Fact Finding Nuclear Energy

A report prepared for the Social and Economic Council of the Netherlands

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Executive Summary

In order to answer the question whether more nuclear energy should be generated to support the objective of realising a sustainable energy system in the Netherlands, and if so, under which conditions, the commission for Future Energy Supply of the Social Economic Council of the Netherlands (SER) issued a study in which facts and figures about nuclear energy are gathered (fact finding). Below a summary is provided of the information that can be found in the fact finding study, based on a number of frequently asked questions.

What are the technical characteristics of nuclear energy?

The energy production in a nuclear power plant is based on fission of atomic nuclei of heavy elements, so-called fissionable material, in the course of which matter is converted into energy. By maintaining a chain reaction (the process of consecutive nuclear fissions) energy is continuously produced that is used to power a generator that generates electricity via a number of intermediate steps. Various types of reactors have been developed over the years. The most common types of reactors currently in use are the Pressurized Water Reactor (PWR), as in the nuclear power plant in Borssele, and the Boiling Water Reactor (BWR). Both reactor types contain a closed reactor vessel that is filled with water. The vessel contains a construction in which a large number of nuclear fuel elements are placed (the reactor core). The water in the reactor vessel is heated with the energy that is released in the nuclear fuel elements. In a pressurized water reactor the heat from the water in the reactor vessel is used to produce steam in a so-called steam generator. This steam powers a turbine generator that is used to generate electricity. In a boiling water reactor the steam is produced directly in the reactor vessel itself.

A nuclear power plant uses fissionable material as nuclear fuel, which must first be produced from natural raw materials. Most nuclear power plants use enriched uranium as nuclear fuel. Uranium ore consists almost completely of the isotope uranium-238 (99.3%) and a small fraction of uranium-235 (0.7%). The uranium-235 content is enriched to approximately 3 to 5%. In the Netherlands this is done by means of ultra centrifuges. The steps that have to be followed in order to produce nuclear fuel for the nuclear power plant, i.e. the so-called front end of the nuclear fuel cycle, are the following: mining of uranium ore, extraction of uranium from the ore, conversion into gaseous uranium hexafluoride, enrichment (increasing the uranium-235 content) and nuclear fuel production. After the nuclear fuel has been used in the nuclear power plant it is either stored (direct storage) or reused (reprocessed). This back-end of the nuclear fuel cycle thus has two possible routes. In the case of direct disposal the spent nuclear fuel is first temporarily stored, after which it is conditioned to be converted into a form that is more suitable for final disposal. Current plans provide for storage in deep geological formations, such as salt and clay layers or granite. In the case of reprocessing, fissionable material (uranium and plutonium that was produced as by-product during nuclear fission) is being reused as fuel for

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nuclear power plants. The remaining fraction is vitrified and temporarily stored. Subsequently, it will be restored in deep stabile geological formations, according to current plans.

How did nuclear technology develop and which developments can be expected?
Worldwide 437 nuclear power plants were in operation in 2006, with a total capacity of 370 gigawatt, covering 17% of world electricity demand and 6% of world energy demand. 144 of these power plants were located in the 27 member states of the EU with a total capacity of 131 gigawatt, covering 31% of European electricity demand. Almost all of these power plants have been constructed in the 1970s, '80s and '90s and belong to the second generation. Nuclear power plants of the first generation were built to demonstrate the technology. The nuclear power plant in Borssele has a capacity of 480 megawatt and belongs to the second generation. In the 1990s this power plant was revised extensively, improving the technical safety. Recently it was decided that the power plant will remain in operation until 2033. Two accidents with nuclear power plants of the second generation, i.e. Harrisburg in 1979 and Chernobyl in 1986, had a major impact on developments. After these accidents the construction of new nuclear power plants was delayed significantly. At the same time these accidents have led to improved safety in nuclear power plants (including existing ones) and more international cooperation. Based on experiences with existing reactors, a new generation of reactors was developed with improved technical safety. These reactors belong to the third generation. The nuclear power plants that are currently commercially available with capacities ranging from 1000 to 1600 megawatt make use of reactors of this third generation. Moreover, new reactor types have been developed based on a different nuclear fuel technology and safety philosophy. These High Temperature Reactors (HTR), which have a relatively limited capacity, belong to generation III+. Prototypes of these nuclear power plants are currently being developed for commercial application around 2016. These power plants have an electrical capacity of approximately 160 MW. More advanced reactors of the fourth generation with further improvements in the area of sustainability, safety, reliability and economy are still in development stage and will enter the market around 2030.

