NEA
Nuclear Energy Agency

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Nuclear Energy in Perspective

Nuclear Energy and Addressing Climate Change

Introduction

The need to cut greenhouse gas (GHG) emissions in an effort to tackle climate change has become a major driver of energy policy. Indeed, many believe that an "energy revolution" is needed to decarbonise energy supply, which is heavily reliant on fossil fuels. The consensus among scientists is that at least 50% of GHG emissions must be cut from 2005 levels by 2050 if the world is to limit the average temperature increase to 2-3° C and to avoid the worst consequences of global warming.

Electricity supply is one sector in which measures to cut GHG emissions can most easily be introduced and enforced, since the electricity supply system comprises a relatively small number of facilities that are well-known and owned and operated by large organisations. But decarbonising the power sector over the next four decades is still an enormous challenge. Existing infrastructure is slow to change: coal-fired plants now under construction may still be in operation in 2050. Meanwhile, demand is rapidly increasing in many developing countries, where large-scale, low-carbon energy sources may not be available or will take a long time to develop.

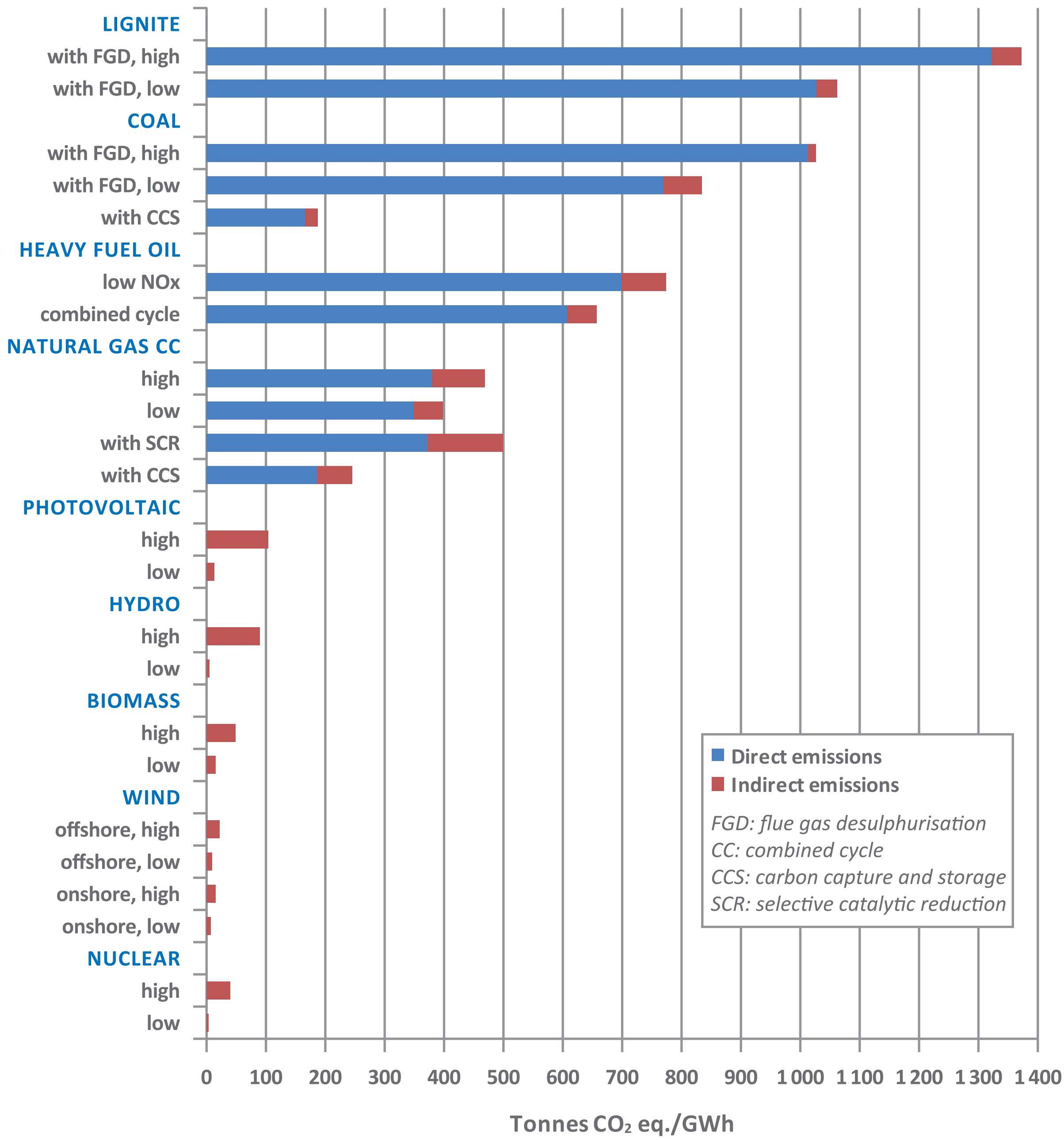
One route to low-carbon electricity is via a major expansion of nuclear power. Nuclear power is an established, large-scale energy source that has great potential to expand rapidly over the next 40 years. It could provide around 25% of global electricity with almost no CO_2 emissions. However, critics of nuclear power remain concerned about safety, disposal of nuclear waste and the potential for nuclear technologies to be used for military, rather than civil, ends.

