How competitive is nuclear energy?

by J.H. Keppler*

The economic competitiveness of nuclear energy will be crucial for determining its future share in world electricity production. In addition, the widespread liberalisation of power markets, in particular in OECD countries, reinforces the role of commercial criteria in technology selection.

The recently published IEA/NEA study on *Projected Costs of Generating Electricity: 2010 Edition* (IEA/NEA, 2010) provides important indications regarding the relative competitiveness of nuclear energy in OECD member countries as well as in four non-OECD countries (Brazil, China, Russia and South Africa). According to its Executive Summary:

> *First, in the low discount rate case [5%], more capital-intensive, low-carbon technologies such as nuclear energy are the most competitive solution compared with coal-fired plants without carbon capture and natural gas-fired combined cycle plants for baseload generation… Second, in the high discount rate case [10%], coal without carbon capture equipment, followed by coal with carbon capture equipment, and gas-fired combined cycle turbines (CCGTs), are the cheapest sources of electricity… The results highlight the paramount importance of discount rates and, to a lesser extent, carbon and fuel prices when comparing different technologies.*

Going beyond this general finding, the study also shows that the relative competitiveness of nuclear energy varies widely from one major region to another, and even from country to country. A breakdown by regions, for instance, shows that nuclear energy remains the most competitive option for baseload generation, including at a 10% discount (interest) rate, in OECD Asia and OECD North America (see graphs next page). The statement quoted above thus reflects the overall average for the study's sample of nuclear plants, but not necessarily each national or regional situation. In fact, the large amount of data provided by European countries, where nuclear has comparatively higher costs, has had a skewing effect on the results.

While the study provides a useful snapshot of the costs of generating electricity with different technologies, it does not provide an absolute picture of the competitiveness of nuclear energy. Like any study, *Projected Costs of Generating Electricity* makes a number of common assumptions about discount rates as well as carbon and fuel prices. In addition, its calculations are based on a methodology that is referred to as the levelised cost of electricity (LCOE), which assumes that all risks are included in the interest or discount rate, which determines the cost of capital. In other words, neither the electricity price risk for nuclear and renewables, nor the carbon and fuel price risk for fossil fuels such as coal and gas, receive specific consideration. The decisions of private investors, however, will depend to a large extent on their individual appreciations of these risks.

The competitiveness of nuclear energy thus depends on three different factors which may vary greatly from market to market: interest rates, carbon and fuel prices, and the volatility of electricity prices. These factors are discussed below.

Interest rates and the cost of capital

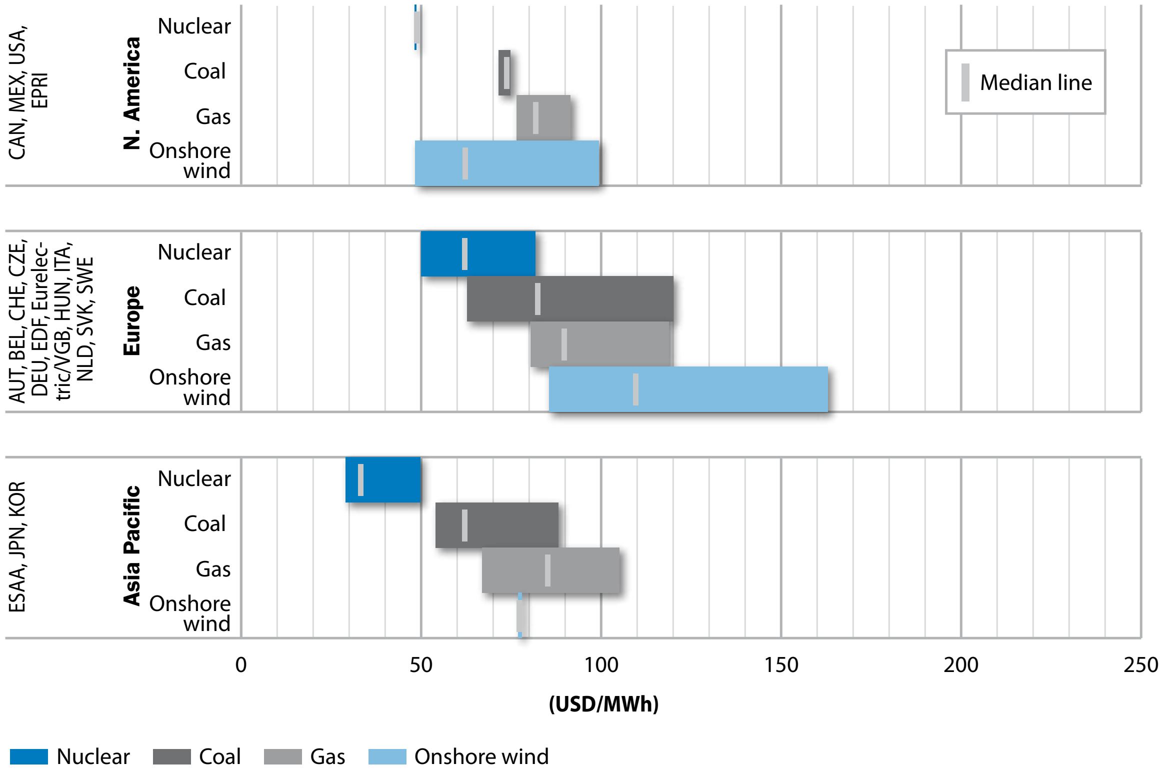
The generic (not technology-specific) risk of doing business in a country is expressed in the discount or interest rate and determines the cost of capital. This affects capital-intensive technologies such as nuclear and renewables comparatively more than less capital-intensive technologies such as gas. Based on interest rates of 5% to 10%, the fixed investment costs vary between 11% and 17% of total lifetime costs for gas-fired power plants, between 26% and 40% for coal-fired plants, between 59% and 76% for nuclear power plants, and between 78% and 85% for wind parks (IEA/NEA, 2010). The range is wider for nuclear power and coal plants since their construction periods are longer. This means that at higher interest rates, costly interest during construction accrues more significantly than for other technologies.

