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IMPACT OF EXTERNALITIES ON VARIOUS POWER GENERATION TECHNOLOGIES

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INTRODUCTION

This analysis develops and compares the cost of electricity of the envisioned nuclear power plant at Belene[1] (with approximately 2000 MW of installed capacity), with the cost of electricity from alternate generation sources, with a view toward the Bulgarian economy. The logical alternate generating sources are:

- New Lignite fueled Thermal Electric Power Plants (TEPPs)
- New Coal fueled TEPPs (based on imported coal), and
- New Natural gas fueled TEPPs.

The developed economic cost of electricity considers the internalized costs such as capital, fuel and operating costs, as well as the external costs, such as health and environmental impacts, to the extent possible.

APPROACH

In order to develop the cost of electricity for the alternatives of interest, the economic model documented in Reference [10] is utilized to evaluate the fossil fuel based options as well as the externality costs.

The Belene Nuclear project evaluated herein will consist of two units of ASE WWER 1000/ B-466. The fossil fueled projects to be compared with the Belene nuclear option will be representative of relevant fuel/ technology options. The performance details of these options are documented in the following sections.

The underlying basis of the analysis is that the alternate units will produce the same quantity of electricity (GWh) as would be produced by the Belene nuclear power plant. Externalities for both nuclear and fossil fueled options are based on a literature review. In later sections, other economic impacts, such as job creation, are also considered.

DEVELOPMENT OF EXTERNALITIES

An external cost or externality[2] "arises from the economic consequences of an activity that accrue to society but are not explicitly accounted for by the owners in their decision-making process." [1] A classic example of an externality is air pollution emitted during the generation of electricity by the combustion of fossil fuels. The pollution has a negative health and environmental impact to society, which is

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1 Belene NPP is expected to cover forecasted growth, and the retirement of Kozloduy NPP Units 3&4, with capacity of 800 MW.

2 An external cost or "externality" my be defined as "A cost or benefit that is not included in the market price of a good because it is not included in the supply price or demand price. An externality is produced when the economic activity of one actor (or group of actors) has a positive or negative impact on the welfare function of another actor (or group of actors) and when the former fails to be fully compensated, or to fully compensate the latter, for that impact. " [2]

typically not considered by the economic/ financial analysis of the decision makers. Since the general public is not the decision maker, is directly affected by the project, and is not compensated for the project's impact to the environment, the pollution and its consequence is an "externality". Recently there has been much interest in quantifying the externalities to assist in the process of decision making and policy development.

EXTERNALITIES OF NUCLEAR POWER

A list of possible impacts often suggested as externalities for nuclear power are [1]:

[1] Future Financial Liabilities for
  a. Decommissioning
  b. Handling of High Level Waste (spent fuel), and
  c. Severe Accidents;

[2] Health and Environmental Impacts of Radiological Releases from:
  a. Routine Operation
  b. Radioactive Waste Disposal, and
  c. Severe Accidents.

The future financial liability for decommissioning will not become an externality provided sufficient funds are reserved during operation. This analysis included internalized costs for decommissioning based on literature and Kozloduy NPP experience. Independent audits are periodically performed on the accrual accounts to verify that sufficient funds are being collected, and ensure that beneficiaries of electricity are paying for decommissioning costs. Costs associated with high level waste are funded in a similar manner.

The financial liability for a severe accident is commonly addressed with a third-party liability system. The 29jul60 Paris Convention on Third Party Liability in the Field of Nuclear Energy; and the 21may63 Vienna Convention on Civil Liability of Nuclear Damage,[3] establish the basis of such a system These conventions are based on the concept of civil law, and share the following precepts [13]:

- Liability rests exclusively with the operators of the nuclear facility;
- Such liability is absolute, i.e., it is independent of fault;
- The liability is limited in amount;
- The liability is limited in time. I.e., claims must be made within 10 years;
- The operator must maintain insurance or financial security; and
- If the security is insufficient, the state must cover the shortfall.