Does nuclear power produce CO_2 emissions?

Unlike the combustion of fossil fuels, the process of nuclear fission does not produce any CO_2 or other GHGs. However, some indirect emissions can be attributed to nuclear energy, principally due to the use of fossil fuel-based energy sources in the various steps of the nuclear fuel cycle, such as uranium mining and enrichment. Energy used in these steps varies significantly from case to case. For example, underground conventional mining uses more energy than *in situ* leach mining techniques, where liquid is pumped through boreholes in the ore to extract uranium in solution, avoiding the need to extract ore.

If there is greater use of nuclear power in the future, lower grade uranium resources might become more economic, which could lead to somewhat higher energy use. However, low-energy, *in situ* mining techniques are also becoming more widespread, and increased uranium exploration could result in additional higher grade resources becoming available. As more energy-intensive gaseous diffusion plants, used for uranium enrichment, are phased out over the next few years, energy use will decrease. And as the use of fossil fuels in the electricity sector is reduced, indirect emissions from nuclear will also fall.

Figure 1. Direct and indirect greenhouse gas emissions for alternative electricity generation systems



Source: *Mitigation of Climate Change*, Intergovernmental Panel on Climate Change, 2007.

Figure 1 compares the GHG emissions per unit of electricity generated from various full life cycle electricity generation chains averaged across several European countries. This shows that lignite and coal have the highest GHG emissions, with natural gas having the lowest emissions among fossil systems. The indirect emissions of nuclear and renewable energy chains are at least an order of magnitude below the emissions of fossil chains.

To what extent is nuclear energy used now?