Reducing construction periods or lead times is indeed an important parameter in determining the cost competitiveness of nuclear energy. Reducing lead times from seven years to four would reduce total capital costs for a typical plant by 13% at a 10% annual interest rate and by 7% at a 5% annual interest rate.[1]

The question is often posed whether an interest rate of 5% is not unrealistically low for a private company, considering that the interest rate corresponds to the rate of expected profit for the investors who make their capital available. This is indeed of utmost importance. If 5% is a realistic interest rate, nuclear energy is easily the most competitive source for

* *Dr. Jan Horst Keppler (jan-horst.keppler@oecd.org) works in the NEA Nuclear Development Division.*

Regional ranges of LCOE for nuclear, coal, gas and onshore wind power plants
(at 5% discount rate)



Regional ranges of LCOE for nuclear, coal, gas and onshore wind power plants
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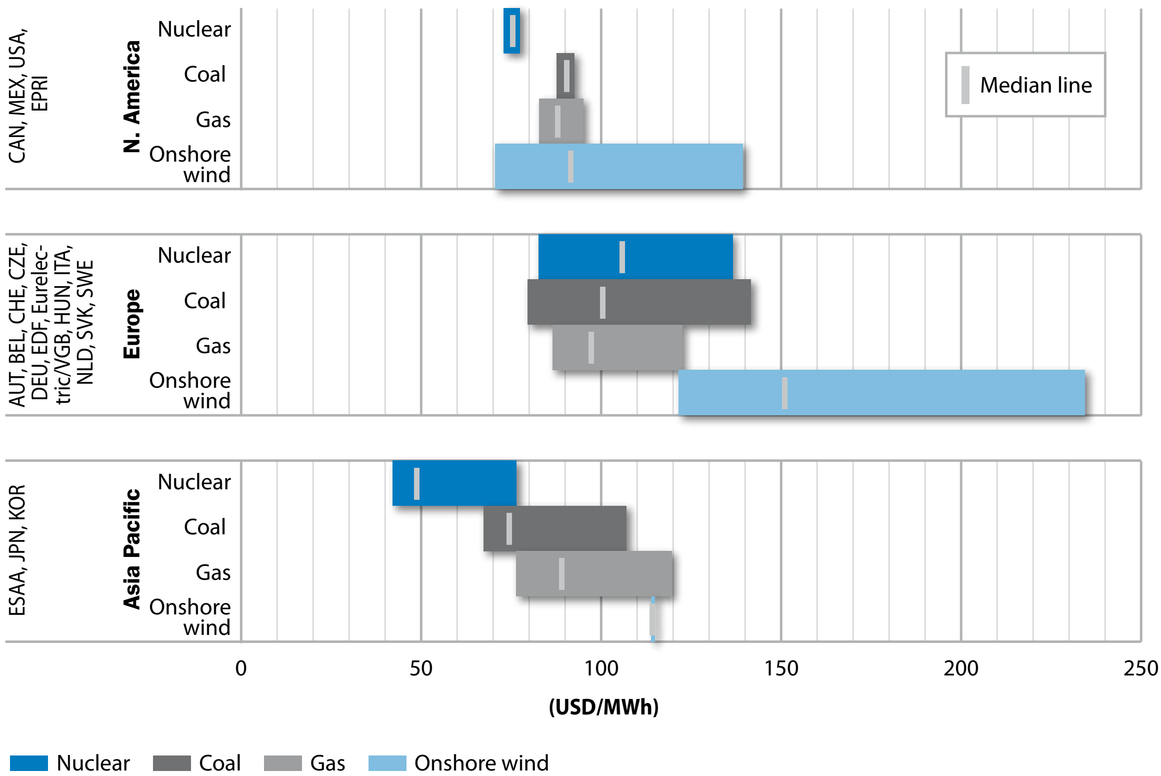
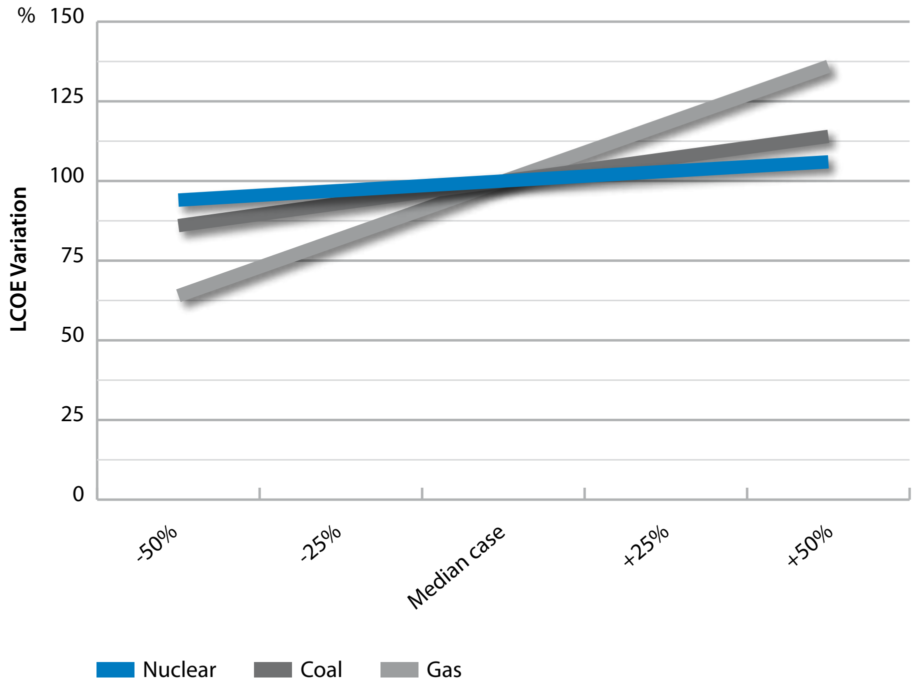


Changes in the LCOE of different technologies in response to changes in the fuel price



Source: Adapted from IEA/NEA (2010).

baseload (around-the-clock) electricity generation. If real rates are closer to 10%, the case is much more difficult to make.

The first answer to this question is that the calculations used here and in the study are based on *real* interest rates that are net of inflation. However, when a bank provides a quote or an investor specifies a hurdle rate for his return on capital, in the real world they quote nominal rates. This means that 5% real interest needs to be compared to 7% nominal interest, which includes 2% inflation (a widespread and not unrealistic assumption). In terms of the cost of a commercial loan, a 7% interest rate is by no means low. In December 2009, the average nominal yield (interest rate) on US investment-grade corporate bonds (rated BBB or higher) was 4.6%. The average nominal yield on high-yield ("junk") bonds was 9.8%. Factoring out inflation, at the end of 2009 real yields for US corporate bond varied between 2.6% for investment-grade bonds and 7.8% for high-yield bonds. Given that very few energy utilities are in the "junk-bond" category, a 5% real interest rate seems to be a very realistic and even generous assumption for the price of debt capital.

