EN13 Nuclear Waste Production

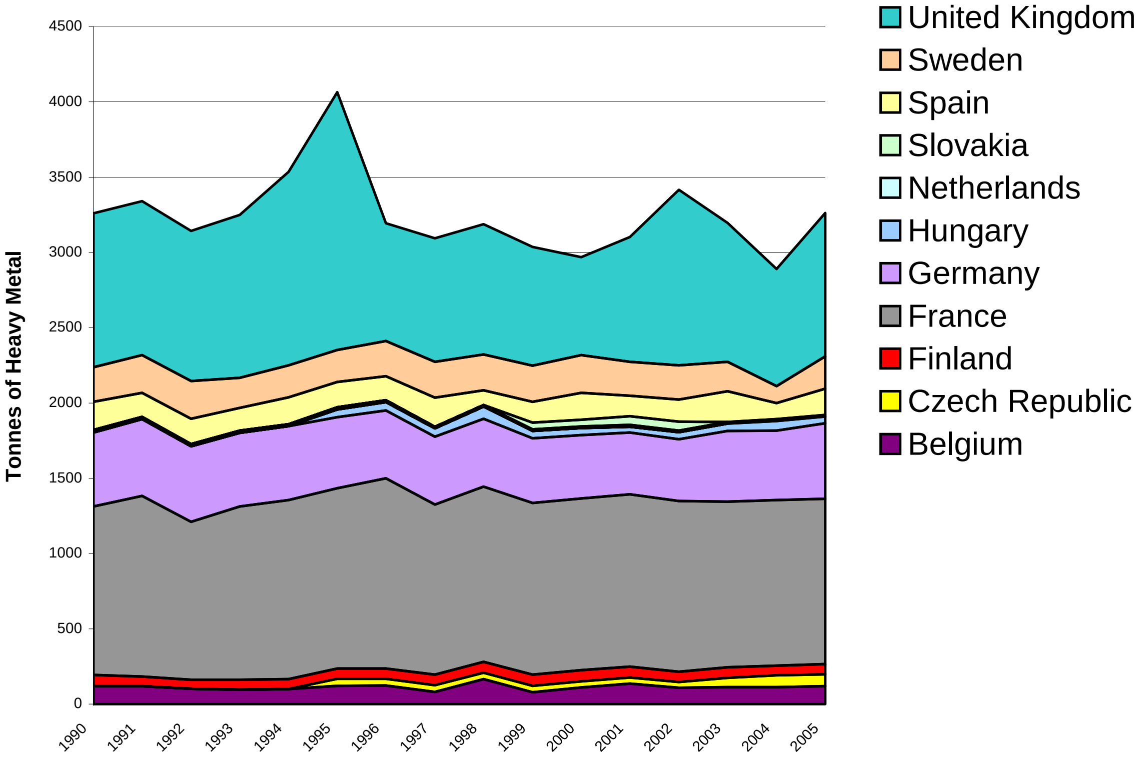
Key message

The amount of highly radioactive waste from nuclear power production continues to accumulate and a generally acceptable disposal route for this waste has yet to be identified. The related potential health and environmental risks, as well as issues surrounding nuclear proliferation, therefore continue to be a cause for concern.

Rationale

Nuclear power is responsible for a steady accumulation of radioactive waste that poses a potential threat to the environment. The quantity of spent nuclear fuel produced provides a reliable representation of the accumulation of radioactive waste and its evolution over time.

Fig. 1: Annual quantities of spent fuel[1] from nuclear power plants in the EU, 1990-2005