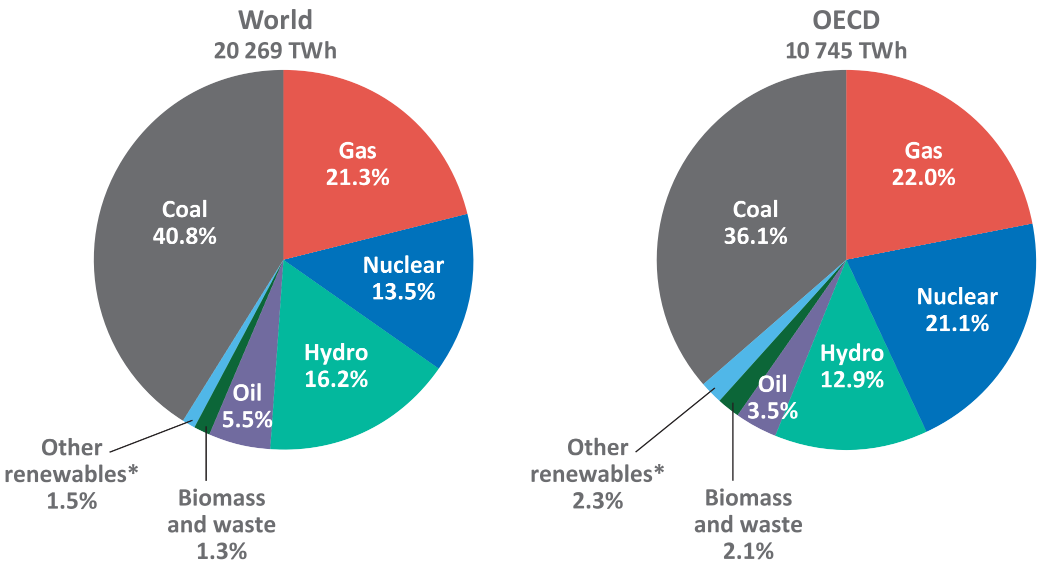
In 2008, about 14% of global electricity production, or about 21% of production in OECD countries, was fuelled by nuclear energy (see Figure 2). Nuclear power grew rapidly in the 1970s and 1980s, but its share has since stagnated and even fallen slightly as electricity demand growth has outpaced the much slower nuclear expansion since 1990.

Nuclear power is nevertheless one of the largest sources of non-fossil energy, with only hydro power making a similarly significant contribution. Using nuclear power reduces CO_2 emissions by up to 2.9 Gt (gigatonnes) per year, assuming that this power would otherwise be produced by burning coal. This means that, without nuclear power, OECD countries would emit as much as one-third more CO_2 from their power plants than they do now.

The cumulative emissions of CO_2 from fossil fuels used for electricity production over the period 1971 to 2007 amounted to roughly 250 Gt, and the cumulative savings from the use of nuclear power were about 65 Gt of CO_2 equivalent. In other words, using nuclear power reduced by about 21% the cumulative emissions from generating power during that period.

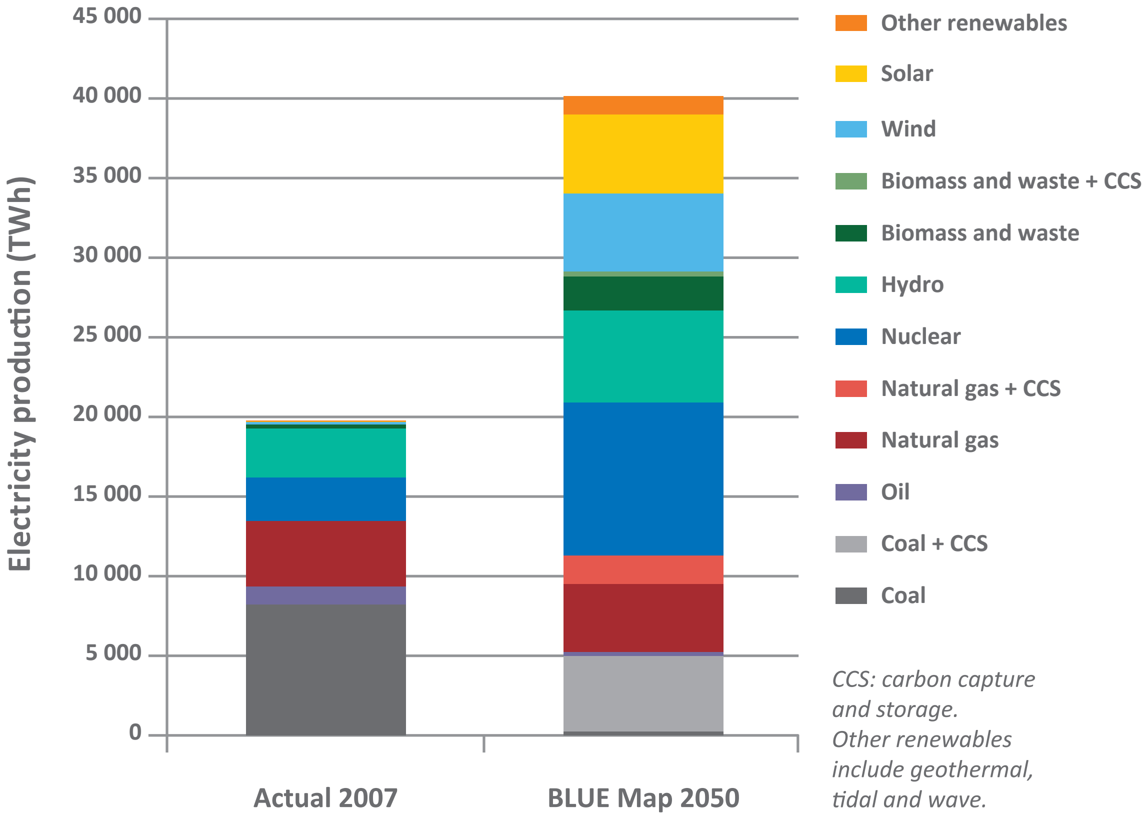
If the present nuclear capacity were to be phased out, it would make the goal of decarbonising electricity supply an even more challenging and distant prospect.

