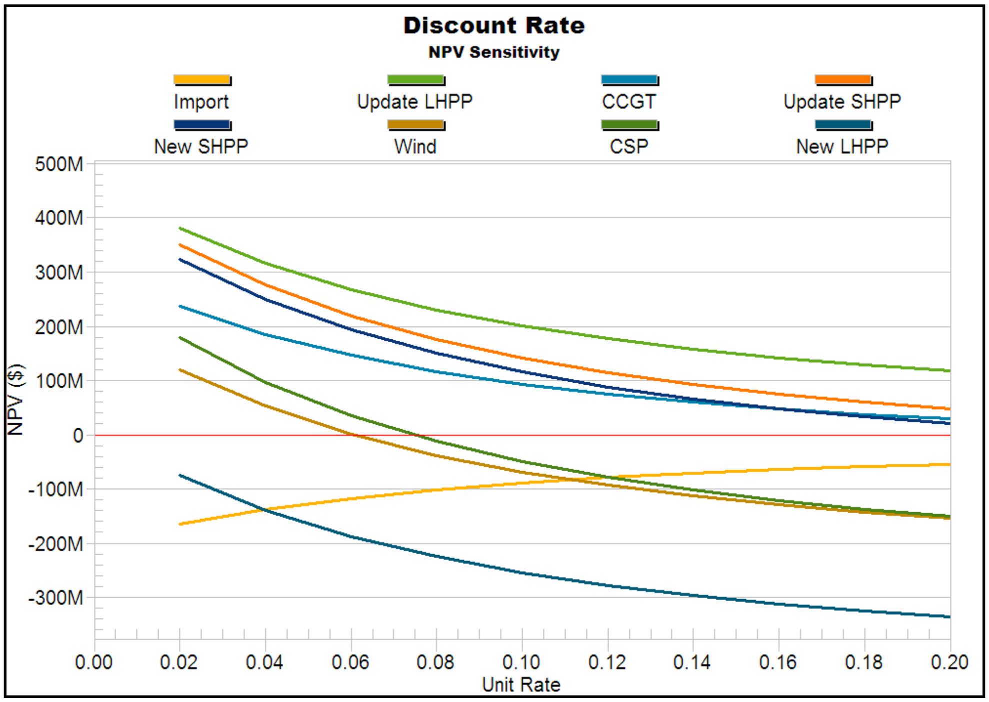

Figure 29: Sensitivity of options to discount rate

Another interesting parameter for the sensitivity analysis is the value of carbon dioxide and other GHGs. Varying the CO_2 price over a range of values is illustrated in Figure 30.