For example, under the Paris Convention, governments set a limit of liability for the nuclear operators, and the operators are then required to purchase insurance to cover the substantial first part of damage to third parties liability resulting from an unlikely severe accident. An industry funded "secondary financial protection" plan, or the government itself, will cover a substantial second part of the potential liability. Any remaining liability would be considered by national legislation[4]. [1]

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3 The 29jul60 Paris Convention on Third Party Liability in the Field of Nuclear Energy was established under the auspices of the OECD; and the 21may63 Vienna Convention on Civil Liability of Nuclear Damage was established under the auspices of the IAEA. These two Conventions are linked by the 1988 Joint Protocol. [1]

4 An example is the Price-Anderson Act in the U.S., under which nuclear operators can be assessed up to $88 million to cover any remaining part of secondary liability. Also, Congress may assess additional fees if the liability still exceeds the available funding.[1]

The limited third-party liability system is crucial to the industry since it resolves the open-ended liability issue for the investor, and ensures the public that resources will be available to address the needs of an unlikely, yet, severe accident.[5]

Bulgaria has ratified the Vienna Convention, and has subsequently established requirements for the coverage of liability from nuclear damage by the Act on Safe Use of Nuclear Energy, Chapter 10, articles 127 to 137, which is confirmed by experts to meet the requirements of the Vienna Convention. Accordingly, the Kozloduy NPP has held civil liability insurance coverage for BGN 96 million since July 2002, and has doubled this amount for aggregate insurance. In addition, KNPP has civil liability insurance to cover damage occurring during the transportation of nuclear fuel.

The portion of the severe accident liability covered by insurance is already internalized. Costs that may be determined and paid in the future remain an external cost, unless some allowances are made in the economic analysis. Thus, it is prudent to examine the external cost of a severe accident and determine its relative significance. Calculations performed for the ExternE study [1] [4] examined a postulated severe accident in France, based on a core melt probability of 10^{-5} per reactor-year, and a release of 1% of the core following a core meltdown[6]. This scenario yields a direct external cost of 0.0046m€[7]/kWh at a 0% discount rate. The ExternE study identifies two multipliers applicable to the direct cost: 1.25 factor to cover indirect macroeconomic aspects, and a factor of ~20 to account for the risk aversion of the population. Thus, an order of magnitude estimate for the external cost of a severe accident is 0.12 m€/kWh at a discount rate of 0%.

Even this figure, which takes no credit for that portion of the cost already internalized, is less than 5% of the external costs for routine operation, and less than 1% of the total nuclear fuel costs excluding externalities.[1] By not accounting for any already internalized insurance cost, the analysis conservatively overestimates the nuclear externality cost.

Considering the financial liabilities addressed above, the remaining issues are the health and environmental impacts. Again, one of the most authoritative studies on the subject is the ExternE study, which utilized a three stage approach:

> <u>Stage 1</u>: Quantify the physical phenomena associated with the construction, operation, and decommissioning of the plant.
>
> <u>Stage 2</u>: Evaluate the environmental impacts of various risk/ externality areas from a "physical" perspective, (e.g., diseases, fatalities, effects on food chain).
>
> <u>Stage 3</u>: "Monetize" their physical impacts, requiring the use of hypotheses, such as the value of lost human life, lost harvest, lost land use, etc.[8]

Some argue that long-term externalities should not be discounted at all, in order to protect the interests of future generations. Others counter that discounting is proper.

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5 Following the Chernobyl accident, the international community convened a "Convention on Supplementary Compensation for Nuclear Damage" to enhance the protection of nuclear accident victims. [1]

6 Several possible accident scenarios release varying amounts of radioactive source. The worst is a core melt event with complete containment breech and release of 10% of the more volatile elements such as cesium and iodine. The smallest release following a core melt event is based on the proper operation of the safety systems and nominal leakage from an intact containment system for a release of 0.01% of the core volatile elements. The 1% core release chosen by ExternE is the same basis used by the French national safety authorities for their reference accident. [1], p 67.

7 m€ is milli-Euro (1/1000 €).

