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Renewable Energies Increase, Fossil Fuels Replacement and Nuclear Option Assessment in the Portuguese Energy Mix

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Abstract. Due to the increase in annual electricity consumption occurring in Portugal and the rising price of fossil fuels, it is imperative to diversificate the energy sources available. The Portuguese investment in renewable energies has increased significantly in the past few years, especially in wind energy. Renewable energies are intermittent and dependent on weather conditions, so fossil fuels are still an important part of the Portuguese energy mix, but with tendency to decrease in the future. In this paper, the nuclear option has been considered alongside the renewable energies increase to reduce fossil fuels dependency, envisaging several plausible scenarios for fuel prices, installed capacity and investment costs.

Key words

Renewable energies, fossil fuels, nuclear option, Portuguese energy mix.

1. Introduction

Given the increasing energy consumption in Portugal, it is necessary that the country upgrades its electricity production facilities in order to cope with this increase. The production of electricity from fossil fuels is one important contributor for CO_2 emissions, contributing to global warming, and avoiding fossil fuels is a great achievement for Portugal. The replacement of coal and fuel oil for natural gas-fired power plants is a less harmful option for the environment, but may not be an adequate option, considering pollutant emissions [1]. The increasing cost of fossil fuels and the different agreements among the industrialized countries with the aim of reducing CO_2 emissions has driven the renewable sources in an increased acceptance for energy production.

The investment in wind energy for the 27 EU Member States is expected to grow in the next two decades reaching almost €20 billion till 2030 [2]. The increased integration of renewable energies into the electric grid poses important challenges due to its intermittency and volatility [3].

Nuclear energy allows mitigating the vulnerability of the economic system in relation to the instability of international prices of crude oil. Still, the construction of a nuclear power plant has a number of possible drawbacks (capital costs, operation and maintenance costs, fuel and decommissioning costs), that should be taken into account.

Nuclear energy represents a strategic alternative to the excessive dependence on fossil fuels worldwide. So, it would be interesting to assess the potential nuclear option in the Portuguese energy mix, as already occurs in Spain [4,5].

2. Portuguese Energy Mix

Figure 1 shows the evolution of electricity consumption in Portugal in the last decade, considering the energy sources available. From this figure, it is possible to conclude that some fossil-fuelled power plants, using coal or fuel oil, are suffering a decline in the production level in Portugal.

As can be seen in Table I, the majority of electricity generation still comes from fossil fuels. It should be noted that wind energy increased from approximately 5.7 TWh in 2008 to about 7.5 TWh in 2009 [6].

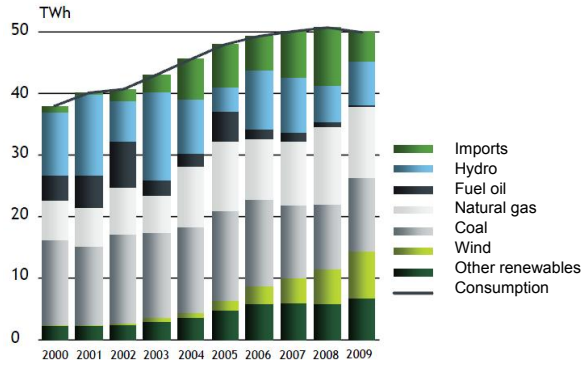

Fig. 1. Evolution of electricity consumption in Portugal in the last decade, considering the energy sources available [6].

Table I. - Data regarding electricity production in Portugal.

	2009 (GWh)	2008 (GWh)	Variation (%)
Production in "Ordinary" Regime	31600	30238	5
Hydro	7892	6441	23
Thermal	23708	23797	0
Coal	11942	10423	15
Fuel	303	801	-62
Natural Gas	11463	12573	-9
Production in "Special" Regime	14417	11565	25
Hydro	823	660	25
Thermal	5963	5177	15
Wind	7492	5695	32
Photovoltaic	139	33	316
Balance Importer	4777	9431	-49
Pumped Hydro	929	639	45

Portugal will have in 2020 a consumption of about 72 TWh, which means a 43% increase in relation to consumption that occurred in 2008 (Figure 2).