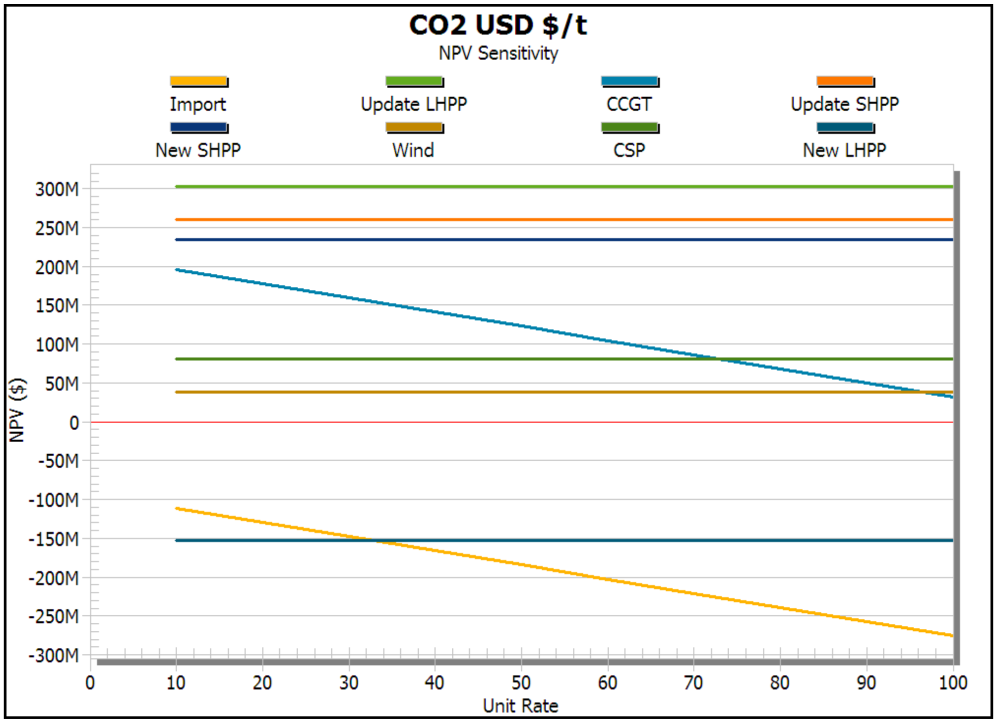

Figure 30: Sensitivity of options to carbon dioxide and other GHGs

As expected, the economics of a group of renewable assets are generally insensitive to the value of carbon dioxide and other GHGs. Those options that are sensitive to increasing value are “CCGT” and “Import” (the latter assumed to be generated via CCGT), due to the fact that they both use fossil fuels. The higher the value placed on carbon dioxide and other GHGs, the more unfavorable the “Import” and “CCGT” options become in relative terms.

The sensitivity of the options to water value is shown in Figure 31. The LHPP options exhibit the largest sensitivity to the value of water. “New LHPP” remains the least favorable option under conditions where the value of water is greater than USD 0.71/m^3. However, even at lower values (down to zero) “New LHPP” does not become favorable in comparison to any of the other options except “Import.” The value of water also has a large impact on the relative attractiveness of “Update LHPP”; the higher the value of water, the more appealing are alternative options.

As mentioned already, due to the high-level nature of this analysis, other possible benefits that may be very relevant when considering a *specific* project have not been considered.