8 The discount rate is related to the cost of capital, and is used to value investment against future cash flows. Even with a discount rate of only 4%, the compounding effect serves to value future cash flows in year 30, 40, 50, etc., as very small, and for the life of certain nuclear isotopes, negligible.

A high discount rate favors the present generation, while a low discount rate favors future generations. The selection of discount rate is thus "political" in nature and some have qualified it as "meta-ethical." [3][4] The ExternE study has avoided this sensitive issue by calculating externalities with 0, 3 and 10% discount rates.

The following documents the external cost of a French nuclear fuel cycle published in the 1995 ExternE study for the three discount rates and various fuel cycle stages:

		Discount Rate		
Fuel Cycle Stage		0%	3%	10%
Fuel Preparation:	Mining and Milling	6.45E-02	1.84E-02	6.26E-03
	Conversion	9.74E-04	4.78E-04	2.26E-04
	Enrichment	1.19E-03	7.90E-04	4.13E-04
	Fuel Fabrication	1.89E-03	7.35E-04	3.10E-04
Electric generation:	Construction	3.94E-02	3.94E-02	3.94E-02
	Operation	4.41E-01	1.68E-02	4.12E-03
	Decommissioning	1.93E-02	6.91E-03	9.26E-04
Reprocessing (note)		1.92E-00	1.45E-02	1.90E-03
Waste Disposal:	LLW disposal	4.80E-03	8.52E-06	4.13E-07
	HLW disposal	2.54E-02	6.41E-09	1.12E-10
	Transportation	6.54E-04	2.66E-04	1.21E-04
Total, m€/kWh		2.52	0.10	0.054

Note: Should direct disposal be chosen over reprocessing, the mining and milling external costs would be more significant, and the reprocessing entry would become zero. ExternE assumed that the increased emissions from mining and milling are comparable to the decrease in emissions from reprocessing. [4]. Thus the external costs based on a fuel cycle with reprocessing should be comparable of the direct disposal fuel cycle. Source: ExternE 1995 [1].

The difference in externalities with a 0% and 10% discount rate displays a multiple of 50, and demonstrates the impact of the discount rate.

External costs from various studies are cited by reference [1]. Three of the four cite lower externalities, while the Pace study yields higher values, due to some overly conservative inputs, and double counting of certain factors[9]. The ExternE methodology and calculations are widely accepted in the industry and present a reasonable estimate of the external costs of nuclear power.

Considering that the external cost of a nuclear fuel cycle in routine operation is ~2.4 to 7.4 m€/kWh, and that the external costs of a severe accident are ~0.12 m€/kWh, the total external costs for nuclear power would be ~2.5 to 7.5 m€/kWh, based on a discount rate of 0%. This compares to direct nuclear costs of ~35 to 60 m€/kWh.

EXTERNALITIES OF FOSSIL-FUELED ELECTRIC GENERATION

This section reviews the externalities associated with electric generation by fossil fueled technologies. As with the nuclear externalities, one of the best references on this topic is ExternE. Seven major types of damage were addressed [8]:

- Human health – Mortality (fatal effects),
- Human health – Morbidity (non-fatal effects)

9 The PACE study included US$5 mills/kWh for decommissioning, however this is usually included as an internalized cost. The PACE study also considered a severe nuclear accident of Chernobyl magnitude once every 3300 years (or core release probability of 3.0E-04 per reactor-year), significantly more frequent than what experts consider appropriate for modern reactors. Lastly, occupational health impacts are based on estimates of delayed deaths twice those of the 1998 NEA study based on 1991 Helsinki Symposium Conclusions. [1]

