ATLANTIS PRESS
*Advances in Computer Science Research (ACSR), volume 73*
7th International Conference on Education, Management, Information and Computer Science (ICEMC 2017)

# Nuclear Fission in Fast Breeder Reactors and Its Economic Outlook

Zhanbo Wang
North China Electric Power University, Beijing, China
berrybz@126.com

**Keywords:** Nuclear Fission; Fast Breeder Reactors; Power Plant; Economic Outlook

**Abstract.** This study specifically analyzes the economic viability of nuclear fission fast breeder reactors. Through the collection of large amounts of data and field surveys. We choose a city in the United States to try to make a viable solution to analyze its economic benefits. The higher safety requirements of the power plant resulting in a larger initial investment demand. But the long-term benefits are high, and also will made a great contribution to environmental protection.

## Introduction

Due to the high efficiency of both energy production and fuel consumption, FRBs provide a solution to the major problems facing nuclear energy today: availability of fuel and storage of waste. As the efficiency of the technology increases, the immediate need for fuel processing and waste storage decreases and the impact the technology has on the environment decreases as well. [1]Fast breeder technology is the natural progression of nuclear fission, and as nuclear energy grows all over the world, development of this technology becomes ever more important. Through FBRs, we can continue to lessen the world's reliance on fossil fuels and move towards clean energy production globally.[2]

## Environmental Impacts

During operation of power plants for producing electricity, the fossil fuels plants have the highest CO2 emissions per kWh. [3]Compared to these fossil fuels, nuclear has a significantly low CO2 emission. And the CO2 emission of a nuclear power plant only comes from the construction period and the decommissioning phase. And according to OECD-NEA, from 1971 to 2004, nuclear power has already avoided more than 20% of the CO2 which would have been emitted.[4]

Table 1: Carbon emissions by energy type

| Energy chain | Average $CO_2$ emissions |
|---|---|
| Lignite | 1.2 |
| Hard coal | 1.07 |
| Oil | 0.9 |
| Natural gas (combined cycle) | 0.4 |
| Solar PV | 0.060 |
| Wind (offshore) | 0.014 |
| Wind (onshore) | 0.011 |
| Nuclear | 0.008 |
| Hydro | 0.005 |

Particulate emissions refer to aerosol particles (solid or liquid) in the atmosphere. The main sources of particulate emissions are power stations and diesel engines and some other industrial processes. We can see from the picture nuclear power shows an excellent performance for the emissions of particulate matter. [5]

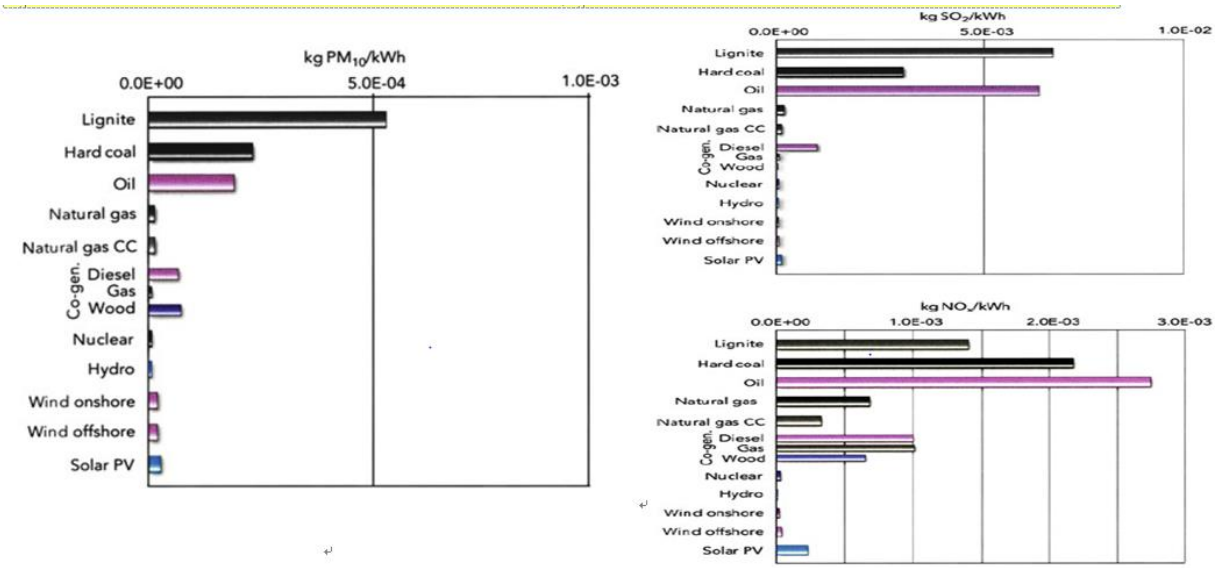


Figure 1: (Left) Particulate emissions by energy type (Right) SO2/NOx emissions by energy type

The combustion process of lignite, hard coal, oil and natural gas at a high temperature with air is the main reason for the high NOx emissions. Lignite, hard coal and heavy oil have the highest SO2 and NOx emission. Again, nuclear power has the lowest NOx emissions.[6]

There will only be a small amounts of radioactivity released into the environment during normal operation of nuclear power plants at a monitored and controlled rate.[7]

According to the German Radiation Protection Ordinance, the limit for the annual effective radiation dose due to radioactive emissions from nuclear installations to the population permissible on top of the natural background radiation is 1mSv. [8]And now, the radioactive exposures to the public from the nuclear facilities are well below the permissible effective radiation exposures.