Figure 2. Electricity generation by source in 2008, worldwide and for OECD countries



*Includes wind, geothermal, solar, tidal and wave.
Source: *Electricity Information,* International Energy Agency, 2010.

Figure 3. "BLUE Map" scenario for electricity supply in 2050, which would reduce CO_2 emissions to half of 2005 levels



Source: *Energy Technology Perspectives,* International Energy Agency, 2010.

Can nuclear power capacity be expanded quickly?

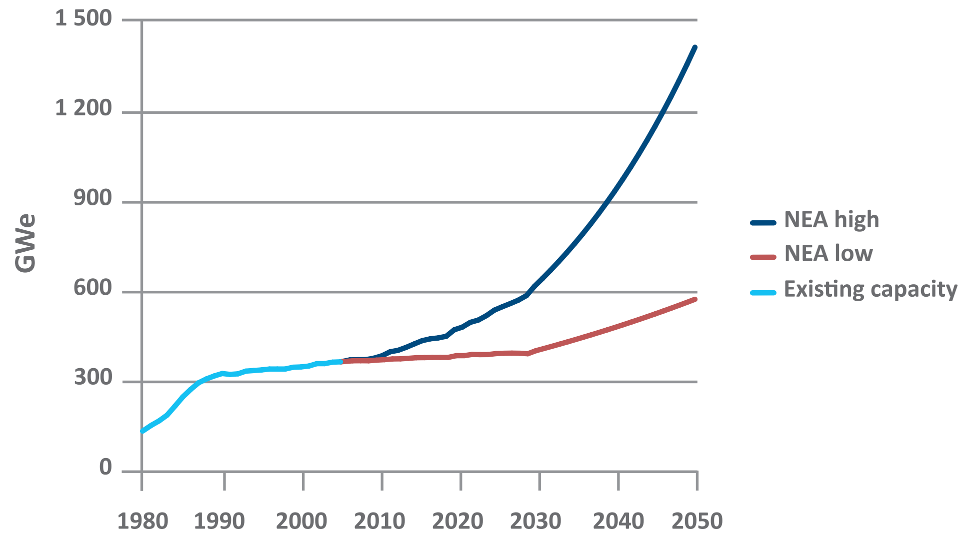
Nuclear power technology has been developed over more than 50 years, and the latest designs for nuclear power plants incorporate the knowledge gained over that time. While further technological development is expected, nuclear power is already a mature technology. The barriers to its rapid deployment are social, political and financial, rather than technical.

Before significant nuclear expansion can begin in any country, clear and sustained policy support from the government will be needed as part of an overall strategy to address the challenges of providing secure and affordable energy supplies while protecting the environment. In recent years, a number of governments have reassessed their approach to nuclear energy and now view it as an important part of their energy strategy. Others, however, continue to believe that nuclear should not be part of their energy supply mix.