The true problem is a slightly different one. In a liberalised electricity market no company would be able to finance all of its investments with the help of relatively risk-averse debt investors.[2] A substantial part of the investment would have to be carried by equity investors with a direct stake in the project, who would be willing to incur higher risks such as market and price risk. Higher risk, however, means higher average returns, which means that equity investors may demand nominal rates between 10% and 15% depending on the project. The cost of debt and the cost of equity weighted according to their respective share in financing together form what is called the weighted average cost of capital (WACC). For example, if the cost of debt is 5% nominal, the cost of equity is 15% nominal and their respective shares are half and half, then the nominal WACC would be 10% and the real cost of capital net of inflation would be 8%. An IEA analysis on the total cost of financing for US electricity companies showed that the WACC was 10.5% in the fourth quarter of 2008 (IEA, 2009). The real rate was thus 8.5%. Considering that the end of 2008 saw the height of the financial crisis, this is probably on the high side. We may conclude that the real total cost of capital for electricity companies is probably in the range of 7% to 9% real or 9% to 11% nominal. Using two cases of 5% and 10% real thus provides a very realistic range.

Carbon and fuel prices

The second decisive factor determining the competitiveness of nuclear energy is the price of carbon or CO_2 emissions. The 2010 edition of the *Projected Costs of Generating Electricity* assumed for the first time a price of USD 30 per tonne of CO_2 that would prevail over the complete lifetime of all generation projects. USD 30 is higher than the current price of roughly EUR 16 (USD 21) in the European Emission Trading

Scheme (EU ETS). However, it is much lower than what most modellers indicate to be the explicit or implicit price that would need to prevail to stabilise global emissions at a level that would limit the increase of global mean temperatures to 2° Celsius by 2050.[3] While estimates of the prices necessary to achieve such stabilisation vary widely, there is no doubt that they will need to be significantly above USD 100 per tonne of CO_2 and probably above USD 200 per tonne of CO_2. There is thus a realistic expectation that carbon prices might rise, perhaps significantly in the coming decades.

The competitive advantage of nuclear power in this context is, of course, that it produces largely carbon-free, baseload electricity at stable variable costs and is unaffected by any changes in the global climate regime. The fuel with which nuclear energy is in direct competition is coal, which emits 0.8 tonne of CO_2 per MWh for a typical coal plant (IEA/NEA, 2010). A simple doubling of the carbon price would increase its total cost by between 30% and 37%, while for a gas-fired combined cycle turbine with emissions of 0.35 tonne of CO_2 per MWh, cost would go up between 11% and 12%. Clearly, carbon prices are a decisive factor for determining the competitiveness of nuclear energy. It is thus no surprise that potential investors in new nuclear power plants in the United Kingdom, for example, are pressing the UK government for a carbon levy of around EUR 30 (USD 40) per tonne of CO_2 (Johnson, 2010). This would, of course, make the competitiveness of nuclear energy very robust indeed.

According to the IEA/NEA study, a similar reasoning holds for fuel prices. Even a doubling of the price of uranium would only increase the total cost of electricity produced by a nuclear power plant by 10%. However, doubling the fuel price would increase the total cost of gas-fired electricity by 70% or USD 61 per MWh! For coal, the total cost would increase by about 25% or USD 18. The stability of variable costs is thus a distinct competitive advantage of nuclear energy. In all fairness, there is also some likelihood that gas prices might go down in the next few years due to overinvestment in the expectation of ever-rising gas prices. However, energy choices are long-term choices. A decision to construct a nuclear power plant today can commit a company up to a century if one includes construction, decommissioning and dismantling. There is a very real probability that gas and coal prices will rise over this period. For a large, diversified utility in the business for the long run, it is thus almost indispensable to have a significant share of nuclear energy in its portfolio in order to hedge itself against a rise in coal, gas and carbon prices over the next 10, 30 or even 50 years.

Volatility of power prices and types of electricity markets

The third key aspect impacting the competitiveness of nuclear energy is the most technical one as it is related to the exposure of different technologies to the volatility of electricity prices. Its impact thus varies greatly with the form of market organisation, in particular whether prices are liberalised or regulated.