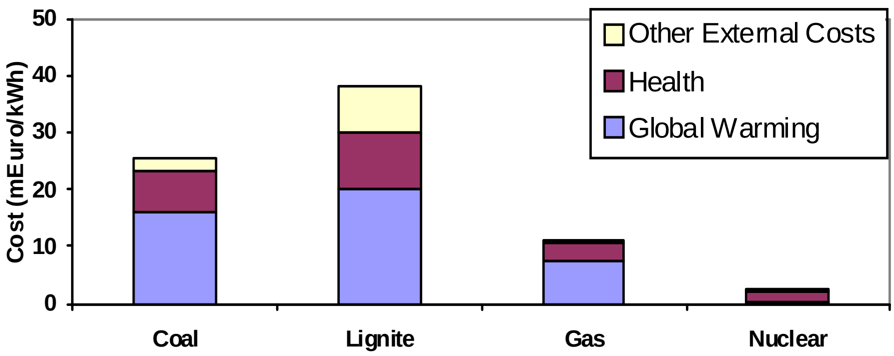
- Building materials
- Crops
- Global Warming[10]
- "Amenity" losses (noise), and
- Ecosystem (Acid and Nitrogen deposition)

The external costs are dependent upon fuel, technology, location and other key assumptions. By example, the following presents the marginal external cost for these seven areas for electric production in Germany (m€/kWh).

	Coal	Lignite	Gas	Nuclear
Damage Costs				
Noise	0	0	0	0
Health	7.3	9.9	3.4	1.7
Material	0.15	0.20	0.07	0.02
Crops	0	0	0	0.008
Total Damage costs	7.5	10.1	3.5	1.7
Avoidance Costs				
Ecosystems	2.0	7.8	0.4	0.5
Global warming	16.0	20.0	7.3	0.3
Total Avoidance Costs	18.0	27.8	7.7	0.8
Total External Costs	25.5	37.9	11.2	2.5

Note: These values are based on median estimates for current technologies. Ecosytems and global warming costs are based on avoided costs, with the later being valued as a €19/tonne CO_2 avoidance cost based on Kyoto reduction targets. Utilizing damage costs for these items would increase the total external cost. Source: [8].

A review of the values reveals that external costs are dominated by health and global warming effects. Presenting these external costs graphically below, it is clear that the external costs for fossil-fueled electric generation are substantially more significant than for nuclear, independent of location.



Comparing these external costs with the average European Union country direct costs, we see that the fossil-fueled external costs are on the same order of magnitude, while the nuclear external costs are approximately one order of magnitude smaller.

[10] Global Warming Damage costs evaluated in ExternE include: "World wide effects on mortality, morbidity, coastal impacts, agriculture, energy demand, and economic impacts due to temperature change and sea level rise." Since the uncertainty for global warming damage is very high, ExternE evaluated marginal and avoidance costs to reach the Kyoto reduction targets, and these costs are used. [8]

The table below demonstrates the range of external costs (m€/kWh) that are evident with various countries and fuel type. The costs are influenced by the plants proximity to population centers particularly for the cost impacts associated with particulate matter. The higher external costs generally belong to the Central European countries, mostly because of the large population that is affected.

	Coal & Lignite	Oil	Gas	Nuclear
Belgium	37-150		11-22	4 - 4.7
Germany	30-55	51-78	12-23	4.4 - 7
Denmark	35-65		15-30	
Spain	48-77		11-22	
France	69-99	84-109	24-35	2.5
Greece	46-84	26-48	7-13	
Italy		34-56	15-27	
Netherlands	28-42		5-19	7.4
Portugal	42-67		8-21	
UK	42-67	29-47	11-22	2.4-2.7

Note: This table is based on the quantifiable externalities and is based on a global warming damage cost range of €18 to 46 per tonnne of CO_2. Therefore, these costs are generally higher than the costs in Exhibit 2 based on avoidance costs for global warming and ecosystem. Source: [8].

While external costs vary considerably by fuel technology and power plant location, the difference in externalities costs between nuclear and fossil-fueled power is sufficiently pronounced that the following external costs are utilized in the economic sensitivity analysis for Belene that include the external costs (m€/kWh).

	Coal & Lignite	Oil	Gas	Nuclear
Analysis Input	50	50	15	5

Note: Coal and Lignite are grouped together since lignite values were only developed for two countries, and the average range data for lignite only is similar to that of coal alone.

