AKKUYU NUCLEAR POWER PLANT COST & BENEFIT ANALYSIS

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Introduction to Akkuyu Nuclear Power Plant

Turkey is in need of finding a sustainable source for electricity production due to an increasing demand and consumption for electricity. The country has a huge current account deficit most of which results from its energy imports. Plans for nuclear power construction are a key aspect of the country's aim for sustainable economic growth. In Turkey, building up a nuclear power plant has always been a hot topic for discussion at least for 40 years. Turkey has had plans for establishing nuclear power generation since 1970. Today an application has been made for construction and operating licenses for the first plant at Akkuyu.

Turkey's electricity production was 240 billion kilowatt hours (kWh) or 240 Terawatt hours, gross from 53 gigawatts electrical capacity (GWe) in 2012. Of this, 105 150 Terawatt hours (TWh) (44%) came from gas (two thirds of this from Russia, most of the rest from Iran), 68 TWh (28%) from coal, and 58 TWh (24%) from hydro. In 2015, the percentage of electricity produced by gas decreased to 40%, which is still high. Net import was 3 TWh. Demand growth is about 8% pa, and in the first half of 2012 consumption was 119.3 billion kWh. Per capita consumption has risen from 800 kWh/yr in 1990 to about 2700 kWh/yr in 2011. Demand in 2023 is expected to be about 450 billion kWh, implying new investments by then of $100 billion. (World Nuclear Association, 2014)

Plans for nuclear power are a key aspect of the country's aim for economic growth, and it aims to cut back its vulnerable reliance on Russian and Iranian gas for electricity. The Ministry of Energy and Natural Resources (ETKB) projects 2020 electricity production as possibly 499 TWh in a high scenario of 8% growth, or 406 TWh with a low scenario of 6.1% growth. Plans are to have 30 gigawatts of coal fired electrical capacity by 2023. However, much of the country's coal resources are lignite with low calorific value – less than 12.5 MJ/kg, and a substantial amount (Afsin Ebistan) at less than 5 MJ/kg. (World Nuclear Association, 2014)

The Akkuyu nuclear project has an estimated investment cost of about US$ 20 Billion. Akkuyu plant will have four 1200 MWe AES-2006 units. The plant is estimated to be paid off in 15 years. It is planned to be operational in 2018.

Identification of Costs and Monetization

Pre-Investment Costs

Pre-development costs are the expenditure before the building phase of a nuclear power plant. They include research and development of the plant site, setting up necessary governmental bodies and streamlining the law. These costs will be mostly incurred by the government. Expenditures that had already been incurred amounted to $33.2 million (including operational costs of the Turkish Atomic Agency (TAEK), research and core activities, grants for investment in construction and assembly, power plant and nuclear waste location analyses). (Akkuyu Nuclear, 2016)

Construction Costs

Capital costs are incurred while the plant is under construction and consist of expenditure on the necessary equipment, engineering and labor. They are often presented as overnight costs, i.e. exclusive of interest accruing during the construction period, and include engineer-procure-construct costs, owners' costs and various contingencies. Once the plant is completed and electricity sales begin, the plant owners begin to repay the sum of overnight costs and accrued interest charges.

Building a NPP is a long and costly process and it has enormous up-front cost. Reactors are extremely expensive to build and future income is unpredictable because of the deregulated electricity market. Construction costs of third-generation reactors amount to $3.2 million per MW of capacity built. This means that the construction of four 1200 MWe units with a total capacity of 4800 MWe would cost $15.36 billion (4800MWe*$3.2million). (IEA, 2005)

In this project, it was assumed that these expenditures consist of overnight costs and capital institutions' interest costs. Regarding the volume of expenditure incurred year, we assume that the construction costs are incurred within the first 2 years.

Operating Costs

Nuclear power plants have lower fuel costs but higher operating and maintenance costs than coal power plants. Operations and maintenance (O&M) costs are very variable for NPPs, depending on such factors as plant size and age, but on average they account for 20% of the total costs per year, Deregulation of electricity markets has helped in introducing best practices in reducing O&M costs throughout the industry, while maintaining or improving high safety standards. (World Nuclear Association, 2014)

Fuel

The supply of nuclear fuel, that is uranium, for the NPP planned in Akkuyu will come from imports. Two-thirds of the supply of uranium globally come from primary sources or from mines in Canada, Australia, Kazakhstan and Niger. Security of supply of nuclear fuel depends on the certainty of supply of uranium ore and concentrate uranium,

access to fuel cycle services, as well as a reliable and secure transport of finished nuclear fuel.

Turkey at the beginning will not produce the fuel, but buy it from one of the several global fuel suppliers. (Akkuyu Nuclear, 2016) Purchase of fuel will be bound, at least in the first phase operation of NPP, with the purchase of technology. The world practice is that the technology provider also provides the fuel supply for the first 5-10 years operation.