Scenarios for future electricity supply prepared by the International Energy Agency, based on a reduction of CO_2 emissions to around half of 2005 levels by 2050, show that nuclear power has a vital role to play, alongside improved energy end-use efficiency, a major expansion of renewables, and carbon capture and storage (CCS) from fossil fuel burning (see Figure 3). These scenarios envisage a nuclear capacity of around 1 200 GWe by 2050, compared with 375 GWe today – an expansion of over 300%. This would require the completion of around 20 large nuclear plants (of 1.5 GWe each) per year during the 2020s, rising to 25 to 30 plants per year in the 2040s. In its *Nuclear Energy Outlook* (2008), the NEA found that nuclear capacity could reach 1 400 GWe by 2050 under its high scenario, through an even stronger expansion in the 2040s (see Figure 4).

Clearly, these scenarios would require mobilising much greater industrial, human and financial resources than currently exist within the nuclear and related industries. Such expansion would take years to achieve, not least because it would require large-scale investment and a major increase in the workforce with the necessary skills and training. Not only would the nuclear power plants have to be built, but a commensurate increase in uranium mining, processing and waste management capacities would also be needed.

Figure 4. NEA scenarios for nuclear expansion to 2050



Source: *Nuclear Energy Outlook,* OECD Nuclear Energy Agency, 2008.

A comparison with the major expansion of nuclear power in the 1970s and 1980s indicates that, given strong policy support, nuclear power can expand rapidly. During the 1980s, nuclear plant completions peaked at over 30 units per year, with an average of 22 units per year over the decade. Although these were smaller than many current designs, the technology was also less well-developed at that time. In addition, relatively few countries were involved in that expansion, and overall global industrial capacity was significantly smaller.

Much of the future expansion of electricity supply will take place in large developing countries that did not have large nuclear power programmes in the past. As they industrialise, these countries will have greater capacity for nuclear expansion. Foremost among them are China and India, both of which are already embarking on ambitious nuclear power programmes.

Are supplies of nuclear fuel adequate?

As noted above, a major expansion of nuclear power would require a commensurate increase in nuclear fuel cycle capacities. Nuclear power has a relatively complex fuel cycle, involving uranium mining and several industrial processes to prepare the finished fuel assemblies, which, for most reactor types, consist of pellets of enriched uranium dioxide encased in a lattice of metallic tubes. However, the expansion of uranium production, which depends on the availability of known, economically viable uranium resources, and uranium enrichment, which requires sensitive technology, present the main challenges.

Throughout the 1990s and until 2003, prices for uranium were low due to lower-than-expected nuclear expansion, and the fact that large stocks of previously mined uranium held by utilities and governments, including former military stocks released through nuclear disarmament after the Cold War ended, were released onto the market. As a result, uranium production is only about two-thirds of annual consumption. This production is, however, expected to increase over the next few years.

Uranium exploration since the 1980s has also been limited, although it has risen more than three-fold since 2002 in response to higher uranium prices. Despite limited recent exploration, the ratio of known uranium resources to present consumption is comparable to other mineral energy resources, at about 100 years. Additional resources that are expected to be discovered, on the basis of existing geological information, could expand the resources-to-consumption ratio to around 300 years. If known, "unconventional" resources are included, notably uranium contained in phosphate rocks, the ratio grows to about 700 years (see Table 1). If significant nuclear power expansion were to begin, a sustained increase in uranium exploration could be expected, and that could mean the discovery of many more sources of uranium.

Table 1. Ratios of uranium resources to present (2006) annual consumption, for different categories of resources, showing the impact of recycling in fast neutron reactors (in years)

	Known conventional resources	Total conventional resources	With unconventional resources
With present reactor technology	100	300	700
With recycling using fast neutron reactors	> 3 000	> 9 000	> 21 000

Source: *Nuclear Energy Outlook,* OECD Nuclear Energy Agency, 2008.

A greater challenge could be the time taken to expand uranium production capacity due to the large investments needed and the lengthy approvals process for new mines in several major producing countries. This again indicates the importance of government support for the expansion of nuclear capacity.