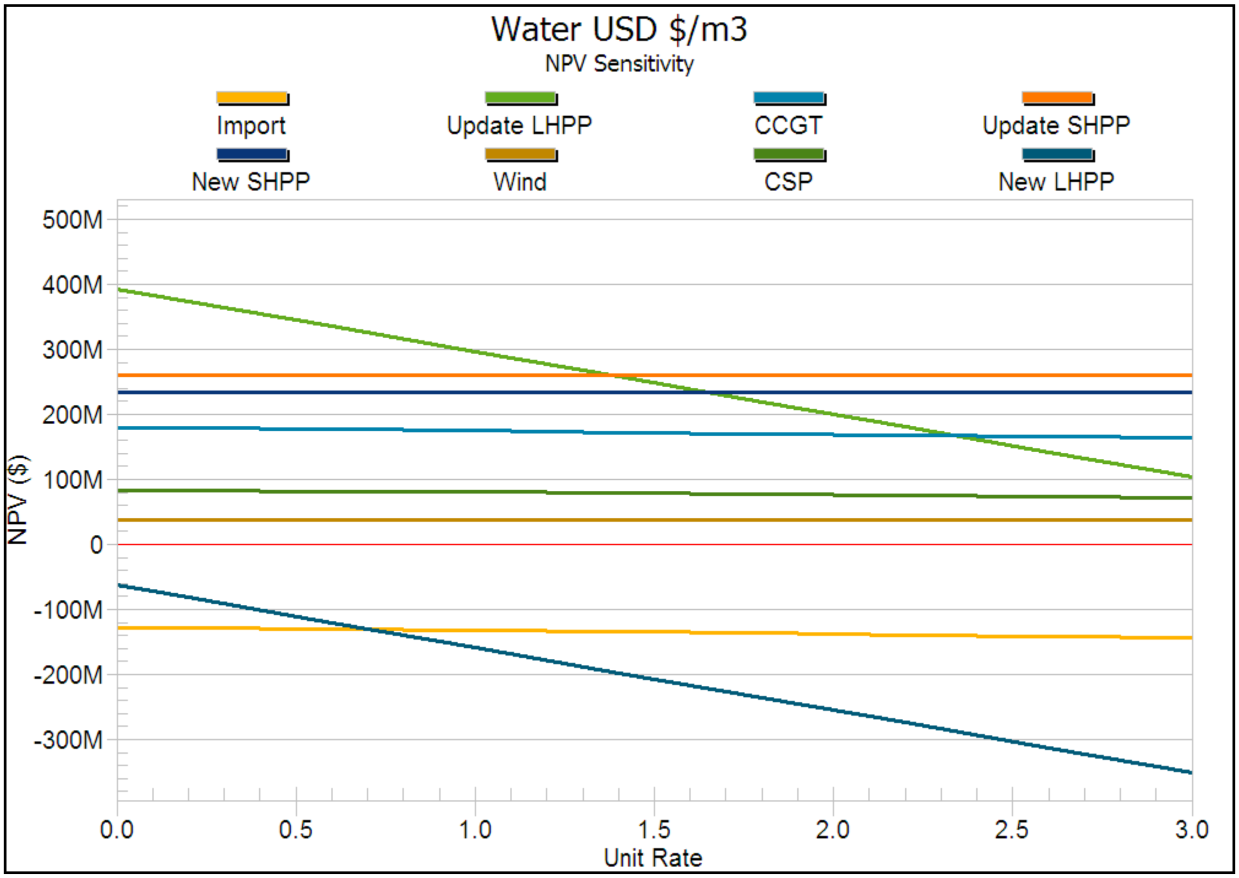

Figure 31: Sensitivity of options to the value placed on water

5.7 USING THE RESULTS OF THE COST–BENEFIT ANALYSIS TO SUPPORT DECISIONS TO MANAGE THE ALBANIAN ENERGY SECTOR IN THE FACE OF CLIMATE CHANGE

The high-level cost–benefit analysis examined eight options to provide equivalent power generation of 350 GWh per year for the next 20-year planning horizon, where existing technology and current asset life span remains most relevant. This analysis therefore ranks the options based on a common measure. On the one hand, it is recognized that the projected shortfall in energy supply due to the impacts of climate change will gradually increase over time, and that some technical options are more flexible in their implementation and may be more economic where an incremental increase in supply capacity is preferred (e.g., gradual implementation of small hydroelectric or wind power schemes). On the other hand, it may be considered that larger plants built early in the planning period may provide additional returns. These considerations could be examined in further detail by future studies, but are beyond the scope of the current assessment.

In addition, to fill the projected energy shortfall, the CBA indicates that the most economic/ sustainable options to consider are enhancing existing small and large hydropower schemes and development of new small hydropower schemes. However, it is recognized that there may be a limit to the amount of additional hydropower generation capacity within Albania. METE estimates that there is capacity for only 3,200 MW installed HPP in Albania (Tugu, 2009), and there may be insufficient additional capacity, beyond that used in the projections for supply to 2050, to accommodate all additional requirements due to climate change. Therefore the results of the CBA could be used to some extent to prioritize adaptation measures, starting initially with upgrading existing facilities, moving on to exploiting remaining small hydroelectric power opportunities, before consideration of other assets that may be less economic/sustainable.

Important Notes

As noted above, this analysis addresses only a small part of the larger context of the effects of climate change on Albania's energy sector. Additionally the high-level nature of the assessment means that in specific situations the results of a CBA could be different. Several constraints and limitations on the CBA are worth mentioning.

First, the environmental and social effects of the construction phase for energy assets were not considered; only the financial aspects. Although the construction of a power plant is a resource-intensive undertaking, it is difficult to make a general qualification about social and environmental impacts without studying a specific project. For instance, in some cases the construction of an equivalent capacity hydropower facility may cause more CO_2 emissions than constructing a thermal power plant, especially during the construction of a dam. However, in other cases—for instance, if a thermal plant were sited in an environmentally valuable area—its construction may have the greater impact.