The only significant economic use of naturally occurring uranium is to use it to produce nuclear fuel necessary in nuclear reactors. It has such large amounts of energy that the annual operating NPP with a capacity of 1000 MWe needs only about 25 tons of nuclear fuel a year, so 120 tons (4.8*25) are necessary for a NPP of 4800 MWe capacity. The costs of fuel are low and relatively stable. The Ux Consulting Company publishes daily price for uranium (The Ux Consulting Company, 2016).

In November 2016, the approximate cost to obtain 1 kg uranium as nuclear reactor fuel (at current long-term uranium price): (World Nuclear Association, 2016)

Table 1. Approximate Costs to Get 1 Kg Uranium as Nuclear Reactor Fuel

Uranium	8.9 kg U_3O_8 x $97	$ 862
Conversion	7.5 kg U x $16	$ 120
Enrichment	7.3 Separative Work Units (SWU) x $82	$ 599
Fuel fabrication	per kg (approx)	$ 300
Total, approx.		**$ 1880**

The Cost of fuel per MWh is about $5.22 (1 kg fuel yields approximately 360MWh. So $1,880/360MWh = $5.22/MWh). If one assumes that the plant would produce approximately 37.8 million MWh per year (4800 MW capacity*90% operational performance*24 hours*365 days), then the annual cost of fuel would be $198 million.

Waste

The regulations controlling nuclear power industry typically require the plant operator to make a provision for disposing of any waste, thus these costs are internalized (World Nuclear Association, 2016). It has been assumed that high-radioactive waste and spent fuel disposal costs around $1/MWh (Kennedy, 2007), resulting in the annual cost of waste for a 4800 MW NPP to be around $38 million (37,843,200 MWh*$1) per year.

Management and Labor

In this analyses average management and labor cost are estimated at $10/MWh (Kennedy). Thus, annual management and labor cost would be about $378 million (37.8 million MWh*$10).

Decommissioning Costs

At the end of a NPP's lifetime the plant must be decommissioned. This process begins immediately after final and permanent closure and continues ideally to the point of leaving a clear site where the facility had once stood. It incorporates some or all of the following activities: the safe management of nuclear materials held in the facility as well as radioactive and other wastes, decontamination, plant dismantling, demolition and site remediation. This entails dismantling, safe storage or entombment.

Operators are usually required to build up a fund to cover these costs while the plant is operating to limit the financial risk from operator bankruptcy. Provision for decommissioning costs is made by making financial contributions over the economic life of the plant towards plant dismantling and eventual site restoration. Given that plants are expected to have long lives, the contributions are not significant. The World Nuclear Association (2005) states that they amount to less than 1% of the overall costs per year (1 % of overall operating costs is about $6.1 million). It is required for the plant owners to set aside money when the plant is still operating to pay for the future shutdown costs (World Nuclear Association, 2005)

Identification of Benefits and Monetization

Lower Energy Cost

For the last decades, electricity demand in Turkey has been growing at a significant rate. It almost reached an annual increase of 6.5%. (TEIAS, 2016) As mentioned, Turkish electricity production rests on hydropower and fossil-fueled thermal power generation. Regarding the shares, almost 40% of the total has been produced by using natural gas in 2015. In our estimations, we referred to unit costs of production factors i.e. natural gas and nuclear power. Based on International Energy Agency (IEA) data, unit cost of electricity production with natural gas ranges between 0.086 $/KWh and 0.092 $/KWh and unit cost of production by using nuclear power plants (NPP) ranges between 0.059 $/KWh and 0.099 $/KWh.

In our analysis, we used average value of both these amounts. Obviously, NPP has a 0.01 $/KWh cost advantage compared to natural gas. Given the total capacity of 4,800 MWh and the 90% capacity utilization ratio, net present value of reduced energy cost reaches $ 6 billion which is a great contribution to Turkish economy.

Carbon Emission Reduction

One of the most significant benefits of NPP to Turkey will be the reduction in the carbon emission. Based on IEA data, the annual carbon emission reduction from operation of 1000 MWh of NPP is approximately 2.5 million tons of CO_2 which means 700,000 tons of carbon annually, compared to gas-powered electricity production (DTI, 2016). In our case, Akkuyu NPP will have 4,800 MWh total capacity, with a 90% capacity utilization. Based on these data, valuing emissions savings at a carbon tax of $30/ton gives

us a present value of $772 million approximately.

Employment Benefits

In Turkey, the unemployment rate is almost 10% and for the last decade, government has been trying to decrease this amount to reasonable rates. Even though there has been great progress on that front, unemployment stays high due to both cyclical and structural factors such as low capacity of industrial and business sector. Based on Bloomberg HT data, Akkuyu NPP will provide 10,000 jobs during the construction and 3,500 jobs after the construction with employment. Based on expert views on both sectors, we assume that 20% of the workers employed during the construction and 80% of the workers employed after the construction are skilled. Based on wage data by related institutions[1], $ 3.8 billion net present value is estimated from additional employment contribution of Akkuyu NPP. In this estimation, wage increases were also considered for the upcoming years.