Direct Emission Costs

Direct emission costs result as a consequence of emitting certain pollutants and/or by obtaining emission allowances/ credits that allow their emission. These costs are relevant to the fossil combustion power cycles that will be analyzed for comparison with a nuclear power plant and include trading fees for Greenhouse gases per the Kyoto Protocol.

Greenhouse Gases under the Kyoto Protocol

The "Kyoto Protocol (KP) to the United Nations Framework Convention on Climate Change" adopted in December 1997, establishes legally binding greenhouse gas emission targets for "Annex I" (industrialized) countries (including Bulgaria). The reduction target for the six key greenhouse gases[11] is 8% from a reference baseline, for most of the EU, with a default reference year of 1990 (Bulgaria is 1988).[5] Each member country must achieve their target emissions by 2008-12, based on a 5-year average, and must develop a National Allocation Plan for greenhouses gases, in terms of equivalent tonnes of CO_2, for each industrial site.

[11] The six Greenhouse gases (GHG) include: carbon dioxide (CO_2), methane (CH_4), nitrous oxide ($N_2 0$), hydroflourocarbons (HFC), perflourocarbons (PFCs), and sulphur hexafluoride (SF_6). Approximately 87% of global warming is attributed to CO_2 emissions, and as such the GHG are expressed as tonnes of CO_2 equivalent, or CO_2,e. GHGs from combustion based power plants are essentially limited to the generation of CO_2.

Companies have flexibility in how they meet their allocation.[5] Reductions can be achieved through real reductions (i.e., process or efficiency changes), or via emissions trading. Emission trading can consist of emission reduction projects in other countries via "joint implementation", "clean development mechanism,"[12], or "international emission trading." The "international emission trading" allows entities with surplus credits to sell them to those desiring to increase their allocations. Entities that emit more than their allocation levels allow, must either supplement with emission credits, or pay a penalty. The operator of the violating facility must surrender allowances equivalent to the violation in the following year. [6]

EU CO_2 trade allowances for 2004 to 2007 currently (as of Aug04) range from €8.35 to €8.85 /tonne CO_2 equivalent; however, if this mechanism is retained, the growing consensus is that the cost of CO_2 obtained via emissions trading will rise significantly above €20/tonne.[6]

Greenhouse gas emissions from Bulgaria and other countries are presented below:

Country / Country Group	All GHGs, Base year (Gigagrams)	All GHGs, 1999 (Gigagrams)	Percent Change	Kyoto Target (%)
Bulgaria	157 090[b]	84 317	-46.3%	-8%
Annex I Countries	18 147 110[c]	16 982 195[e]	-6.4%	-5%
Annex II Countries	12 686 651[c]	13 553 405[e]	+6.8%	NA
Economies in Transition (EIT)	5 460 459[d]	3 428 790[e]	-37.2%	NA

Notes: a. Carbon removal by sinks are excluded.
b. The base year for Bulgaria is 1988, as an Economy in Transition (EIT).
c. The base year for the Annex I and II countries is 1990.
d. The base year for EIT's vary from 1985 to 1990.
e. The most recent data is not from 1999 but from 1998. This data is indicated.
Source: [5]

As indicated above, between 1988 and 1999, the CO_2 emissions in Bulgaria have decreased by 46.3%, significantly more than the Kyoto Target of 8%. Thus Bulgaria seems to have ample room for economic growth, increased electric exports as well as the potential sale of emission credits.

In comparing a fossil unit to a nuclear unit in a financial analysis, the fossil unit should be charged the emission credit for the full greenhouse gas emission, since if they are not needed for the fossil plant, they could be sold on the international emissions trading market. Thus in a financial analysis comparison of a new fossil-fueled power plant and a nuclear fueled power plant going on line after 2008, the cost of emitting CO_2 should be taken as €20/tonne. This is roughly equivalent to €20/MWh for a coal/lignite fueled power plant, and to €7.5/MWh for a natural gas fueled combined cycle[13].

Social Impacts

The selection of technology, the use of indigenous fuels, and the use of domestic equipment and services all have a significant impact on the economy, and should be considered in the project development stage.