How is the safety of the technology assured?
In each of the processes of the nuclear fuel cycle there is a certain risk of accidents in which quantities of radioactive material might be released into the environment in an uncontrolled manner. In order to limit both the probability of such an accident as well as the amount of radioactive material that could be released in such an accident, a large number of technical and organisational measures are applied in the processes of the nuclear fuel cycle. The requirements have been tightened continually over the years. The International Atomic Energy Agency of the United Nations in Vienna (IAEA) plays a important role in this process. The IAEA, which monitors the use of nuclear technology and materials, draws up safety standards, among other things. These standards are based on the defense in depth principle. A strategy of safety measures and safety precautions is used with the ultimate objective of preventing damage resulting from human action, mechanical failure or a combination of both to the health of the people living in the neighbourhood. The defense in depth principle is implemented by means of applying multiple safety layers. These consist of physical barriers (and their safeguarding), safety systems and organisational measures.

Different safety philosophies are pursued for the various reactor types. Reactor types of the third generation are based on the same defense in depth safety philosophy as existing nuclear power plants in which additional safety systems have been added. The safety philosophy is based on active and passive safety systems. Active systems are switched off under normal operational conditions and are only switched on (activated) when necessary for safety reasons. Passive systems use forces that are always present, as for example gravity, which ensure that safety systems take immediate action when necessary. Reactor types of generation III+ use a different safety philosophy, making the application of separate safety systems obsolete. In the case of inherent safety the reactor and the nuclear fuel are designed such that an uncontrolled reactivity excursion (an increase in reactivity), which damages the reactor core, is not possible and the reactor switches off when cooling fails. When cooling fails, the reactor core remains intact and the melting of the reactor core is made physically impossible.

How much fuel is available for nuclear power plants?

The volume of recoverable uranium resources is related to the cost of uranium production. As the recovery of uranium becomes increasingly complicated (for example because the ore layers lie deeper or because the ore contains less uranium), the price will become higher. At a price of less than $40 per kilogram the identified uranium resources amount to approximately 2.7 million tons uranium. At a price of $130 per kilogram the identified resources increase to 4.7 million tons. These resources are spread worldwide. The largest resources can be found in Australia, Kazakhstan and Canada. At the current rate of uranium use for approximately 440 nuclear power plants in the world (approximately 67,000 tons per year) there will be enough for approximately 70 years. This period depends on the number of nuclear power plants that will be exploited in the future. In addition to these supplies, some estimates indicate that there are uranium resources that are more difficult to recover with a volume of 10 million tons. Unconventional uranium resources are also present in phosphate deposits (22 million tons) and in sea water (4000 million tons). Developments in nuclear technology focus on more efficient use of uranium, among other things. The fourth generation of reactors that is currently being developed aims to use uranium 100 times more efficiently. Moreover, thorium can also be used to produce nuclear fuels. The natural resources of thorium are at least comparable to the uranium resources.

How is nuclear waste handled?

A distinction is made between low, medium and high-level radioactive waste. A large share of the low and medium-level radioactive waste will decay to non-radioactive waste in one hundred years' time. High-level radioactive spent nuclear fuel needs more than 100,000 years before the radioactivity of the long-living radioactive elements reach the level of natural uranium. This time span is mostly determined by the plutonium that is present in the spent nuclear fuel. Many countries temporarily store the spent nuclear fuel elements in a separate basin at the nuclear power plant site. Some nuclear power plants use special containers for this purpose (dry storage). The ultimate objective is to store the spent nuclear fuel elements in a final disposal storage facility underground after necessary conditioning and packaging.

In the Netherlands, spent nuclear fuel from the nuclear power plant in Borssele is first reprocessed. The high-level radioactive vitrified waste from the reprocessing plant in France, which has a lifetime of approximately 10,000 years, is stored in the Netherlands in a special bunker-like building, the so-called HABOG at the COVRA facility in Vlissingen. Annually, this amounts to approximately 1.3 cubic metres. The HABOG is a surface storage facility in which radioactive waste is temporarily stored (up to a maximum of 100 years). In this period the activity of the waste decreases by a factor 10. According to current plans, high-level radioactive waste will be stored in a deep geological repository after this period of storage in the HABOG.

In Europe, there is currently no underground final disposal facility for high-level radioactive waste in existence. Many experiments are taking place in underground test laboratories, to study final disposal in stabile geological layers (e.g. in Belgium, France, Germany, Switzerland, Sweden and Finland). In Sweden and Finland, there are concrete projects for the realization of final disposal facilities for the storage of spent nuclear fuel. In the Netherlands no decision has yet been made about the manner in which high-level radioactive waste will be stored underground, but retrievable final disposal has already been opted for. This means that radioactive waste in final disposal can always be retrieved if new (other) solutions for processing or storage of this waste are found.