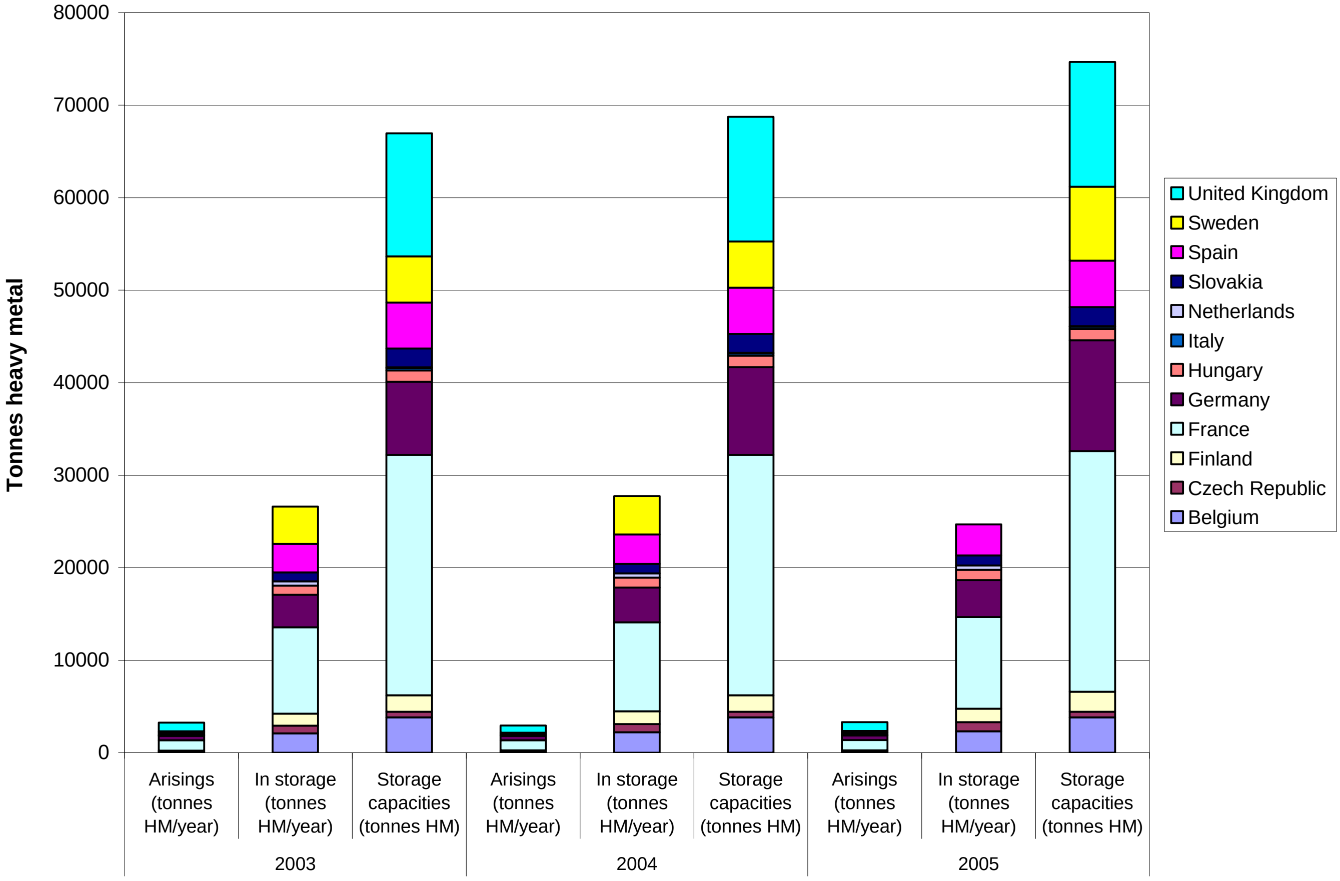


Data source: OECD, 2004; NEA, 2005

Notes: The vast majority of highly radioactive waste consists of spent fuel and spent fuel reprocessing wastes. No data on quantities of spent fuel are available for Lithuania or Slovenia, and limited time series data are available for the Czech Republic and Hungary (no data prior to 1995) and Slovakia (no data prior to 1999). The Member States not listed in the above figure do not have nuclear power plants. Italy phased out commercial nuclear power in 1987.

[1] Spent fuel does not represent all radioactive waste generated but, according to the OECD, it is a reliable proxy for overall radioactive waste and its evolution over time: i.e. "spent fuel arisings are one part of the radioactive waste generated at various stages of the nuclear fuel cycle (uranium mining and milling, fuel enrichment, reactor operation, spent fuel reprocessing). Radioactive waste also arises from decontamination and decommissioning of nuclear facilities, and from other activities using isotopes, such as scientific research and medical activities". The focus of the fact sheet is on the link between energy production from nuclear power stations and the high-level radioactive waste generated (spent fuel). High-level waste (HLW) is highly radioactive, contains long-lived radioactivity and generates a considerable amount of heat. It accounts for 10% of the volume of radioactive waste generated and contains about 99% of the total radioactivity and includes fission products and spent fuel.

Fig. 2: Annual quantities of spent fuel, storage and capacity in EU countries between 2003 and 2005



Source: OECD

Notes: The vast majority of highly radioactive waste consists of spent fuel and spent fuel reprocessing wastes. Data on storage are not available for the UK (2003 to 2005) or for Sweden (2005). No data are available for Lithuania or Slovenia (both have nuclear power plants). Other Member States not listed in the above figure do not have nuclear power plants. Italy phased out commercial nuclear power in 1987.