[12] The "Joint Implementation" allows an Annex 1 country (developed country) to take credit for implementation of an emission reduction or increased removal (CO_2 sinks) project, in territories of other Annex 1 countries. The "Clean Development Mechanism" allows an Annex 1 country to take credit for implementation the same in a developing country. [6]

[13] The CO_2 emitted per MWh is dependent upon the fuel utilized and cycle efficiency of the plant. Per Reference [11], representative quantities of CO_2 per MWh are 0.985 tonnes CO_2 per MWh for a coal-fired plant with an efficiency of 33% HHV (~36% LHV), 0.376 tonnes CO_2 per MWh for a natural gas combined cycle with an efficiency of 48% HHV (~53% LHV).

Each technology has its own characteristic contribution to employment, and related impact to the Bulgarian economy. Natural gas plants rely heavily upon imported equipment and fuel, and also have a relatively low contribution to short-term and permanent employment. Coal plants add considerably to the Bulgarian economy by creating permanent jobs and using indigenous resources (lignite), as well as maintaining Bulgaria's energy security. Hydro plants provide a high level of short-term employment, and should be considered, within the limits of available resources, and environmental impacts. As with coal, nuclear plants offer both a high level of short-term and permanent employment.

Each local job created to satisfy requirements of construction, operation, or fuel supply, in conditions other than full employment, benefits the Bulgarian economy including the cost to the government of an unemployed person vs. an employed taxpayer. Each direct job created also has a multiplier effect in the economy, i.e., additional employment to satisfy the needs of the employed person. While this multiplier effect varies and is specific to the economy, a very conservative value of 0.5 indirect job to direct job ratio has been used, consistent with a previous study in the U.K.[14]. Considering the differences in technologies with respect to employment, these values should be considered when analyzing project options.

In Bulgaria, the development of jobs in the nuclear industry that are generally technically oriented and higher paying than other sectors, and to develop such jobs in a geographical area that is economically depressed, will result in a positive economic benefit that is only conservatively estimated herein.

Economic Analysis

The options were evaluated on an economic basis.

Basis and Assumptions

The fuel costs of the fossil fueled options are presented following. The fuel cost for the nuclear options are as presented in Section 5.4.3 of Reference [9]. (i.e., €5.35/MWh for the Skoda WWER-1000/B-320 and €4.57/MWh for the ASE WWER-1000/B-466).

Fuel	USD/tce	USD/Gcal (LHV)	Basis[a]
Lignite	30	4.29	2003 & 2004 LCP [10]
Imported Coal	42	6.00	2003 & 2004 LCP [10]
Natural Gas	119	17.01	Note b

Notes: a. tce - tonnes of coal equivalent, 7.0 Gcal (LHV); LHV - lower heating value; LCP - Least Cost Plan.
b. Limiting sale price for gas from the Gas Transmission Enterprise to consumers is 227.50 leva/1000 Nm3 as of July 01, 2004. With a 1.6 leva to US$ exchange rate, and 35 MJ/Nm3, the cost is $4.29 per MMBtu.

As mentioned previously, the basis of this analysis is that the fossil fueled units will each deliver the same quantity of electricity as the Belene NPP.

The characteristics of the options to be analyzed are presented below.

Plant Type	Total Capacity (MW)a	Nominal Unit Size (Net MW)	No. of Units	Fuel
Nuclear	1912	912 & 1000	2	LEU
Pulverized Coal - Lignite	1912	300	~6.4	Lignite
Pulverized Coal – Imported Coal	1912	500	~3.8	Imported Coal
Natural Gas fired GTCC	1912	500[c]	~4.1	Natural Gas

Notes: a. The total capacity of the fossil units are set to deliver the same quantity of electricity as Belene NPP.
b. The GTCC size may not be exactly 500 MWe net, since it depends upon the selected gas turbine model, the configuration, ambient conditions, site elevation, fuel and other factors.

The heat rate, forced outage factor and planned outage factor for the evaluated options are presented below.