Research is conducted with respect to the options for shortening the lifetime of high-level radioactive waste from 100,000 years to approximately 2000 years or less. This technology, which is called 'partitioning and transmutation', is a more advanced type of reprocessing and recycling than is currently being applied. The development of partitioning and transmutation technology will take a long period of time and it may be decades before it becomes available on an industrial scale.

What are the risks of proliferation and how can these be limited?
Proliferation refers to the spreading of nuclear technology and materials for military and non-peaceful use. Regimes in some countries in the world wish to have nuclear weapons at their disposal, because it enables them to yield power and because of the prestige that can be derived from their possession. Moreover, some countries might develop a nuclear weapon to protect their interests when neighbouring countries also have nuclear weapons at their disposal (deterrence). The required raw materials for a nuclear weapon are high-enriched uranium or plutonium. The enrichment technology can be used to produce high-enriched uranium. If the reprocessing process were to use nuclear fuels that have been used in the reactor only briefly, it could be used to extract plutonium that is suitable for nuclear weapons.

It has been internationally agreed that trade in nuclear materials and technology and the dissemination of knowledge on how to build a nuclear installation must be subject to international supervision. This entails monitoring the peaceful use of nuclear energy technology and the management of nuclear fuel. The international agreements have been recorded in the Non Proliferation Treaty (signed by 190 countries) and the Additional Protocol. Because this treaty was deemed not adequate enough, in 2003 the Proliferation Security Initiative was launched. This initiative, which is signed by 60 countries (among which the Netherlands) focuses on intercepting and preventing illegal transports of Weapons of Mass Destruction and goods with which these can be made or launched. Moreover, in 2006 the International Atomic Agency of the United Nations (IAEA) initiated the implementation of a system in which Member States obtain nuclear fuel from an international nuclear fuel bank. The nuclear fuel is returned after use. In the long term this should lead to a situation in which all enrichment and reprocessing plants are placed under international supervision.

What are the risks of terrorism and how might these be reduced?
Three types of terrorist threats can be distinguished: (1) the use of an explosive which spreads radioactive material, also called a ‘dirty bomb’, (2) terrorist organizations getting hold of a nuclear weapon, and (3) an attack on a nuclear power plant, storage facility or transport of nuclear material, with the goal of releasing radioactive material and thus contaminating the area. The construction of a dirty bomb does not necessarily require material from the nuclear fuel cycle. Radioactive material is also available outside the nuclear energy sector. Protection of the nuclear fuel cycle should ensure that this material does not fall into the hands of terrorists. Due to the size and complexity of the required installations it is not easy for terrorist organizations to develop and build nuclear weapons. Protection of nuclear power plants should limit the risk of terrorist attacks. The safety systems that shut down the reactor automatically if the operator carries out unwanted actions, limit the potential threat of an eventual terrorist take-over of the power plant. Moreover, the threat of terrorist attacks is taken into account in the design of nuclear power plants and transport containers. The same applies to the threat of a plane crashing down. Originally, nuclear power plants were not designed to resist a plane crash. For new power plants explicit design requirements are set with regard to the resistance against an attack with an airplane.

What environmental effects can be anticipated from the application of nuclear energy?
The environmental effects of nuclear energy are mainly determined by the ionizing radiation, emissions of radioactive particles and radioactive waste that arise during the various steps in the nuclear fuel cycle as well as during the various phases of the plants (i.e. production, operation and dismantling). This is based on normal operations. For a comparison with other electricity generation options the emissions of carbon dioxide (CO_2) are also relevant.

The environmental burden of recovering and processing of uranium depends on the type of mining, the operation of the mine and management of the tailings (residual product of ore processing). The involved miners are exposed to natural radon gas and dust particles, which is a risk factor for lung cancer. The environmental burden is mainly related to the radon emissions into the air and emissions of heavy metals into the water and soil. Basically, it is possible to minimize this environmental burden to the level of natural emissions of radon from the soil by means of thorough sealing of the tailing reservoirs. But a certain environmental risk remains, even with well-sealed reservoirs, because tailings remain radioactive for thousands of years.

The average radiation dose that each inhabitant of the Netherlands is exposed to amounts to 2500 microsievert per year. The radiation dose that the population is exposed to resulting from nuclear power plants due to emission of radioactive material into the air amounts to less than 0.04 microsievert per year (nuclear power plant Borssele). Looking at the entire nuclear fuel cycle, the reprocessing plant has the largest contribution to the population's radiation dose with 8 microsievert per year, under normal operating conditions. This is mainly determined by emissions of the relatively long-living fission products carbon-14 and krypton-85, which are emitted into the air during reprocessing of irradiated nuclear fuel.