1. Indicator assessment

Thirteen Member States[2] produce electricity from nuclear power. In addition, the acceding countries Bulgaria and Romania also have nuclear power. Together these countries have 156 nuclear reactors in operation, with a further one under construction in Romania and another due to start production in 2009 in Finland. Construction of a new reactor in France is planned to start in 2007, and a number of countries also have proposals for new nuclear plants. Lithuania and France have the world's highest shares of nuclear electricity production within national electricity production (78.4 % and 78.3% respectively in 2004) and Slovakia (55.7 %), Belgium (55.4 %), and Sweden (51.1 %) also have a high contribution from nuclear power (see Energy Factsheet 27 on electricity production by fuel). Italy phased out commercial nuclear power in 1987.

Quantities of spent fuel produced in the EU have shown sharp fluctuations but on average, increased by 1.5% per year over the period 1999-2005[3], reaching a total of 3 300 tonnes of heavy metal (tHM). This growth was mainly due to an increase in the quantity of electricity produced by nuclear power plants due to increasing capacity and demand (nuclear electricity production increased at an annual average rate of 1.3% over the same period). The strongest fluctuations have occurred in the United Kingdom, where annual spent fuel arisings have varied between 650 and approximately 1 700 tHM per year. This was caused partly by variations in electricity production from UK nuclear plants, but the large peaks are linked to decommissioning of a number of older nuclear power plants. For example, decommissioning commenced at Berkley in 1989, at Trawsfynydd in 1993,

[1]Belgium, Czech Republic, Finland, France, Germany, Hungary, Lithuania, the Netherlands, Slovakia, Slovenia, Spain, Sweden and the United Kingdom

[3] This is the period over which a continuous data set is available for all Member states with nuclear power, apart from Lithuania and Slovenia for which no data is available. However, in 2002 their combined share of EU electricity production from nuclear power was only 2.0 %; therefore the effect on overall volumes of waste is likely to be small.

at Hinkley Point in 2000 and at Bradwell in 2002. During normal operations only a fraction of a reactor core is refuelled each year and the spent fuel removed, but during decommissioning the reactor is fully de-fuelled.

Even stable annual quantities of waste imply that the accumulated quantity of waste will continue increasing. Work is ongoing to try to establish final-disposal methods that alleviate technical and public concerns over the potential threat that this waste poses to the environment. In the meantime, the waste accumulates in stores. The European Commission therefore suggested more support for research and development on nuclear waste management in its proposal for a sustainable development strategy (EC, 2001) and proposed a directive on the management of nuclear waste (EC, 2004c; EC, 2002e).

Long-term trends in the production of radioactive waste from nuclear power plants and thus the accumulated amount of radioactive waste depend on the future use of nuclear power. Decommissioning nuclear plants is becoming an increasingly important objective in some Member States due to public concern over environmental impacts while others are re-considering the nuclear power option in the context of climate change and energy security. There is also an on-going debate on the costs of production of electricity in nuclear power plants, which is still seen as an expensive option in the context of a liberalised market.

Projections of nuclear generation can therefore vary considerably depending on which of these concerns it is thought will dominate in decisions over future nuclear power plants. Table 1 shows two projections of nuclear electricity generation. The European Commission's PRIMES projections assume that nuclear power is phased out in line with Member State's current plans and no new plants are constructed, with EU production dropping to around 80% of current levels by 2030. The IEA's World Energy Outlook reference scenario is based on similar assumptions, but shows production falling further, to around 65% of current levels by 2030[4].

Table 1: Projections of nuclear electricity production in EU countries from 2010 to 2030

Data source	Electricity generation (TWh)			
	2010	2015	2020	2030
World Energy Outlook (IEA, 2006) – reference scenario	-	885	-	564
Primes Energy Model (European Commission 2006)	964	934	874	782

Public concern[5] about environmental and safety considerations has led to plans to phase out nuclear power in certain Member States (such as Germany, the Netherlands, Spain, Sweden and Belgium), with some others either declaring or considering moratoria on the building of new nuclear plants. In Germany, a Parliament decision was taken in 2001 to phase out nuclear power. Following a referendum in 1980 in Sweden a parliament decision was taken in 1997 to close the two Barsebäck nuclear reactors. The closure of the second reactor was postponed since the decided conditions about new energy sources and safety of supply were not met on time. Nevertheless, the remaining operational reactor at Barsebäck nuclear power station closed in May 2005. In Slovakia, the government has expressed its unwillingness to issue state guarantees for the Mochovce 3 and 4 reactors, which has put their completion on hold and Poland has halted the construction of its nuclear reactor after the fall of the communist regime and it is not planning to complete it.