Plant Type	Nominal Unit Size, MWnet	Heat Rate [b], kcal/kWh	Forced Outage Factor, %	Planned Outage Factor, %	Overall Plant Unavailability, %
Nuclear	1000	Note a	2.8% (B466)[a]	6.5% (B466)[a]	9.3% (B466)
Pulverized Coal – Lignite	300	2265	5%[c]	10% [c]	15% (12%) [d]
Pulverized Coal – Imported Coal	500	2200	5% [c]	10% [c]	15% (12%) [d]
Natural Gas Fired GTCC	500	1550	2.5% [c]	7.5% [c]	10% (8%) [d]

Notes: a. Nuclear performance data as documented in Section 5.2 of the Feasibility Study for Construction of Belene NPP.
b. The Heat Rate (HR) for the lignite plant is based on Reference [10]; for the imported coal plant on representative numbers; and for the GTCC on heat balances for a 2x1 GE 9001H firing natural gas. .
c. Forced outage and planned outage factors for fossil-fueled plants based on data from NERC GADS [12].
d. Numbers in parentheses represent assumptions.

Assumptions for coal and gas-fired plants may be considered optimistic, based on NERC-GADS operations data; however, some optimism is justified based on recent warrantee information, and general technology improvements. A dispatch factor of 90% was assumed for all plants.

CAPITAL AND OPERATING COST DEVELOPMENT

Capital and operating costs utilized in the analysis are documented following.

Plant Type	Unit Size (Net MW)	Capital Cost	Fixed O&M	Variable O&M
Nuclear	1000	Note 1	Note 1	Note 1
Pulverized Coal – Lignite	300	US$ 1310/kW (€1178/kW)	US$ 28.19/kW/y (€25.35/kW)/y	US$ 4.05/MWh (€3.64/MWh)
Pulverized Coal – Imported Coal	500	US$ 987/kW (€887/kW)	US$ 18.07/kW/y (€16.24/kW)/y	US$ 3.8/MWh (€3.4/MWh)
Natural Gas Fired GTCC	500	US$ 420/kW (€376/kW)	US$ 9.8/kW/y (€8.81/kW)/y	US$ 0.63/MWh (€0.57/MWh)

Notes: 1. The nuclear plant cost data will be utilized as documented in Section 5.2 of the economic analysis for the Feasibility Study for Construction of Belene NPP for Option 1.1, Reference [10].
2. Capital costs and operating costs are converted from US$ to Euros based on an exchange rate of $1.10/€.

Costs are based on U.S. prices, adjusted for the Bulgaria situation.

Value of Employment

Each technology has its own impact to employment, and related impact to the local economy, shown in below for a nominal unit size 900 to 1000 MWe.

Plant Type	Nuclear	Pulverized Coal		Gas Fired GTCC
		Lignite	Imported Coal	
Construction Labor (No. of Jobs)				
Year 1	3,637	1668	1,223	377
Year 2	4,696	2002	1,468	604
Year 3	4,601	2002	1,468	528
Year 4	3,757	1001	734	
Year 5	3,253			
Year 6	2,656			
Permanent Plant Operating Staff	774-806	367	367	132
Fuel Supply-related Jobs[a]	0.25/MW	1.94/ MW	0	0

Notes: a. Counted only within Bulgaria, i.e., except for fuel delivery, imported fuels provide virtually no domestic job creation.
Source: Feasibility Study for Belene NPP, Part 5, Economic Assessment, -BNPP-FS-PEC-NEK-0004-R2-E-5 (30jul04)

A "value" of €5,000/y represents the average economic benefit of creating one job in Bulgaria. Further, a conservative ratio of 0.5 indirect to direct jobs is used. As expected, the highest benefit is accrued by the NPP, and the least by the GTCC.