## Political/Social Acceptance

Indiana, like many states in the United States, offers government incentives for clean and renewable energy production and use. Commercial energy sources can benefit from these incentives if the energy production fits the criteria for the specific incentive. [9]These incentives exist as both tax credits or rebates and are offered for a wide range of renewable sources. These include solar power, wind, geothermal, and other renewable sources. Since a FBR would produce virtually no carbon emissions during operation and its increased fuel efficiency as compared to traditional nuclear fission, it appears very likely that this technology would qualify for government incentives. This would further reduce the cost of production, making FBRs a more viable means of energy production for the region.[10]

## Financial Analysis

The Nuclear fission plant characteristics are shown in the Table 4:

Table 2: Proposes plant characteristics

| | |
|---|---|
| Notional size of installation(MW) | 880 |
| Economic life-expectancy(years) | 35 |
| Construction period(years) | 5 |

Table 2: Proposes plant characteristics

| | |
|---|---|
| Capital cost ($ per kw) | 4000 |
| Annual operation ($ per Mwh) | 20.62 |

Assumption: The fast breeder plant is operated at full load for the whole year.

Annual electricity generation:880*1000*24*365=7.7088*10^9kWh = 7708.8million kWh.

By calculating the percentage of the electricity consumption by india state, which is 106943 million kWh, we can conclude that the assumption is correct since the percentage is 7.2%(7708.8/10693) which is relatively small.

**Income.** Using the average price of electricity price in Indiana state which is 9.34cents/ kWh, we can calculate the Annual money by selling electricity: (7.7088*10^9kWh)x($0.0934/kWh)=$720.0million

**Annuity.** According to the data from the reference which reflects that the direct local jobs is 504 and the workforce income is $ 32.49 mil for a 1000 MW nuclear plant, we can assume that the annuity is $28.4 mil based on the linear evaluation method.

**Capital cost.**

$$P = A\frac{(1+i)^N - 1}{i(1+i)^N}$$

Since the overnight cost of nuclear power plants to about $4,000/kW, we calculate the capital cost is $4,000/kW *880 MW*1000KW/MW= $ 3520 million.

**Loan cost.** Loan interest rate: 7% Length of loan: 35

Annual Loan Cost: $ 0.07 * 3520 = $246.4million per year

**Annual cost for operation and fuel**. (Operating cost+ Fuel cost) *capacity*time =$159.49 million

**Equivalent present value.** Annual worth: Annual money by selling electricity- Annual cost for operation and Fuel-Annuity-loan

$720.0million- $159.49 million-$28.4 million- $246.4million =285.71million

**Equivalent present value.** By substituting the Interest rate:0.016, N=35 and A=285.71million, P=7611.55million is calculated.

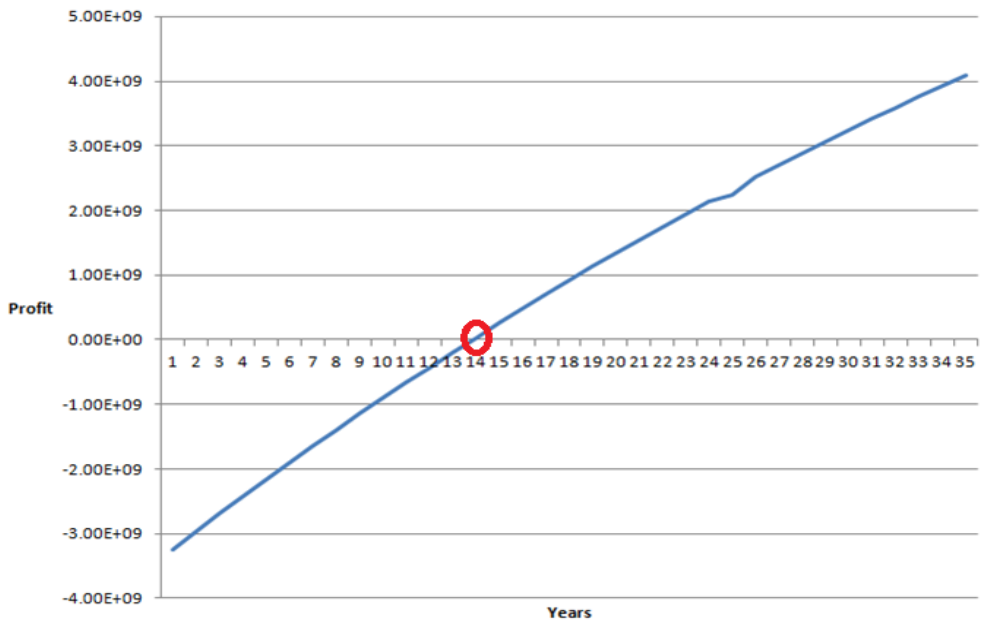


Figure 2: Profit projections over plant lifetime

According to the figure, we can know that the even point is between the year 13 and 14. Since the normal life expense of the nuclear station is 35-40 years, the nuclear station is economical feasible, which makes a profit for $4.091 billion when N = 35. And the cost for fuel is much smaller than the other nuclear plants owns, so the fast breeder nuclear station is more economical.

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