On the other hand, some Member States are currently discussing the construction of new nuclear capacity. In Finland and in France, the process of building additional capacity, based primarily on new nuclear designs such as the European Pressurised Water Reactor (EPR) and Westinghouse Advanced Passive technology, is ongoing. The Finnish reactor of Olkiluoto 3, is under construction and should start-up in 2010, and in France, construction of an EPR on the site of Flamanville should begin in 2007, with start-up planned in 2012. France also has plans to replace its current reactors as they reach the end of their life in the

(1) 4 The IEA also produced an alternative policy scenario where policy measures addressing climate change would include increased use of renewables promoting energy efficiency and nuclear. Existing phase-out policies are then assumed to remain in place but are delayed by ten years. Nuclear generation is projected to remain relatively stable to 2015 and then falls to around 83% of current levels (therefore higher than in the Primes model projections).

[5] According to the latest Eurobarometer Survey "European citizens' opinions towards radioactive waste: an updated review", six out of ten citizens acknowledge the benefits of the use of nuclear energy as regards diversification of energy supply, reducing dependence on oil and lowering greenhouse gas emission. Nevertheless, only 37% are in favour of the use of nuclear energy unless the issue of radioactive waste is not resolved (80% of citizens agreed that all radioactive waste is "very" dangerous). If the issue of radioactive waste were considered as resolved, 58 % of citizens would be in favour of using nuclear energy.

2020s. In the accession country Romania, the Cernavoda 2 reactor is due to be completed in 2007. A number of countries including Belgium, Sweden, Germany and Spain are increasing capacity at existing plants, and plant life extensions are also being sought in some countries, for example the UK.

In terms of nuclear waste, additional capacity might increase the quantity of spent nuclear fuel. However, efficiency improvements within existing plants can reduce the demand for fuel and hence spent fuel (NEA, 2003), and furthermore, the new generation of reactors is likely to lead to lower levels of waste per unit of electricity production compared to existing plants. During the period to 2010, the amount of spent fuel produced is expected to decrease at an average rate of 1.7 % per year (OECD, 2003). This projected decrease is predominantly due to a projected decline in nuclear electricity production (see also EEA, 2005), combined with small improvements in the quantity of electricity produced per unit of nuclear fuel[6]. In the longer term, waste production (per unit of electricity produced) is expected to fall as a result of improved design of the next generation of nuclear reactors and fuel rods, allowing a larger fraction of the fissile material in the fuel to be used before the rods are replaced.

Large-scale reprocessing facilities for nuclear waste are currently in operation in France, Russia and the UK. A number of other Member States, including Belgium, Germany, the Netherlands, Sweden and Switzerland currently reprocess a significant quantity of spent fuel in France and the UK.

2. Indicator rationale

2.1 Environmental context

Nuclear waste production is a pressure indicator. The annual and accumulated amount and level of activity of nuclear waste and its development give a broad indication of associated potential environmental and health risks. Storage and final disposal of spent fuel and other nuclear waste poses a potential risk of quantities of radiation being released to the environment (to the atmosphere and/or land and/or water). The release of radioactivity to the environment can result in acute or chronic impacts that, in extreme cases, can cause loss of biota in the short term and genetic mutation in the longer term, both of which may result in unknown and potentially fatal effects. Increased levels of radioactivity can also be passed up through the food chain and affect human food resources.

Spent nuclear fuel is the most highly radioactive waste. It decays rapidly at first, i.e. after 40 years the level of radioactivity has typically dropped to 1/1000th of the initial value. But it takes around 1000 years to drop to the level of the original uranium ore which was needed to produce that quantity of spent fuel (WNA, 2003). The potential impact of nuclear waste on humans and the environment depends on the level of radioactivity and on the conditions under which the waste is managed. The majority of member states currently store spent fuel and other high level radioactive wastes in above ground storage facilities. However, deep geological disposal in an underground repository is currently favoured as a long-term option by many countries. Geological disposal facilities currently operate in Finland and are well advanced in Sweden. Lower level radioactive wastes are commonly stored in surface disposal sites.