In liberalised markets, although gas prices can be very volatile, investors in gas-fired power plants are to some extent protected against price swings given that gas-fired power generation is the fuel with the highest variable cost and thus frequently sets the electricity price. In other words, if gas prices go up or down, so will electricity prices and the stream of net profits for the investor, the investor's only true risk, stays the same. Investors in nuclear energy instead would be exposed to more volatility in profits precisely because their costs remain stable while their revenues vary.

There is thus a mismatch between private and social incentives. From a social point of view, stable variable costs and stable electricity prices as provided by nuclear energy would, of course, be an advantage for investment, industrial consumers and households. Due to the peculiar price setting mechanism in the electricity market, however, only one technology (gas) profits from an automatic hedge through the alignment of its variable cost and electricity prices. Nuclear, despite its contribution to long-term cost price stability in electricity markets, does not benefit from such an automatic hedge. Coal is somewhere in the middle, as coal and gas prices frequently vary in tandem.

Electricity price volatility also affects the expected profits of gas and nuclear through another channel. Depending on whether interest rates are estimated at 5% or 10%, the fixed investment costs of gas-fired power plants vary between 11% and 17% of total lifetime costs, and between 59% and 76% for nuclear power plants (IEA/NEA, 2010). This means that investors are facing different effective risks if electricity prices fall, temporarily or permanently, below average costs. As soon as prices fall below the variable costs of gas-fired production, gas-fired production will stop, but production of nuclear energy will continue. What looks at first sight like a comparative disadvantage of gas-fired production is in fact a comparative strength in adversity. The investor in gas-fired capacity will exit the industry at a relatively small cost (the capital cost). The investor in nuclear capacity will lose proportionately more as there will be little chance to recover the massive capital cost, even though small profits will continue to be made over the lifetime of the plant.

In order to ensure its competitiveness and attractiveness for investors, nuclear energy thus requires stable long-term pricing arrangements. This can be achieved in either of two manners. First, it can be achieved through straightforward price regulation which establishes a given tariff. It is, of course, no coincidence that of the 21 projects for new nuclear plants in the United States, 19 are being undertaken in regulated markets.[4] The alternative for liberalised markets would be long-term supply contracts. Long-term hedging provisions locking in stable electricity prices are indeed an alternative that is actively being explored.[5] However, larger-scale adoption might suffer from limited liquidity in markets for multi-year forward contracts and would thus carry additional financing costs.

Conclusion

The real competitiveness of nuclear energy cannot be determined once and for all in the abstract. It is clear that in an environment with low financing costs, high carbon prices and stable electricity prices, the competitiveness of nuclear energy is manifest. On the other hand, in an environment with high financing costs, low or absent carbon prices and volatile electricity prices, the economic case for nuclear energy is harder to sustain. Both observations also apply to renewable energies, which just as nuclear energy are high fixed cost, low-carbon technologies.

Following the above observations, in order to bolster the long-term competitiveness of nuclear energy, the nuclear industry and governments would need to:

1. develop financing mechanisms with the help of long-term investors that keep financing costs at a minimum;
2. help establish, perhaps in co-operation with the renewable energy industry, a stable, long-term carbon price;
3. help create, again possibly in co-operation with the renewable energy industry, market conditions that minimise electricity price volatility.

So far the industry and governments have just begun to address the first point. The sector's long-term competitiveness will, however, also depend on progress made in addressing the second and third.

Notes

1. This calculation only takes into account the cost-of-capital effect with constant overnight costs. Normally one would expect additional savings from a reduction in lead times. The most obvious item would be labour costs, which would need to be paid over a much shorter period.
2. Indeed, the considerations which follow apply only to fully liberalised energy markets. In markets where governments are major shareholders of energy companies, financing costs might be much lower. Even 100% debt finance might be a possibility in such cases.
3. According to the influential Stern Review on *The Economics of Climate Change,* such a limited increase would correspond to a reduction of global annual emissions by 50% and a reduction in the emissions of OECD countries of roughly 80%. Unsurprisingly, it foresees a near-doubling of global nuclear capacity by 2050 to 700 GWe as one of the measures to stabilise greenhouse gas concentrations.
4. See www.nrc.gov/reactors/new-reactors/new-licensing-files/expected-new-rx-applications.pdf.
5. See the Exeltium project in France at http://medias.edf.com/fichiers/fckeditor/Commun/Presse/Communiques/EDF/2010/cp_20100325.pdf.

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