The expansion of uranium enrichment capacity, which is needed to prepare fuel for most reactors now on line and all of the more advanced designs, would also need to keep pace with nuclear expansion. Enrichment technology is, however, highly sensitive and only a handful of countries possess it. In principle, these countries could expand their capacities to supply other countries, which would present few technical difficulties. However, some countries are concerned about the security-of-supply implications of allowing a few countries to control all enrichment facilities. Proposals to alleviate these concerns range from legally binding assurances of supply by the enriching countries to establishing new enrichment facilities under multilateral control. Strengthening policy measures to control sensitive nuclear technologies while assuring supply would help nuclear power achieve its full potential.

Nuclear fuel also offers possibilities for recycling, since only a small fraction of the energy in the uranium is consumed in the reactor. This could vastly increase the energy potential of existing uranium stocks and known resources from a few hundred to several thousand years of nuclear fuel demand. It could also greatly reduce the radiotoxicity of the resulting high-level waste. Current recycling techniques use sensitive technologies and are unlikely to expand significantly in the short to medium term. However, developing advanced recycling and reactor technologies could allow better use of uranium and plutonium resources and increase the availability of nuclear fuel over the long term. As with enrichment, measures to control sensitive nuclear technologies while ensuring adequate access to the necessary fuel cycle capacities may also be needed.

What about safety, waste and proliferation concerns?

Governments and the nuclear industry must work together to achieve safe management and disposal of nuclear waste. Low- and intermediate-level wastes account for the largest volumes of radioactive waste, although they only contain a small proportion of total radioactivity. Technologies for the disposal of such wastes are well-developed, and most countries with major nuclear programmes operate facilities for their disposal or are at an advanced stage in developing them.

Most radioactivity is concentrated in the smaller volumes of high-level waste, which comprise spent nuclear fuel and some wastes from recycling. There is, in fact, no immediate requirement to dispose of such materials as they can be safely and easily stored in existing facilities for many years. Nevertheless, countries with existing nuclear power programmes are developing long-term plans for final disposal of such wastes, and there is an international consensus that geological disposal of high-level waste is technically feasible and safe. However, so far no facilities for final disposal of high-level waste have been constructed.

The safety performance of nuclear power plants and other civil nuclear facilities in OECD countries is generally excellent, certainly by comparison with other energy cycles. Reactors of the latest designs, now under construction, have enhanced safety features, including increased levels of "passive" safety, meaning their safety is less dependent on active intervention by human operators or automated safety systems. However, the fear of an accident continues to weigh heavily on public perceptions of nuclear energy and undermines global confidence in nuclear power.

A major expansion of nuclear power would imply that countries without previous experience in nuclear regulation will be building nuclear plants. Ensuring that these new nuclear countries follow appropriate industrial and regulatory approaches and implement adequate legal procedures will be the responsibility of the international community, particularly of the vendor countries. The International Atomic Energy Agency (IAEA) is already engaging with many of these countries to develop their institutional capabilities in this regard.

There is, of course, the potential for materials or technologies developed for civil use in electricity production to be diverted for military purposes. The IAEA safeguards system under the Treaty on the Non-proliferation of Nuclear Weapons has greatly limited such diversion of civil nuclear materials and technologies. However, a major expansion of nuclear energy, involving many more countries, is likely to require the strengthening of the non-proliferation regime and ensured implementation. A balance must be found between achieving non-proliferation goals and providing adequate supply assurances to countries relying on nuclear power.

Further reading:

OECD/NEA (2008), **Nuclear Energy Outlook 2008**
ISBN 978-92-64-05410-3, € 105, 460 pages.

OECD/NEA, IAEA (2010), **Uranium 2009: Resources, Production and Demand**
ISBN 978-92-64-04789-1, € 130, 456 pages.

IEA (2010), **Energy Technology Perspectives 2010: Scenarios and Strategies to 2050**
ISBN 978-92-64-08597-8, € 100, 650 pages.

OECD/NEA (2007), **Risks and Benefits of Nuclear Energy**
ISBN 978-92-64-03551-5, € 24, 84 pages.

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