It is noted that nuclear power produces low emissions of carbon dioxide and lower emissions of acidic gases compared to fossil fuel-based electricity generation (taking into account the entire life-cycle).

The quantity of spent nuclear fuel provides a 'reliable representation of the production of radioactive waste situation and its evolution over time' (OECD, 1993). Data on quantities of all waste produced, by activity category and level of radiation, are difficult to find and often include inconsistent definitions of activity categories, as they relate to a mixture of nuclear wastes generated from all sources (i.e. military, medical, industrial isotope and research activities as well as nuclear power production). Spent fuel reprocessing is the predominant source of high level waste[7] (i.e. waste with high levels of radioactivity), and together with nuclear power reactors constitutes the main source of intermediate and low level wastes. Other sources of intermediate and low level waste (the military, nuclear energy R&D and medical and industrial uses) are much smaller.

As well as being an important waste stream due to its high level of radioactivity spent fuel is also precisely defined, unambiguous and relates purely to electricity generation. The quantity of spent fuel generated has therefore been chosen as a proxy to the nuclear waste indicator, despite limited available data on quantity of spent fuel for some Member States.

2.2 Policy context

[6] Although there isn't much room for improving the efficiency with which the heat generated is converted into electricity in existing plants.

[7] For example in the UK, Spent fuel reprocessing accounted for 100% of radioactive waste arisings to 2004 and just under 50% of intermediate and low level wastes (Nirex, 2005)

The 1957 Treaty establishing the European Atomic Energy Community (EURATOM Treaty) is one of the founding treaties of the European Union. It addresses issues in the field of nuclear power such as radiation protection of the work force and the public, the supply of nuclear fissile materials for the developing nuclear power sector, the safeguarding of nuclear fissile materials to prevent them from being used for unauthorised military purposes, and general aspects such as research and dissemination of information. However, the treaty makes little or no specific mention of aspects such as operational safety of nuclear power plants and radioactive waste storage or disposal facilities. As a result, these aspects have become the responsibility of National Authorities in the individual Member States.

The European Commission's work and strategy for radioactive waste management and decommissioning of nuclear facilities is further set out in the following documents oriented towards safety and environmental protection concerns, with particular regard for the safe management of long-lived radioactive waste or final disposal of radioactive waste. These include the Community Plan of Action in the field of Radioactive Waste, renewed for the period 1993–99 by a Council Resolution in June 1992 (92/C158/02), and COM (2002) 605 final, on nuclear safety in the European Union, which proposes that Member States commit themselves to authorise deep disposal sites for highly radioactive waste by 2008 and to bring such sites into operation by 2018. Furthermore, the European Commission suggested more support for research and development on nuclear waste management in its proposal for a sustainable development strategy (EC, 2001) and proposed a directive on the management of nuclear waste (EC, 2004c; EC, 2002e).

On an international level, the International Atomic Energy Authority (IAEA) Joint Convention on the Safety of Spent Fuel Management and on the safety of Radioactive Waste Management sets out measures to ensure the safe management of radioactive waste and contains requirements regarding: general safety; location of facilities; design and construction of facilities; safety assessment; environmental assessment; operational control; regulatory bodies and licensing; decommissioning; and trans-boundary movement.

3. References

Community Plan of Action in the field of Radioactive Waste, renewed for the period 1993–99 by a Council Resolution in June 1992 (92/C158/02).

COM(2002) 605 final, on nuclear safety in the European Union, proposes that Member States commit themselves to authorise deep disposal sites for highly radioactive waste by 2008 and to bring such sites into operation by 2018.

OECD Environmental Data, Compendium 2002. OECD, Paris 2003.

OECD (2003) Nuclear Energy Data, Nuclear Energy Agency.

OECD (2005) Nuclear Energy Data, Nuclear Energy Agency

European Commission (2001), A sustainable Europe for a better world: A European Union strategy for sustainable development. COM(2001) 264 final, Communication from the Commission to the Council and the European Parliament, European Commission, 2001.

European Commission (2002), Nuclear safety in the European Union, COM(2002) 605 final, Communication from the Commission to the Council and the European Parliament.

European Commission (2003) European energy and transport, Trends to 2030, Directorate General for Transport and Energy.

European Commission (2004) Amended proposal for a Council Directive (Euratom) on the safe management of the spent nuclear fuel and radioactive waste. COM (2004) 526 final.

European Commission (2004) European energy and transport – scenarios on key drivers, Directorate General for Transport and Energy.

European Commission (2006) European energy and transport: Trends to 2030 – Update 2005

EEA (2005) Climate change and a low-carbon European energy system, European Environment Agency report No 1/2005.