Another issue that is not addressed directly in this economic cost–benefit assessment, but that would need to be addressed in further analysis, is the political and business climate in Albania.

This includes factors such as Albania's ability to attract investment funds and obtain necessary permitting.

Many of the effects of climate change are seasonal in nature, though this analysis does not account for this, as the available data on seasonal water flows and energy production are sparse. However, it is worth noting the range of effects climate change may have on seasonal performance of energy assets, in particular HPPs. Not only may climate change affect the quantity of precipitation at any given period of the year, climate change may also influence the timing of changes. For instance, it was noted by Albanian energy sector stakeholders that existing SHPPs rely on runoff generated by spring and summer melting of the snow pack in the mountains. This runoff extends the period that the SHPP are able to operate. Although insufficient data were available for this assessment to determine the possible changes in snowmelt, it is anticipated that the timing and rate of spring melt may increase runoff and the risk of spillover of LHPP dams, which means that less water would be available for power generation if reservoirs were not sized adequately.

To provide some illustration of the seasonal effects associated with power generation in Albania, historical monthly river flow rates into the Fierze Reservoir on the Drin River and power generation in the Drin Cascade were reviewed. Seasonal variations were examined for a relatively wet year (2006, Figure 32) and a relatively dry year (2007, Figure 33), from datasets provided by KESH. It should be noted that the *flow rate* presented on the graphs is the rate of inflow into Fierze reservoir and that the power generation—Drin total is the combined power generation for Fierze, Koman, and Vau i Dejes hydropower plants. The demand data presented are the demand that was met, and not necessarily the demand that may have existed if there had been unrestricted supply (i.e., had there been no load shedding, demand might have been greater).

Although it is recognized that operation of dams and power generation from hydropower plants is potentially complex, a number of observations about the potential impacts of seasonality and possible future climate change impacts can be made based on these data.

Figure 32 (wet year) indicates that river flows are highly seasonal, with the winter and spring months having the greatest flow. In the wet year, power generation is more correlated with river flows than in the dry year. Generation appears to be independent of demand, as throughout the year demand exceeds generation, except for a short period during the spring.

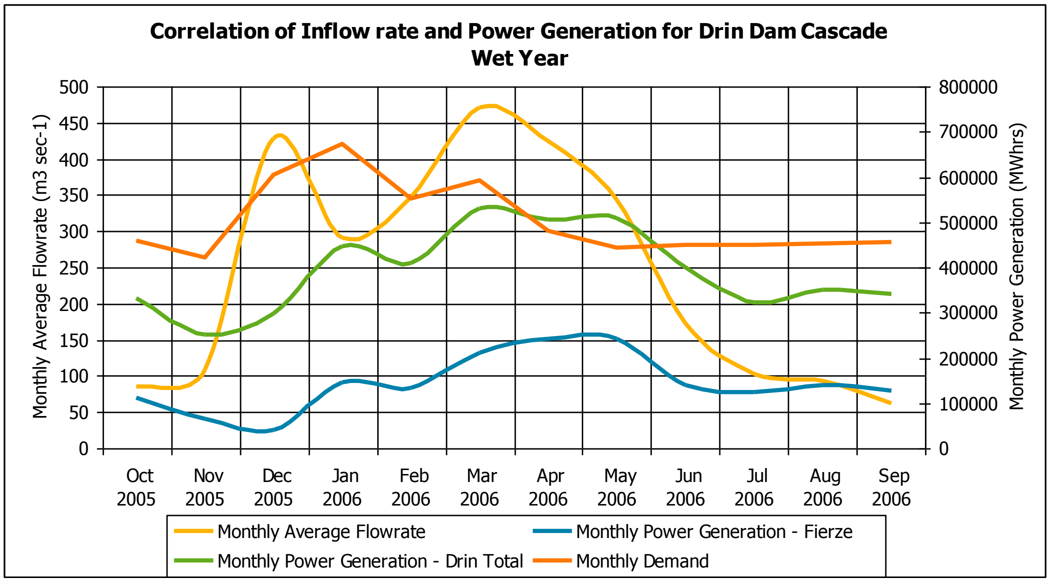

Figure 32: Rainfall and Drin Dam Cascade generation in a wet year (October 2005 to September 2006)