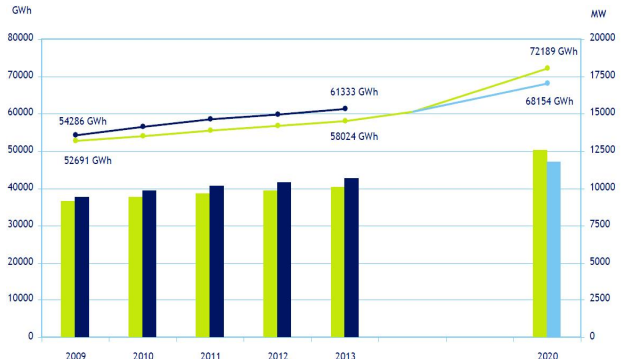

Fig. 2. Scenarios for evolution of electricity consumption [6].

The total installed capacity is expected to have a gradual increase, nearly doubling the installed capacity in 2020 comparatively to 2008. The growing share of energy derived from the "special" regime is expected to reach almost 50% of all electricity production in the country, especially wind energy, with added intermittency and volatility [6].

In this context, alongside the massive investment on wind energy, the potential nuclear option in the Portuguese energy mix is assessed in this paper.

3. Economic Analysis of the Nuclear Option

For the economic evaluation of the nuclear option, a model was built consisting of a baseline scenario and from which various sensitivity analyses were carried out by changing several parameters (fuel prices, installed capacity, and investment costs).

A power plant of about 1600 MW was envisaged, requiring an investment of 1.9 k€/kW. The fuel cost is already included in the initial investment. All the costs regarding waste treatment and decommissioning are included in the variable operation and maintenance costs. The parameters are described in the Table II [7].

Table II. - Technical features of the project - Baseline Scenario.

Technical Features	Value
Electric power (MW)	1600
Investment cost per power output capacity (k€/kW)	1.9
Fuel price (€/MWh)	2.70
Annual fixed operation and maintenance costs (% of investment)	1.50
Variable operation and maintenance costs (€/MWh)	3.63
Annual peak load utilization time (%)	92
Economic lifetime (years)	40
Annual power prodution (MWh)	12894720

The economic assumptions are set at an interest rate for financing the investment as 5%. The remuneration payable to shareholders is 8%. With these two rates, a weighted average cost is obtained: 6.5%. Since this could represent a relatively high investment, it is considered to be made by public and private capital, 50% each. The average market price is set at 50 €/MWh.

The criteria for the evaluation of profitability are based on cash flow. These are: Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period (PP). The investment was considered to be accessed in full in year zero and no residual value was considered, which a worst-case scenario.

After the application of financial evaluation criteria, the following results (shown in Table III and Figure 3) were obtained for four scenarios: doubling of fuel prices; doubling of installed capacity; doubling of the initial investment cost and 50% increase of average market price; 50% increase of the economic assumptions.

Table III. - Financial indicators of the project for the various scenarios.

	NPV (k€)	IRR (%)	PP (years)
Baseline Scenario	3390456	14.68	10
Scenario I	2897982	13.26	11
Scenario II	6440999	14.29	10
Scenario III	3375541	10.66	15
Scenario IV	2876273	13.40	15

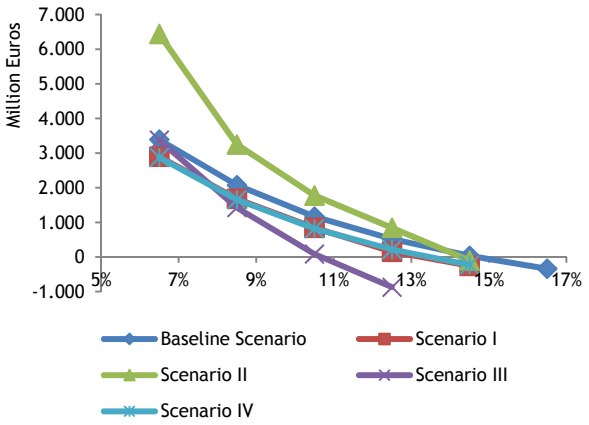

Fig. 3. Financial indicators of the project for various scenarios.

