Security of energy supply and the contribution of nuclear energy

by R. Cameron and J.H. Keppler*

The continuous availability and affordability of energy and, in particular, electricity has become an indispensable condition for the working of modern society. This is especially true for advanced industrial or post-industrial societies, where electricity provides the services essential for production, communication and exchange. Unsurprisingly, governments of OECD countries are thus concerned with understanding the factors influencing the security of energy and electricity supplies and seek to develop policy frameworks and strategies to enhance them.

As a domestically produced, largely carbon-free source of electricity, nuclear energy is, in principle, well-placed to play a constructive role in this context. This is why the NEA launched a comprehensive study on "The Security of Energy Supply and the Contribution of Nuclear Energy", seeking to empirically assess the contribution of nuclear energy to the energy supply security of OECD countries over the past four decades. It is the first time that quantitative indicators for energy supply security have been developed and applied to a coherent set of data over such a long time frame. The results are telling. While not the only factor, nuclear energy has been a significant contributor to the notable improvement in the security of energy supplies of many OECD countries.

However, before considering quantitative indicators, the concept of "security of energy supply" must be defined and understood as it applies to the formulation of government policy. This is less straightforward than it may seem. Energy supply security can mean very different things to different people. A foreign policy expert will look at the issue from another angle than a network engineer or an economist. Definitions of what is security of energy supply by various experts abound, but they are often too abstract to address the concrete issues intrinsically linked to geopolitical preferences, strategic technology choices and fundamental orientations of social policy. Definitions also change from one country to another. For example, a country with limited access to cross-border energy infrastructures but a broad domestic resource base will think differently about the security of its energy supplies than a small, open economy closely interconnected with its neighbours but with few resources of its own. Not unlike the notion of "sustainability", another key dimension of energy policy in OECD countries, the notion of security of energy supply is often being applied in diverse ways to support different policy objectives.

A general starting point is the following consensus definition: *"Security of energy supply is the resilience of the energy system to unique and unforeseeable events that threaten the physical integrity of energy flows or that lead to discontinuous energy price rises, independent of economic fundamentals."* It can be shown that "import dependency and diversification", "resource and carbon intensity" as well as "infrastructure adequacy" are three key verifiable parameters that are encapsulated in this general definition. It is important, however, to keep in mind that these three parameters are not identical with energy supply security, but their qualification and contextualisation are important in each individual case.

Two key dimensions of energy supply security

Energy supply security is a classic example of an externality, i.e. of an impact on the well-being of individuals and society generated by an economic activity, but which is not already priced in the marketplace. Being a negative externality, energy supply risk constitutes a policy issue. This means that private individuals cannot cover themselves for such risks due to their complexity and unquantifiable nature. This is where governments need to step in. Energy supply risks can be considered in terms of two main dimensions: the external or geopolitical dimension, and the internal dimension that includes technical, financial and economic issues. Nuclear energy can play a constructive role in both of them (see Figure 1).

Import dependence, resource exhaustion and carbon policy: the external dimension

Geopolitical risk almost always refers to primary energy carriers (oil, gas, coal, uranium or renewables) since their location depends on the vagaries of geology and climate. Production and consumption are