As high-level radioactive spent nuclear fuel produces ionising radiation for over 100,000 years, it must be properly isolated from the living environment in a final disposal facility. Analyses have been performed to establish the maximum radiation dose to which the population would be exposed if, for various reasons, the final disposal facility would provide less isolation than anticipated. The calculated risks are small but have some uncertainties, which are mainly determined by local circumstances. Further site-specific research is needed before a definitive choice can be made for a final disposal facility for high-level radioactive waste.

During the decommissioning of a nuclear power plant emissions and radiation are monitored in the same way as during the operation of the power plant. Dismantling leads mainly to low and medium-level radioactive waste. This waste is processed in the same manner as low and medium-level radioactive waste arising during operation of the nuclear power plant.

The CO_2 emissions per kWh of nuclear energy during the life cycle of a nuclear power plant are comparable to those of electricity from renewable sources. Nuclear power plants produce 5 to 65 gram CO_2 per kWh. For European nuclear power plants, emissions of 8 to 32 grams CO_2 per kWh are calculated. These figures apply to current uranium mining practices, but may increase when low grade uranium ore is mined. For wind energy CO_2 emissions have been calculated of 6 to 23 grams per kWh and for electricity from currently used solar panels CO_2 emissions of 30 to 100 grams per kWh were calculated. As for CO_2 emissions from the life cycle of coal-fired power plants without CO_2 capture and storage, values are reported ranging from 815 to 1153 grams per kWh and for gas-fired power plants values between 362 and 622 grams per kWh.

What are the risks of accidents occurring when nuclear energy is applied?

With respect to risks due to accidents occurring in the nuclear fuel cycle a distinction must be made between the general public and personnel. Of all the personnel involved in the nuclear fuel cycle the individual risk of dying is largest for miners in uranium mines. The accidents involved are generally similar to accidents occurring during the mining of other minerals. In the other parts of the nuclear fuel cycle the risks for personnel are similar or even smaller than in manufactory. Apart from the above-mentioned mining risks, the risks due to increased exposure to radiation and radioactive material during accidents are comparable to those in light industry.

The risks for the general public due to accidents in the various processes of the nuclear fuel cycle are small compared to the other hazards that the population is exposed to. Exposure to a high radiation dose results in death from radiation diseases in the short term. A lower dose leads to an increased risk of health detriment, with possibly death as a long term result. The risks of nuclear power plants are periodically tested against legally established risk standards. Apart from casualties and health detriment, a nuclear accident may lead to severe environmental, economic and socio-psychological damage on a scale that normally does not occur in accidents in other electricity generation technologies. If the entire energy chain is considered, serious accidents (more than five casualties) also occur in coal mining (e.g. mining accidents), natural gas and oil production. A breach in a dam of a hydropower power plant can also lead to a large number of casualties.

What are the costs of nuclear energy?

Nuclear power plants that are now commercially available belong to the third generation. The construction costs of such a nuclear power plant, excluding interest during construction, lie between € 1590 and € 2297 per kilowatt electric capacity. For a nuclear power plant with a capacity of 1600 megawatt this amounts to € 2.5 to € 3.7 billion. This range depends on the question to what extent the risks of cost over-run are included. So far, hardly any nuclear power plants of the third generation have been built. Due to construction interests, investment costs increase further (to € 4.2 to € 4.7 billion for a nuclear power plant of 1600 megawatt). The construction time amounts to 4.5 to 6 years. In this period, funds must be made available without revenue from electricity generation. The cost of interest on loans during the construction period is relatively high. If the building period extends, investment costs rise due to construction interest.

The cost of exploiting the nuclear power plant ranges from 1.1 to 1.8 €ct/kWh. Next to maintenance and operation costs this includes the costs of the nuclear fuel cycle (nuclear fuel costs: 0.3 to 0.6 €ct/kWh; costs of processing and disposal of nuclear waste: approximately 0.1 €ct/kWh) and the cost of decommissioning the nuclear power plant (approximately 0.1 €ct/kWh). This is based upon current practise of processing and disposal of nuclear waste and decommissioning.

The cost price of nuclear energy ranges from 3.1 to 8 €ct/kWh. This bandwidth is based on six cost studies. The highest value comes from an American study, which is followed by a European study with a cost price of 5.4 €ct/kWh. 70-80% of the cost price is determined by capital costs. As a result, the cost price of nuclear energy is relatively stable. Projections of the capital costs vary because various exploitation periods are used (25 to 40 years; from a technical viewpoint nuclear power plants can be kept in operation longer than that), various assumptions are made about interest on loans (the duration of the loan is shorter than the exploitation period) and different returns on invested private capital are used. The interest rate that was used for calculating the capital costs thus varies from 5 to 11.5%.