ECONOMIC MODEL

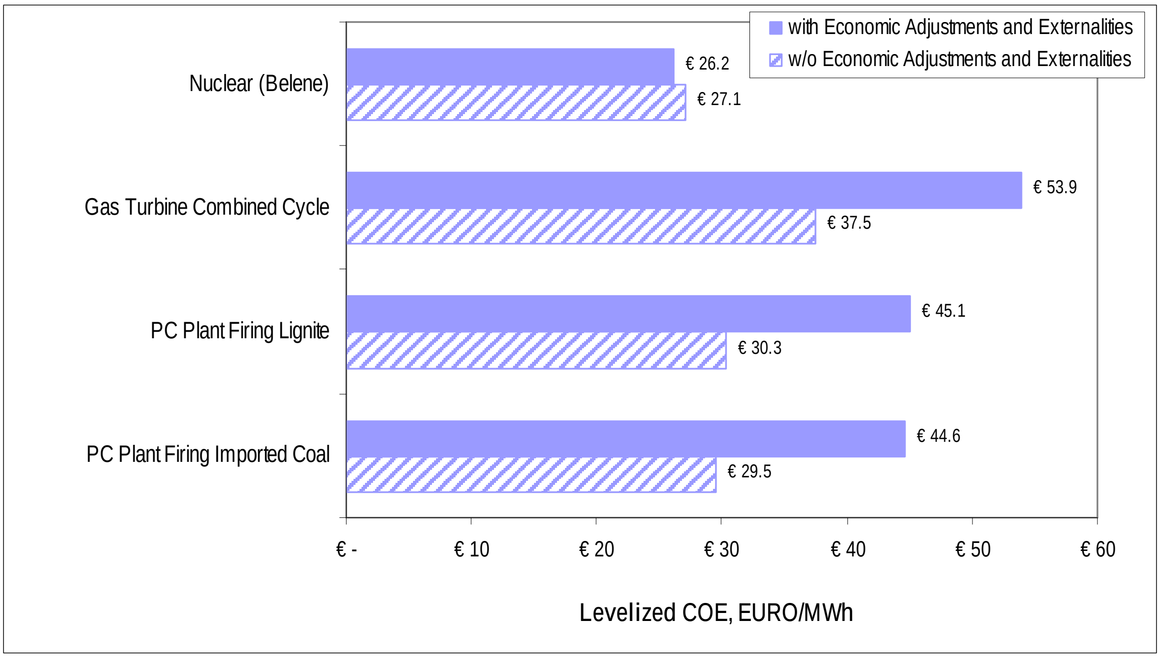
The spreadsheet financial/ economic model was developed specifically for the Belene Project, and used in this analysis. Options are evaluated as "projects, executed in two steps (phased installation), matching the sequence of Belene NPP implementation. The primary figure of merit is the Levelized Cost of Electricity (COE), calculated as follows:

$$\sum_{1}^{n} \frac{AnnualCosts}{(1+i)^n}$$

where: n=year and i = discount factor

On an economic basis, it excludes the impact of taxes, internal debt service charges, and selected externalities.

Economic Analysis results are presented below.



Conclusions

In the absence of externalities and other economic benefits, nuclear, and specifically Belene NPP, is economically superior to other reasonable options. Externalities associated with the development of fossil and nuclear technologies have been studied in some detail, and quantified in many reference works for the purpose of comparative analysis. When externalities and other economic benefits are included, the advantage of nuclear is much more pronounced.

A nuclear plant provides a large source of economic benefits in terms of short and long-term job creation which can have a substantial primary and secondary economic benefit. In addition, the inclusion of externalities is heavy in the favor of nuclear power over fossil-based technologies.

Nuclear power has the potential to assist Bulgaria in meeting CO_2 emissions targets established through the Kyoto Protocol and subsequent initiatives, as well as the elimination of SO_2, NOx and CO emissions associated with fossil fuel technologies.

Nuclear Power, and specifically the Belene NPP Project, has the potential to provide Bulgaria with considerable short- and long-term economic benefits, including energy security, significant job creation, and electric generation revenue, when compared to fossil fuel options.

Comparative economic benefits exist for the Belene NPP Project when compared to coal-fired plants, but are even more pronounced when compared to gas turbine combined cycle plants.

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