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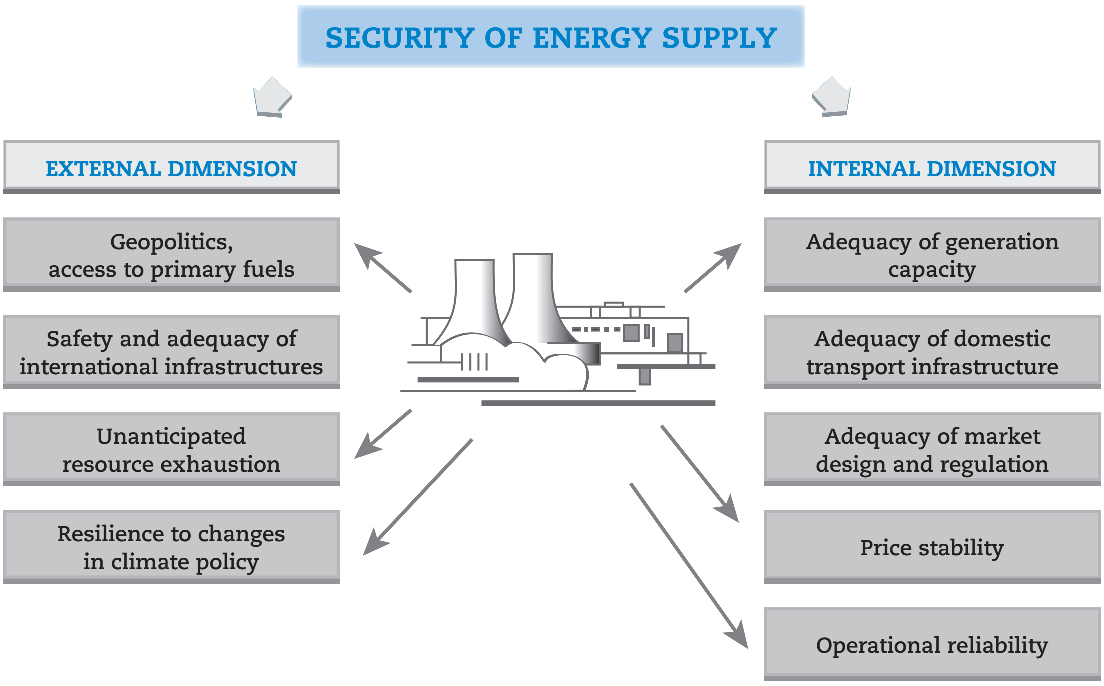
Figure 1: **Dimensions of energy security and potential contributions of nuclear energy**



thus often physically located far apart, in countries and regions with different histories, cultures and values. Apart from exploration and production, all other steps of the energy chain such as refinement or enrichment, conversion and distribution can be moved physically closer to the final customer or are, like consumption, directly under the latter's control.

Given that a fundamental cause of geopolitical supply risks is the physical separation of the centres of primary energy production and consumption, it is tempting to address the issue by striving to bring production home ("energy independence"). Whether this is a good approach depends on a country's geographical position, its own energy endowment, the state of its physical infrastructures for transport and storage, the diversification of its supplies, the willingness of its population to accept higher, average long-term prices for lower volatility and a host of other issues.

In an ideal world, security of energy supply would not be equated to energy independence or self-sufficiency. Free and global energy trade through smoothly functioning competitive markets would guarantee timely delivery of all necessary energy resources. Most countries are relying at least partially on the international trade of energy and will continue to do so. However, the issue of self-sufficiency does assume a particular significance in electricity markets since, due to the technical and economic challenges associated with its storage, electricity is only transported over relatively short distances. In island countries such as Japan and Australia, or *de facto* isolated countries such as the Republic of Korea, national electricity generation *must* be able to cover national demand.

Economic, financial and technical conditions for energy security: the internal dimension

Energy security begins at home. The most important responsibility for OECD governments is to establish appropriate framework conditions for providing incentives to private actors to install domestically an adequate level of facilities for the production, transport, conversion and consumption of energy. Important elements in this strategy are regulatory stability, market organisation, fiscal coherence and predictability of environmental policy. The challenge in the electricity sector is the creation of framework conditions that:

- do not discriminate against domestically produced, low-carbon energy sources such as nuclear and renewables; and
- allow for the construction of adequate transport, production and conversion capacity with appropriate long-term financial arrangements.

OECD governments thus have a responsibility to create market conditions that allow low-carbon technologies with lower supply risks to compete on a level playing field. Governments also have a role to play with regard to the provision of adequate levels of transport, distribution and conversion capacity.

Such capacity can partly be provided by markets themselves, but in other cases, it requires regulation and supervision. First, regulation must provide sufficiently attractive financial conditions for investment in transport and conversion infrastructure. Second, projects must have political backing at the national level against excessive delays, through appropriate regulatory processes and zoning laws, as well as effective mechanisms for consultation, mediation and compensation.