The cost price can be compared to the electricity price on the wholesale market, where the nuclear energy operator sells the produced electricity and to the cost price of other electricity generation technologies. The average price for base load electricity in 2006 on the Dutch power market amounted to 6.6 €ct/kWh and 5.5 €ct/kWh on the German power market. These were the highest average prices for base load annual contracts since the liberalisation of both electricity markets. The cost price of electricity from coal-fired power plants varies from 2 to 5.6 €ct/kWh and the prices of gas-fired power plants range from 3.4 to 6.6 €ct/kWh. The electricity market prices and the cost prices for coal and gas-fired power plants are influenced by the fuel prices and the price of CO_2 emission allowances. The cost price for wind energy currently ranges from 4.1 to 8.4 €ct/kWh for onshore wind and 8.6 to 11.2 €ct/kWh for offshore wind. All these cost indications are borrowed from the same cost studies that were used for reporting the cost of nuclear energy. These cost studies are based on current technology. As a result of technological development and the development of fuel prices and the CO_2 price, future prices may differ (e.g. higher for coal and gas and lower for wind).

Utilisation of nuclear energy may result in external costs and benefits. These occur when the exploitation of a nuclear power plant leads to negative or positive effects that are transferred to third parties and thus not reflected in the price of nuclear energy. The external costs of environmental effects for nuclear energy amount to less than 1 €ct/kWh, which is comparable to the external costs of wind energy and electricity from solar panels. External costs of electricity from coal and gas (without CO_2 storage) are a factor ten higher. Other examples of external costs are costs governments incur to inform the public on nuclear energy, for security of waste transports and for protection against terrorist actions or costs related to the depletion of uranium resources and costs related to the consequences of nuclear proliferation. The utilisation of nuclear energy has a positive effect on the security of energy supply and the reduction of greenhouse gas emissions. Benefits arising from high electricity prices as a result of price increases of fossil fuels or the price of CO_2 emission allowances are not automatically transferred to the consumers, though. These benefits can thus not be marked as *external* benefits.

Does expansion of nuclear energy affect the electricity price?

Power stations receive the electricity market price for produced electricity. The electricity market price determines approximately 30% of the end user price of small-scale consumers. In the case of industrial consumers this amounts to approximately 75%. The rest of the end user price is intended for the grid company or the government (taxes and levies). Expansion of nuclear energy in the Netherlands hardly affects the electricity market price. A nuclear power plant is a ‘price taker’, which means that it receives the price that is determined by other types of electricity generation in the market. In the Netherlands, these are mainly coal-fired power plants in off-peak hours and gas-fired power plants in peak hours. In Germany fewer gas-fired power plants are deployed in peak hours, as a result of which the average German electricity price is lower than the Dutch price. The electricity market price changes as a result of changes in fuel prices and the emission allowance price. Price benefits for the operator of the nuclear power plant are not automatically transferred to consumers. Long-term contracts between (industrial) consumers and nuclear energy operators do not lead to a different situation. The contract price will be based on the expected future market price. Long-term contracts divide the price risk between the power plant operator and the consumer. Any advantages or disadvantages experienced by contract parties -due to the price differences between contract price and average realised market price- can only be established afterwards. Electricity contracted in long term contracts remains tradable on the electricity market for the duration of the contract.

In the current electricity market, electricity producers are exposed to the risk of decreasing profits when there is a strong increase in production capacity. This could happen, for example, if the intended plans for new power stations are realised. This would lead to a boom and bust cycle, which is also quite common in other capital intensive product markets.

What other electricity generation technologies are competing with nuclear energy?

Nuclear power plants are base load power plants that produce electricity during off-peak and peak hours. Nuclear power plants compete with other base load power plants, which are mostly coal-fired power plants and gas-fired CHP plants in the Netherlands. Dutch nuclear power plants also compete with foreign base load capacity from coal-fired power plants and nuclear power plants. Further integration of the Dutch electricity market with neighbouring markets will lead to an enhanced market for base load capacity. At the same time, a strong growth of wind capacity will decrease demand for base load capacity. Wind energy also produces electricity during off-peak hours. If this is not the case, electricity will be produced with other flexible production units (possibly storage), but not with base load capacity. If the market structure remains unchanged, the future electricity price for base load capacity will also be determined by electricity generation technology with the highest variable production costs during off-peak and peak hours. As the variable production costs of renewable sources (except biomass) and nuclear energy are lower than those of fossil fuel-fired power plants (coal, gas), the latter will continue to determine the electricity price in the long term.

Is the Dutch electricity market attractive for nuclear energy?