From the scenarios, it is possible to conclude the feasibility of the project, due to a positive NPV. Still, this project only allows a return on investment after 10 to 15 years. Also, the risk of investing in a nuclear option has increased significantly after Fukushima, albeit being a non-polluting source such as the renewable sources.

The average production costs for the various scenarios are presented in Table IV.

Table IV. - Average production costs for the various scenarios.

	Investment Costs (€/MWh)	Fuel Costs (€/MWh)	O&M Costs (€/MWh)	Total Cost (€/MWh)
Baseline Scenario	10.79	2.70	7.17	20.66
Scenario I	10.79	5.40	7.17	23.36
Scenario II	10.79	5.40	5.40	21.59
Scenario III	21.59	2.70	10.70	34.99
Scenario IV	15.77	2.70	7.17	25.64

In Scenario III, the investment risk is high and dependent on the average market price (set at 75 €/MWh), so this choice is not advisable, although the total production cost (34.99 €/MWh) is covered by the market price.

4. SWOT Analysis

The SWOT analysis (Figure 4) allows to minimize or overcome the weaknesses and to counter threats. The need to reduce CO_2 emissions means that nuclear energy may have a strategic importance for Portugal.

Betting on this technology would also open-up new business opportunities for suppliers and components, aiming to include national technology and staff. The country has reserves of uranium, which could be prospected more intensively, leading to the creation of jobs in poorer areas of the country.

The nuclear industry may also have other applications, such as in medicine and in the environment.

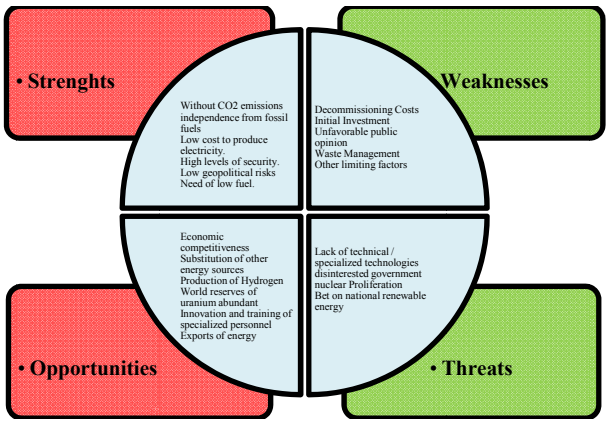

Fig. 4. Matrix of a SWOT analysis for investment in nuclear energy in Portugal.

5. Possible Localizations for the Plant

Analyzing the geographical regions of the country, and known security issues such as the seismic risk, Portugal has two possible locations: one near the Douro River and the other near the Tagus River. These regions have a very low seismic risk and rivers have a high flow rate for cooling the reactor.

These locations would facilitate the transmission of electricity throughout the country, using the high-voltage lines in those regions. They are also relatively close to the two largest urban centres, Lisbon or Oporto respectively.

The region of the Guadiana has drawbacks, such as the fact that this river has a low flow and this region has a higher seismic risk.

6. Conclusion

The construction of a nuclear power plant in Portugal could be favourable in the search for new energy alternatives. The country has reserves of uranium that would make it less vulnerable to imported energy. In this paper it has been demonstrated that, with various scenarios, the adoption of nuclear power in Portugal is feasible and can be seen as an example in reducing pollutant emissions. Portugal could replace thermal power plants causing the greenhouse effect with a nuclear one. Additionally, there was a big investment today on renewable energy in Portugal. Renewable energies are extremely volatile and dependent on weather conditions. So, the nuclear energy could provide an interesting complement to the energy mix, reducing the country's external dependence on fossil fuels.

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