Empirical evidence

Indicators for energy security of supply thus need to include information on:

- import dependency and diversification of fuel and energy supply;
- resource and carbon intensity;
- system and infrastructure adequacy.

The NEA study applied the Simplified Supply and Demand Index (SSDI) that is capable of working with the only available, consistent data set on OECD countries' energy sectors over the past 40 years, the *IEA Energy Statistics*. The SSDI is composed of three weighted contributions: demand, infrastructure and supply. These contributions take into account the degree of diversity and supply origin of different energy carriers, the efficiency of energy consumption and the state of the electricity generation infrastructure.

The evolution of the SSDI throughout the period (1970-2007) was analysed for several OECD countries: Australia, Austria, Canada, Finland, France, Italy, Japan, the Netherlands, the Republic of Korea, Sweden, the United Kingdom and the United States (see Figure 2). It identifies changes in the trend when important policy changes have been implemented, such as the United Kingdom's switch from coal to gas or the introduction of nuclear power programmes in France and the United States.

Figure 2 shows that the value of the SSDI has significantly increased between 1970 and 2007 in the case of most countries under study: Canada, Finland, France, Japan, the Netherlands, Sweden, the United Kingdom and the United States. The improvement in the SSDI in the first set of OECD countries is due to three different factors:

- the introduction of nuclear power for electricity generation;
- the decrease in energy intensity;
- the increase in the diversification of primary energy sources.