Nowadays, electricity producers are international businesses operating in different countries. In investment decisions, these companies will be able to choose from various national electricity markets. Given the expected returns on investment in a base load power plant, the Netherlands seems an attractive market. The electricity prices for base load capacity are relatively high, because gas-fired power plants set the marginal price part of the time. Due to the expansion of the number of interconnections, among other things, the Dutch electricity market becomes increasingly well-integrated with electricity markets in neighbouring countries. As a result, not only competition increases, but also the size of the market that can be supplied with electricity from Dutch power plants. Other aspects that are taken into account by the electricity producer are the national legislation and regulations for nuclear energy, the existence of reservations in the spatial planning for the construction of nuclear power plants, the availability of cooling water and options for connection to the electricity transmission network.

As investing in new production capacity in the Netherlands is attractive, early 2007 there were several initiatives of various parties to construct new (conventional) power plants. In total 12 plans for new constructions with a joint capacity of approximately 10,500 megawatt are involved. This amounts to nearly half of the Dutch installed production capacity in 2005 (21,800 megawatt).

How is nuclear energy developing in other Western European countries?
There are various views on the role of nuclear energy in other European countries. Countries such as Germany, Belgium and Sweden decided several years ago to phase-out the role of nuclear energy in national energy supply in the long term. In Sweden, two nuclear power plants were closed, but the closure of the remaining nuclear power plants is still uncertain. Under specific conditions (e.g. for reasons of security of energy supply), Belgium may revoke its decision. Finland and France have decided to maintain or even expand the role of nuclear energy in their national energy system. Finland is currently constructing a new nuclear power plant and there are plans for yet another nuclear power plant. France will also start with the construction of a new nuclear power plant in the near future. For the moment the viewpoint of the British government is that nuclear energy should continue to play a role in the UK energy supply system. They are considering enabling the construction of new nuclear power plants.

Can new nuclear power plants be integrated in the Dutch energy supply system?
There are currently various plans to build new power stations in the Netherlands, among other things in places that are considered possible locations for a new nuclear power plant (Eemshaven, Borssele, Maasvlakte). The regulator of the national electricity transmission network, TenneT, has to invest in the network to accommodate the current plans for new constructions. Connection of a new nuclear power plant, should this initiative be taken in the coming years, depends on how fast TenneT can provide sufficient network capacity. Nuclear power plants have a significantly higher capacity (1000 to 1600 megawatt) than the power stations that are currently connected to the Dutch electricity transmission network (approx. 600 megawatt). In order to be able to set off the sudden large production unit outage, sufficient backup capacity will have to be available. The current volume of regulating and reserve power generally amounts to 750 to 1500 megawatt. According to TenneT’s expectations the market will provide the expansion of this backup capacity.

The wind capacity in the Netherlands is expected to increase strongly in the coming years. The Dutch installed capacity can grow from 1600 megawatt (current capacity) to possibly 9000 megawatt (of which 6000 megawatt offshore). Due to a relatively strong growth of wind capacity, there will be a greater demand for flexible production capacity and less demand for base load capacity, as supplied by a nuclear power plant. This could lead to a surplus in base load capacity. On the other hand, due to new interconnections with Norway, Germany and England the cross-border capacity will increase from 3500 to 6000-7500 megawatt. If there is sufficient demand from abroad, a surplus of electricity can be exported.

To what extent does the government influence investment decisions?

According to current Dutch policy, the building of new nuclear power plants should be stimulated nor hindered in a liberalised energy market. This means that there can be no government subsidies or supporting measures that make the construction of nuclear power plants attractive nor can levies or taxes be imposed that hinder the building of new nuclear power plants. By creating adequate preconditions (e.g. for licensing, solutions for nuclear waste, etc.) the government can help reduce the regulating risks for the investor.

The British government is busy creating these preconditions. In Finland and France new nuclear power plants are built. The Finnish and French governments are not directly involved in this process. The nuclear power plant in Finland is built by a consortium of a Finnish electricity producer and a number of large-scale electricity consumers. According to some reports, the consortium was able to arrange loans under ‘attractive’ conditions. Supplier Areva is building the power plant based on ‘turn key’ conditions, with risks of cost overrunning and construction delays mostly for the expense of the supplier.

Can there be a disturbance of market competition?

The degree of competition on the wholesale market is influenced by the number of market parties and the market shares of these market parties, indicated as market concentration. The market concentration on the wholesale market for electricity changes because of new constructions and closure of power plants, due to changes in import capacity and due to mergers and company take-overs. Increasing import capacity will decrease the risk a market party influencing the electricity price. A nuclear power plant is a relatively large production unit. The market share of a producer expanding its production capacity with a nuclear power plant could therefore increase significantly, especially during peak hours, because the size of the market is geographically more limited in that period. Whether or not the degree of concentration changes as a result is difficult to say. This depends on other factors such as changes in production capacity of competitors, expansion of import capacity and changes in fuel and CO_2 prices.