Figure 33 shows a dry year. Seasonal variations are still apparent but are much less well defined. Generation is also less correlated with flow rate, and again generation appears to be independent of demand. At the beginning of the period examined (October 2006), generation increases, almost in anticipation of the increased flow rate seen in November and December. However, generation quickly levels off to a much lower level than in the corresponding months of the wet year.

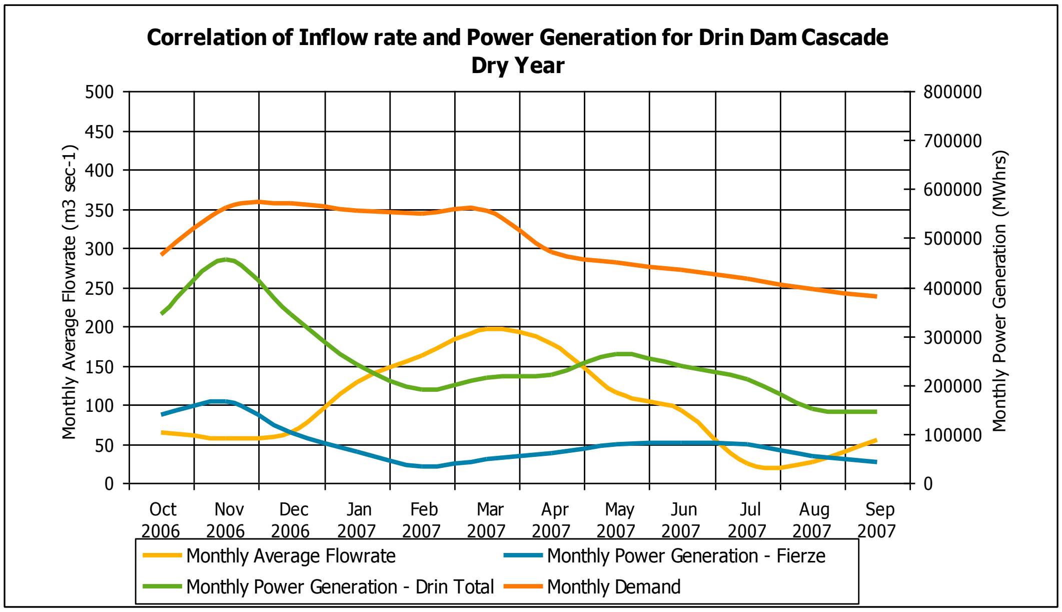

Figure 33: Rainfall and Drin Dam Cascade generation in a wet year (October 2006 to September 2007)

Interpretation of this limited dataset indicates that, as expected, hydroelectric power generation is seasonal and strongly influenced by runoff. When the potential power generation is calculated by dividing the inflow rate by the efficiency factor that KESH reports for the Fierze dam (1.04 m^3/kW in 2008) (Stojku, 2009), it is seen that potential power generation of the Drin cascade closely follows the seasonal pattern, with periods of excess and periods of deficit. This is as expected for a dam storage facility. The climate change projections indicate that future summers will become drier in Albania, runoff from snow melt may occur more rapidly and earlier, and summer energy demand will increase. As a result, these seasonal fluctuations will likely become more pronounced and may negatively impact Albania's energy security. It is therefore important to consider these aspects when interpreting the need for diversification of assets and the conclusions of the cost–benefit analysis. Future studies would be useful, to examine in more detail the seasonal effects on energy security associated with climate change.