Figure 2: Evolution of the SSDI for selected OECD countries

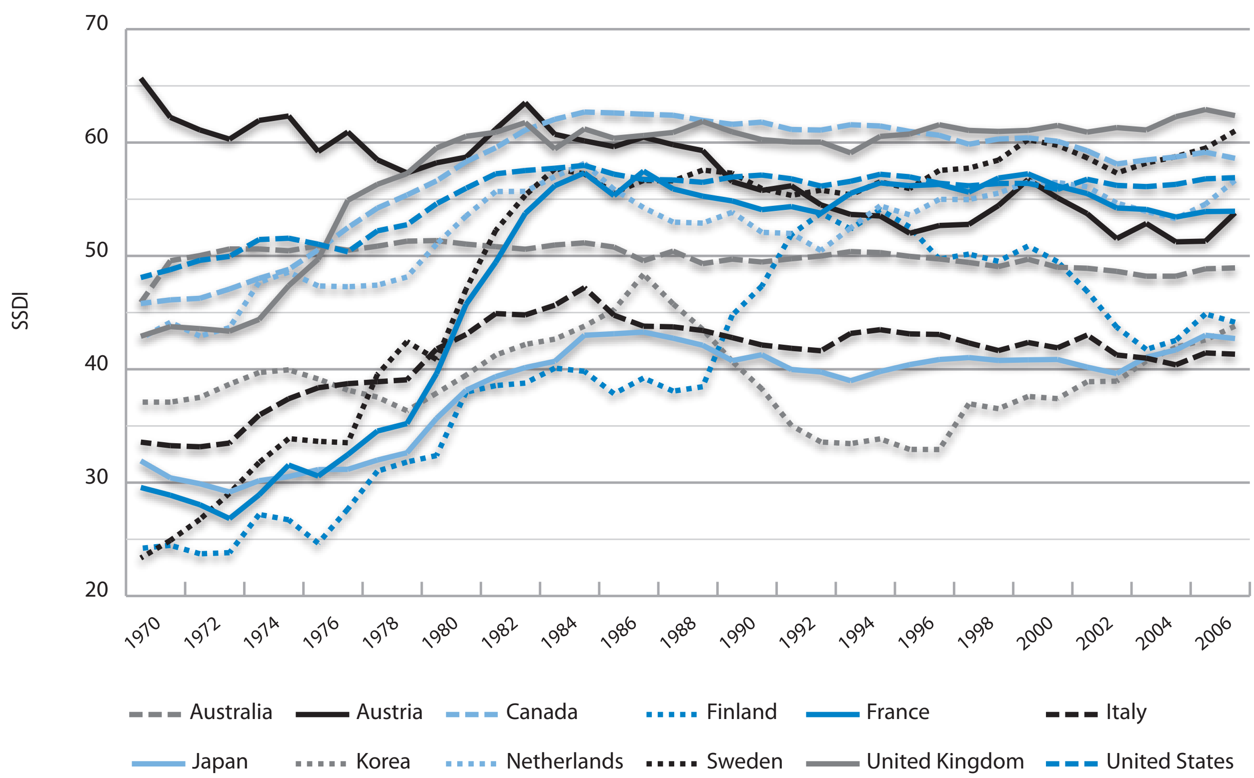
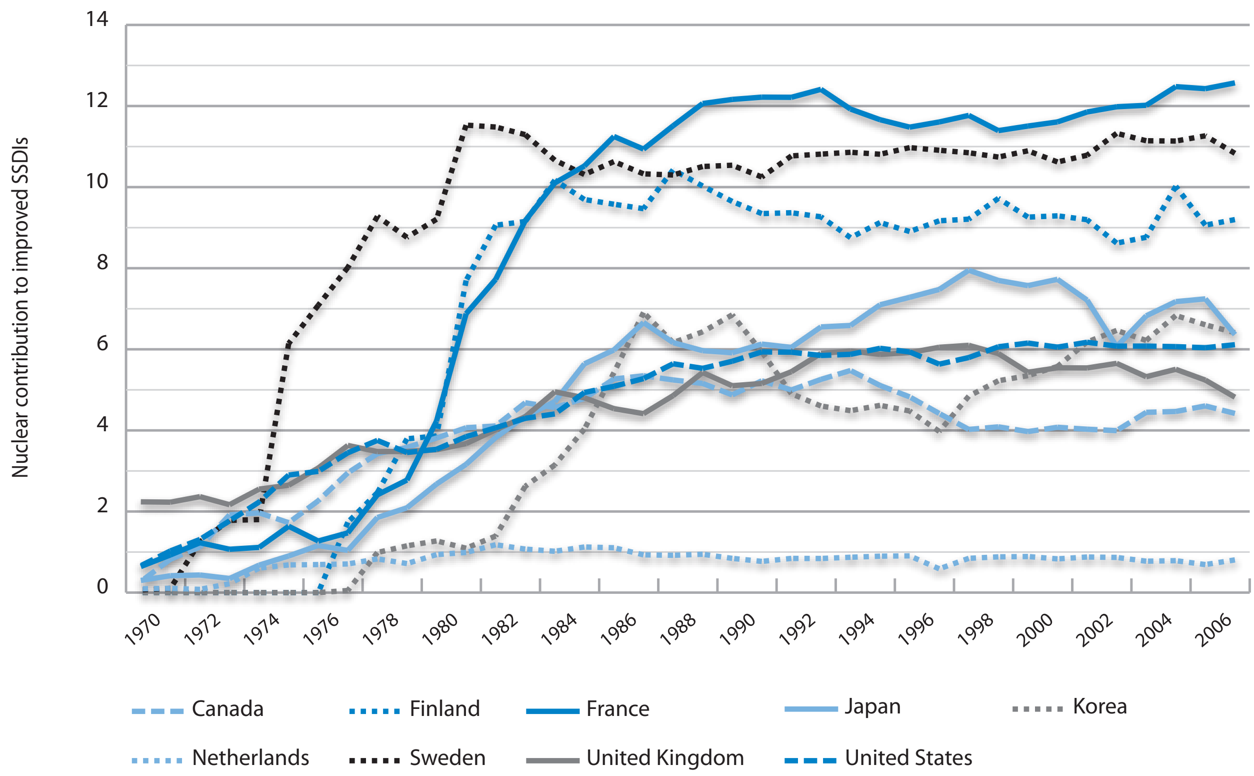


Figure 3: **The contribution of nuclear power to improved SSDIs**



The widespread adoption of nuclear energy from this perspective is understandable given its advantages in strengthening the external dimension of energy supply security:

- In terms of value, nuclear power plants source more than 90% of their inputs domestically.
- Uranium imports are widely diversified and are frequently supplied by other OECD countries.
- Nuclear energy would be unaffected by a sudden tightening of restrictions on greenhouse gas emissions.