What are the conditions new nuclear power plants should meet?

The conditions for nuclear energy expansion can be based on the principle of sustainable development according to which the needs of the present generation are met without compromising the needs of future generations. Moreover, a balance must be sought between economic, social and environmental aspects. Based on these aspects the following questions arise: Is a nuclear fuel supply indefinitely available? Is nuclear power compatible with respect for the environment? Is nuclear energy an economic option in the long-term? Or more specific: under what conditions may nuclear energy qualify as a viable option to fulfil the need for energy services of present and future generations in a sustainable manner.

From the discussions on this last question it can be concluded that the following aspects play a role:

- Public acceptance of nuclear fuel cycles.
- Safety risks of nuclear power plants and other components of the nuclear fuel cycle.
- Lifetime and management of nuclear waste, especially high-level waste.
- Proliferation of fissile material and nuclear weapons.
- Accumulation of radionuclides in the biosphere.
- Scarcity of natural resources for producing nuclear fuel.
- Cost of nuclear energy.
- Industrial development (local capacities, customers interest, spin offs, employment).
- Lock in effects (impact on the development of non nuclear energy options).

Based on these aspects, nuclear energy cannot be considered as a sustainable technology in its current shape. To this end, the technology needs to be improved with regard to several aspects (i.e. safety, lifetime of nuclear waste and proliferation). Whether nuclear energy can play a role in the transition towards a sustainable energy system depends on the assessment of economic, social and environmental aspects of nuclear energy compared to those of other energy sources that play a role in the same transition period.

In coherence with adjustments to the Nuclear Energy Act, the Dutch government (under the third Balkenende cabinet) has formulated a number of conditions. These preconditions have been formulated for a political discussion and play a role in the treatment of law amendments in the Dutch Lower House. The preconditions are related to the deployment of new nuclear power plants, radioactive waste and reprocessing, decommissioning, choice of location, uranium recovery, non-proliferation and security and anti-terrorist measures.

What are the procedures and the regulatory framework for expansion of nuclear energy?

As soon as the political decision-making processs on preconditions has been finished, the government will lay down the conditions for nuclear energy in the amended Nuclear Energy Act. A proposed amendment for the Nuclear Energy Act has been submitted to the Lower House by the previous government, but a decision is yet to be taken. The ministers of the Environment , of Economic Affairs and of Social Affairs and Employment decide jointly about a licence for a new nuclear power plant. More detailed regulation has been laid down in the Nuclear Safety Regulations (NVR), based on the guidelines of the International Atomic Energy Agency (IAEA).

In the past the government designated five locations as possible locations for a new nuclear power plant. At the moment, the locations near Borssele and Eemshaven seem to be more suitable than the other three locations (Westelijke Noordoostpolderdijk, Moerdijk and Maasvlakte). The licence applicant will have to draw up an environmental impact assessment report for the new nuclear power plant. This assessment should describe the environmental impacts of the nuclear power plant as well as those of other alternatives. The Department of Nuclear Safety, Security and Safeguards (KFD) of the Ministry of VROM is also involved in the assessment of the design of new nuclear power plants. The decision-making process of the government includes public participation, enabling citizens to object or give notice of appeal against these decisions. The decision-making and licensing process will probably take up 5 to 7 years.

What reservoir of technical knowledge is available in the Netherlands for expanding nuclear energy?

Expansion of nuclear energy in the Netherlands requires sufficient capacity of people with nuclear knowledge. In the area of nuclear energy, seven Dutch companies and research centers are active in the areas of enrichment, electricity generation with nuclear energy and processing and disposal of nuclear waste (NRG, EPZ, COVRA, RID/R[3], Urenco, Enrichment Technology, Institute for Energy). International cooperation ensures a high level of knowledge. The government requires nuclear knowledge, too - for policy making, the licensing process as well as for regulating the nuclear sector. This knowledge is concentrated at the Policy Department for Chemicals, Waste and Radiation Protection (SAS) of the Ministry of Environment and at the Department for Nuclear Safety, Security and Safeguards (KFD). Due to a stagnating development in nuclear energy over the past years, the knowledge infrastructure diminished gradually in all above-mentioned organizations. Moreover, the ageing of staff has also led to the loss of knowledge and experience. Due to increasing international attention for nuclear energy this problem of ageing is dealt with by hiring and training new staff. Moreover, there are plans for the renewal and improvement of the research and educational infrastructure, thus ensuring the good position of Dutch nuclear research and education. Dutch companies are involved in the global growth of the nuclear energy industry.

What are the views and opinions of the general public about nuclear energy?