Reduced Natural Gas Imported

As mentioned, Turkey`s energy production very much depends on fossil fuels, specifically natural gas which is one of the most significant factors behind the current account deficit of the country. Turkey`s total natural gas import cost reached $ 22 billion in 2015 and expected to reach $ 25 billion in 2018. (TEIAS, 2016) Within the context of "Strategic Energy Plan" by Ministry of Energy, it is planned to substitute electricity production by NPP with natural gas production and thus decrease natural gas imports to achieve more sustainable current accounts. In that context, it is anticipated that the share of the natural gas in electricity production will decrease by 5percentage points (from 40% to 35%). (Enerji ve Tabi Kaynaklar Bakanligi, 2014) Valuing this reduction in our estimations gives us a NPV of $50 billion in 30 years approximately which is a great benefit for the country.

Net Present Value of the Project

To calculate the NPV of the project, the total discounted costs were subtracted from the total discounted benefits. The inflation-adjusted discount rate (DR) applied is 10%. After the discounting, the NPV for 30 years of this project is roughly $40.3 billion, and the benefit cost ratio is 2.98. If the minimal usage time of the NPP is decreased from 30 to 20 years only, the NPV is still positive at $26.6 billion.

1 Bloomberg HT, Turkish Statistical Institute and Turkish Atomic Energy Authority

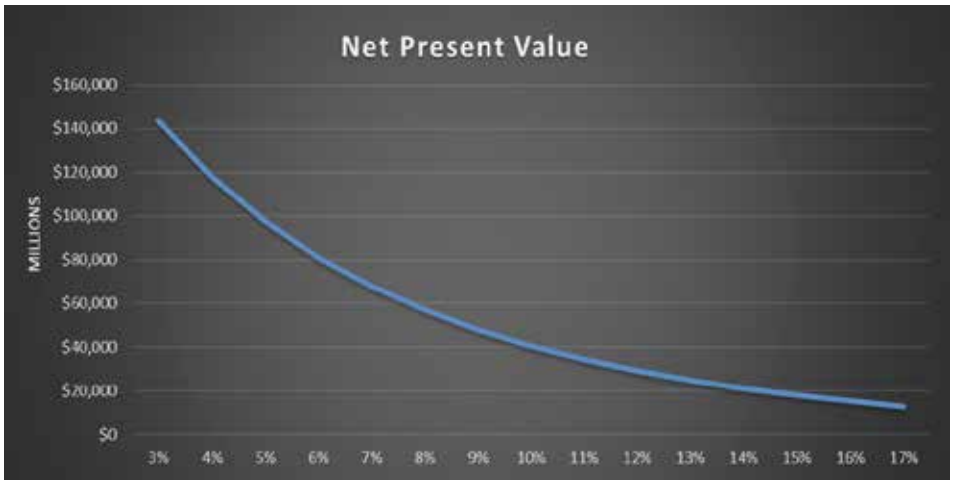
Table 2. Cost Benefit Analysis Summary

Cost Benefit Analysis (as of 2016)			
Costs	**NPV**	**Benefits**	**NPV**
Pre-investment Costs	$33,210,601.60	Lower Energy Cost	$5,981,023,214.17
Construction Costs	$13,963,636,363.64	Carbon Emission Reduction (Net)	$772,736,953.17
Operating Cost	$6,194,329,879.67	Total Employment Benefits	$3,732,227,080.95
Decommissioning Costs	$147,113,094.35	Reduced Amount of Natural Gas Imported(2018	$50,114,772,839.69
Total Cost	**$20,338,289,939**	**Total Revenues**	**$60,600,760,088**
NPV (20 years)	**$26,557,374,224**		**BCR**
NPV (30 years)	**$40,262,470,149**		**2.98**

Sensitivity Analysis

Only the discount rate has been included in this study as a sensitive parameter. This study is based on 10% discount rate (DR). For the DR sensitivity analysis, a range between 3% and 17% is applied. The NPV decreases when the DR increases since the highest benefits (reduced natural gas imported, employment benefits) are mostly in the future and thus receive lesser weight at a higher discount rate, whereas construction cost is incurred in 2016 and 2017. Nevertheless, NPV remains high even for a DR of 17%, where even in this worst-case scenario the NPV would be still positive (See Figure 1).

Figure 1. Sensitivity Analysis of the Project



Conclusion

This study shows a cost-benefit analysis of the Akkuyu Nuclear Power Plant in overall. The main benefits are as follows: i) reduced cost of energy production, ii) lower carbon

emission, iii) additional amount of employment, iv) reduced natural gas imported. The NPV of this analysis is around $40.3 billion from a 30-year perspective.

This analysis shows that at this point the project seems to be quite sensible from the view of the cost and benefit analysis, since its NPV as well as cost-benefit ratio are positive, even with conservative assumptions. Moreover, as the sensitivity analyses show, the project is so solid that it could withstand a significant increase in DR and still have a solid NPV.

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