IEA World Energy Outlook 2006

Nirex (2005) The 2004 UK Radioactive Waste Inventory, DEFRA/Nirex

World Nuclear Association: Information and Issue Briefs: http://world-nuclear.org/info/info.htm

Meta data

Technical information

1. Data source:
   Spent fuel (historical and projected data)– OECD Environmental Data: Compendium 2004 http://www.oecd.org and OECD Nuclear

Energy Agency 2005 http://www.nea.fr/
Production of electricity from nuclear (historical data)- Eurostat http://europa.eu.int/comm/eurostat/
Production of electricity from nuclear (projection data)– Primes Energy Model, European Commission 2006 http://ec.europa.eu/energy/index_en.html; and World Energy Outlook, IEA 2006 – reference scenario and alternative policy scenario http://www.iea.org/.

2. Description of data/Indicator definition:
The indicator measures spent nuclear fuel arising from nuclear electricity production in the Member States that had nuclear powered electricity production capacity between 1990 and 2005 (data for Slovenia and Lithuania missing). It provides an indication of the situation of radioactive waste accumulation and storage. A table showing different projections for the production of electricity from nuclear power is also shown as it provides a broad proxy indication of the rate of accumulation of radioactive waste, which is (very approximately) building up in proportion to power production.
Original measurement units:
    Spent fuel: tonnes of heavy metal (tHM)
    Nuclear electricity generation: terawatt hours (TWh)
According to the World Energy Council http://www.worldenergy.org/wec-geis/focus/nuclear/ nuclear waste falls into the following four broad categories:
Very low-level waste (VLLW) contains negligible amounts of radioactivity, which can, depending on the clearance level, be disposed of in a dedicated surface site or with domestic refuse.
Low-level waste (LLW) contains small amounts of radioactivity and negligible amounts of long-lived waste.
Intermediate-level waste (ILW) contains higher amounts of radioactivity and does require shielding in the form of lead, concrete or water. It is further categorised into short-lived and long-lived. The former is dealt with in a similar way to LLW and the latter to HLW.
High-level waste (HLW) is highly radioactive, contains long-lived radioactivity and generates a considerable amount of heat.
HLW accounts for 10% by volume of radioactive waste generated and contains about 99% of the total radioactivity. This includes fission products and spent fuel.

3. Geographical coverage:
Data on the annual production of radioactive waste (in tonnes of heavy metal) is only available for EU countries that are members of the OCED: Belgium, Czech Republic, Finland, France, Germany, Hungary, the Netherlands, Slovakia, Spain, Sweden and United Kingdom.

4. Temporal coverage:
1990-2005; projections, 2010, 2015, 2020 and 2030.

5. Methodology and frequency of data collection:
Data collected annually.

6. Methodology of data manipulation:
Average annual rate of growth calculated using: [(last year / base year) ^ (1 / number of years) –1]*100

Qualitative information

7. Strengths and weaknesses (at data level)
Time series data on spent fuel arisings is limited and information is only available for the Czech Republic (since 1995), Hungary (since 1995) and the Slovakia (since 1999). No data is available for the two remaining EU countries, Slovenia and Lithuania, that also have nuclear electricity production.
For the production of electricity, data have traditionally been compiled by Eurostat through the annual Joint Questionnaires (although there is no separate questionnaire for nuclear energy), shared by Eurostat and the International Energy Agency, following a well-established and harmonised methodology. The primary energy from nuclear is calculated based on the electricity generation from nuclear with a 33.3 % efficiency rate. Methodological information on the annual Joint Questionnaires and data compilation can be found on Eurostat's website in the section on metadata on energy statistics. http://europa.eu.int/estatref/info/sdds/en/sirene/energy_base.htm

8. Reliability, accuracy, robustness, uncertainty (at data level):
Data on spent fuel arisings have been compiled by the OECD using data from member Governments. This is a consistent ongoing process that is updated annually. However, no data is available for Slovenia or Lithuania which decreases the overall accuracy of the indicator.
The use of spent fuel arisings as a proxy for overall radioactive waste is itself slightly uncertain because of the various inconsistencies in classification of radioactive waste between Member States, although it does provide a 'reliable representation of the production of radioactive waste situation and its evolution over time' (OECD, 1993).

9. Overall scoring – (1 = no major problems, 3 = major reservations):
    Relevance: 1
    Accuracy: 2
    Comparability over time: 2
    Comparability over space: 2