The views and opinions of the general public about nuclear energy are examined in two manners. Scientific research focuses on the various factors that play a role in the acceptance of nuclear energy. This type of research focuses especially on the perception of the risks that are attached to the implementation of nuclear energy technology and other industrial activities. Among other things, this research provides an explanation for the difference in risk perception between 'experts' and persons lacking specific knowledge of certain risks. The risk probability is of less interest to the public. They are more interested in the question whether nuclear incidents such as in Harrisburg and Chernobyl could happen again or not. Scientific research also demonstrates that the Chernobyl incident influenced the risk perception.

Another type of more applied research provides insight in the public acceptance of nuclear energy. A study that was conducted in the Netherlands, in the spring of 2006, brought forward the notion that the government should play an important role in case of a new nuclear power plant. The government should prescribe which type of nuclear power plant can be built. Alternatively, the government should build the nuclear power plant themselves. Citizens express their doubts about the decision-making process within the government and about their actual involvement. A European study conducted in 2006 showed that 35% of the population is in favour of the expansion of nuclear energy because it does not contribute to climate change. 57% is against expansion of nuclear energy as it brings along the risk of accidents and causes radioactive waste. Results of comparable studies in the past show that these results can vary significantly, depending on the exact phrasing of the questions.

Which role is awarded to nuclear energy in long term scenarios?

Energy scenarios are outlooks of future developments and not 'predictions'. A distinction can be made between two types of energy scenarios: trend scenarios, in which current government policy is continued and scenarios that assume intensification of policy. In long-term scenarios there are changes in both electricity demand and electricity supply. In all Dutch and European scenarios, both trend-based and policy intensifying, electricity demand in 2030 is higher than in 2005. The share of nuclear energy in Dutch electricity generation is currently about 4%. In four of the five examined Dutch trend scenarios the share of nuclear energy decreases, because there is no expansion of nuclear energy. In one trend-based scenario, the share of nuclear energy in the Netherlands increases to 17% in 2030. In one of the three policy intensifying scenarios an expansion of nuclear energy to 30% is assumed for 2030.

The share of nuclear energy in European electricity generation is currently 31%. Many of the current nuclear power plants in Europe have been in operation for several decades now. If no new nuclear power plants are taken into operation in addition to the power plants that are currently planned or under construction (3 gigawatt in total) and the exploitation of existing power plants will be limited to 40 years, the share of nuclear energy in 2030 will presumably fall below 5%. This is not only the result of closure of nuclear power plants, but also due to the assumed increase in electricity demand. Should the exploitation of all existing nuclear power plants be extended to 60 years (which will not be the case for all nuclear power plants), this percentage will decrease to slightly below 25% in 2030.

In four European trend scenarios the share of nuclear energy decreases, but in some trend scenarios the construction of new nuclear power plants is foreseen. In various policy intensifying scenarios the share of nuclear energy in European electricity generation increases compared to the trend scenario of the same scenario study. In some policy intensifying scenarios, however, the share of nuclear energy is phased out.

If the Netherlands were to consider increasing the use of nuclear energy, what would the socio-economic effects be?

In a scenario with no long term climate policy, the macro-economic effect (i.e. effect on GDP) of expansion of nuclear energy is uncertain. This depends on the economic attractiveness of nuclear energy compared to the other electricity generation options and on the market structure (e.g. is there import or export of electricity). If nuclear energy is more profitable, this could lead to a positive macro-economic effect. If this is not the case, the effect could also be negative. Under the conditions of a scenario with strict climate policy and high CO_2 prices, a nuclear power plant could have a macro-economic advantage compared to the fossil alternative if the cost of electricity generation with an increased share of nuclear energy is lower than if the electricity is produced with coal or gas-fired power plants. Even when the electricity is produced with renewable sources (without CO_2 emissions), expansion with nuclear energy will prove advantageous due to the higher initial cost of renewable energy technology. On the other hand, when expanding nuclear energy there may be fewer investments in new energy technologies as a result of lesser benefits of positive economic effects that are related to the development and implementation of innovative technology.

Expansion of nuclear energy with only one power plant will hardly affect electricity prices. There will be no competitive advantages for industrial consumers and no effect on employment is to be expected (apart from the construction of the nuclear power plant itself). Further expansion of nuclear energy might lead to a slightly lower electricity price in comparison. However, any possible employment effects in the longer term cannot be foretold.

Expansion of nuclear energy in the Netherlands is expected to stimulate nuclear research in the Netherlands, especially in research institutes and universities. Research of other innovative electricity generation options (e.g. renewable energy, CO_2 capture and storage, etc) will be continued, but the extent of this energy research may be affected. A new nuclear power plant will expand the Dutch nuclear sector. The exploitation of a nuclear power plant requires more staff than gas and coal-fired power plants. This may have a (minor) positive economic effect on the region where the nuclear power plant is located.