Overall, in the face of geopolitical supply risks, whether due to import dependence, resource exhaustion or changes in the global carbon regime, nuclear energy holds advantages that other fuels such as oil, coal and gas do not enjoy: wide availability of resources for a long time to come, modest impacts of increases in resource prices and resilience against carbon policy shifts.

In terms of the internal dimension, the joint IEA/NEA study on the *Projected Costs of Generating Electricity: 2010 Edition* shows that nuclear energy is a very attractive option at real interest rates that are below or only slightly above 5%. The attractiveness of an investment in power generation, however, is not only defined by its lifetime costs of electricity that correspond to the sum of the lifetime costs taking into account the average discounted revenue. One key element is the uncertainty to which investors are exposed. The advantage of nuclear energy in this context is that its average cost remains very stable in the event of changes in fuel costs or in the price of carbon. Doubling the carbon price, for instance, from USD 30 per tonne of CO_2 to USD 60 per tonne would increase the total average cost of coal-produced power by 30%, more than doubling its variable cost in the process. This is not an unrealistic number. Given current commitments to reduce global carbon emissions by 50% by 2050 in order to limit the rise of global mean temperatures to 2°C, modelling results imply marginal costs for carbon abatement of at least USD 100 per tonne of CO_2 and perhaps much higher.

Based on these strengths, many OECD countries invested massively in nuclear power development during the 1970s and 1980s. As shown in the figure, nuclear energy has contributed significantly to the increase in energy supply security of these countries (Figure 3 extracts the nuclear contribution to the SSDI in Figure 2). In the case of France, the contribution of nuclear power to the SSDI is more than 12 points in 2007 (about 30% of its SSDI score), followed by Sweden with 11 points (21%), Finland with 9 points (26%), and Japan and Korea with approximately 6 points (about 17% of the total SSDI score).

The role of governments

To the extent that markets cannot ensure security of supply by themselves, governments need to play a role. Regarding the external dimension, in addition to ensuring adequate shares of domestically produced energy, governments need to ensure transparent global markets; the realisation of the comparative advantage of each trading partner is of particular importance. In terms of the internal dimension, the focus must be on creating appropriate market conditions and incentive systems that enable all technologies to deliver their potential contribution to the security of supply, in particular high fixed cost, low-carbon technologies.

Due to its complexity and the dynamic evolution of the many parameters involved, as well as public demand for "secure" supply, energy security remains an uninternalised externality, or a public good that markets are unable to provide at an appropriate, acceptable level. Even in the presence of a globalised marketplace for most energy commodities, given its importance for the functioning of the economy, energy supply security thus remains a policy issue for which governments need to assume responsibility.

Nuclear energy, as an essentially carbon-free, largely domestic source, possesses a number of attractive characteristics that enable it to contribute to both the external and internal dimensions of energy supply security. It is cost-competitive, with high energetic density and low sensitivity to variations in the resource price, unlike fossil fuels. Uranium resources are also well-distributed, with OECD countries such as Australia, Canada or the United States holding significant shares.

Due to its large fixed costs (not only at the level of the individual plant but also at the level of education, regulatory infrastructures, fuel cycle strategies, etc.), nuclear energy will never be wholly an ordinary industry. Nevertheless, as a concrete response to widely recognised problems, nuclear energy is increasingly being viewed more dispassionately and judged on its merits as part of the solution to questions of security of supply, cost stability and reductions in greenhouse gas emissions.

References

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Further reading

NEA (2010), *The Security of Energy Supply and the Contribution of Nuclear Energy*, OECD, Paris.