Nuclear power, the inconvenient practice

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<1> title

<2> the promise

Ladies and gentlemen. It is a great honour to speak here to you.

This slide shows nuclear power as advertised: simple, safe, clean, cheap.

“You only need a very small piece of uranium and you get a huge amount of electricity.”

<3> the practice

Unfortunately the practice is not that simple.

A nuclear reactor generates heat and human-made radioactivity, simultaneously, inextricably and irreversibly

<4> key questions

From where comes the nuclear fuel feeding the fission process in the reactor?

What happens to the human-made radioactivity?

In this lecture I will assess these questions by means of a comprehensive physical life cycle assessment (LCA) coupled to an energy analysis.

<5> outline

Answering the first question brings us to a more basic question. As uranium is an essential material for the generation of nuclear energy, the availability of uranium is of crucial importance for the global perpective of nuclear power.

1 In part 1 I ’ll briefly discuss the prospects of the uranium supply, based on the findings of the energy analysis. What consequences for the global potential of nuclear power do follow from the specific physical properties of the natural uranium resources?

Assessment of the second question reveals the existence of large and ever increasing health hazards: the inconvenient practice of nuclear power.

2 Part 2 assesses some basics of human-made radioactivity, how it should be managed and how it is managed in practice.

3 Part 3 briefly discusses the health hazards and other hazards posed by nuclear power, exacerbated by an outright inadequate culture of the nuclear industry.

<6> part 1, global potential of nuclear power

Part 1 of this lecture comprises the results of the energy analysis of nuclear power and a brief discussion of the following issues:

- how large is the contribution of nuclear energy to world energy supply, now and in the future?
- the nuclear industrial process chain
- the principle of energy analysis
- energy costs energy: the energy return on energy investment
- energy quality of uranium resources
- the coal equivalence
- the energy cliff
- CO2 trap

<7> nuclear share (pie diagram)

If all useful energy units produced during 2010 are added, we get this distribution. Nuclear power delivered 1.9% of the useful energy in 2010. At present the nuclear share is lower. Even if nuclear power would be carbon-free, which it is not, the mitigation of the CO_2 emission could not be more than 1.9%. If the world nuclear capacity remains level during the next decades, the nuclear share would decline to less than 1% by 2050, due to the increasing world energy demand. In fact, since a couple of years the global nuclear capacity is slowly declining and likely this trend will accelerate in the future.

Besides, even a constant nuclear capacity would imply a massive construction programme, a nuclear renaissance, for the nearly the whole world nuclear fleet has to be replaced by new build by 2050.

To keep the nuclear capacity at the 2% level, some 1000 new large nuclear power plants have to be built by 2050, in addition to the 400 units to be replaced by that year

<8> nuclear chain

A nuclear reactor is not a stand-alone system. This slide represents a simplified outline of the complete system of industrial processes needed to generate nuclear power, from cradle to grave. Jointly these processes and activities are called the nuclear chain, the most complex technical system ever designed by man.

Nuclear fuel is not found in nature but has to be prepared from uranium minerals in the earth’s crust. The upstream processes, also called the front end of the chain, comprise all processes from mining to fabrication of fuel elements with enriched uranium, and include the construction of the nuclear power plant.

The nuclear waste containing the human-made radioactivity does not disappear from the biosphere spontaneously. The downstream processes, or back end of the chain, comprise all industrial processes needed to safely handle the radioactive waste (and other, non-radioactive waste), and to isolate it from the biosphere for millions of years. We return to this issue later.

Note that all processes of the nuclear chain occur within the biosphere: all materials needed are withdrawn from the biosphere, and all waste returns into that same biosphere.

<9> full nuclear chain

This slide shows the complete nuclear process chain, as it ought to be. I am not going to discuss all these processes. This slide is only meant to show you the complexity of the nuclear chain. All components of the nuclear chain, except the fission process in the reactor, are essentially conventional industrial processes, consuming materials, electricity and fossil fuels. Consequently all processes of the nuclear chain, except the nuclear reactor itself, emit carbon dioxide CO_2.

The processes of the front end, within the blue frame, are technically mature processes.

The most important processes of the back end, within the yellow frame, are still non-existent. We return to this later.

Note that all parts of the nuclear chain routinely release radioactivity into the biosphere: air, water and soil.

<10> method

Based on a complete life cycle assessment, see previous slide, an energy analysis of nuclear power from cradle to grave can be done. A generic industrial process needs a direct input of energy (fossil fuels and electricity), and an indirect input of energy embodied in materials, equipment, buildings, services. All these commodities require energy to produce from raw materials as found in nature. According to the current conventions of energy analysis no embodied energy is attributed to human labour and raw materials.

The output of a proces can be processed materials, equipment or useful energy, such as electricity.

In addition each process generates waste heat and material wastes: solid, liquid and gaseous (including greenhouse gases). Management of the waste requires often secondary industrial processes: the downstream part.

<11> chain E inputs-outputs

We return to the simplified nuclear chain. Here is the chain presented as it ought to be: from cradle to grave. The nuclear chain is comparable with the chain of any industrial activity and even of daily household activities:

preparing a meal (front end), enjoying the meal (mid section), followed by washing the dishes and clearing the mess (back end), As pointed out each partial process of the nuclear chain consumes energy, fossil fuels and electricity, directly and indirectly as embodied energy. The energy inputs of the still non-existent back end processes can be estimated, because these would be comparable with other, currently operational processes.

<12> energy return on energy investment (EROEI)

The energy return on energy investment (EROEI) is defined as the ratio of the energy production of an energy system over the energy inputs needed to construct and operate that energy system from cradle to grave. This ratio is convenient to compare different energy systems, for example nuclear power and solar power. A fair and reliable comparison is only possible if all inputs and outputs of the compared energy systems are included, from cradle to grave.

<13> uranium resources of the world

This bar diagram shows the known amounts of uranium in the earth's crust as function of the ore grade. Note that the horizontal axis has a decreasing logarithmic scale.

The ore grade distribution of the known uranium resources of the world exhibits a characteristic pattern. The deposits of ore at the highest grades are the most rare and the most limited in size. The number and sizes of uranium deposits increase with declining ore grade. The lower the grade, the more uranium is present in the earth's crust. This is a common geologic feature of all metal ores.

The uranium distribution has a particular feature by the low peak at high grades, probably due to specific geochemical properties of uranium.

At very low grades, below 200 ppm (parts per million, or milligrams uranium per kg rock) few deposits are listed. This not a geologic but an economic phenomenon. At that low grades recovery of uranium is not economic anymore.

At lower grades the ore minerals tend to be harder to process, which results in a relatively higher specific energy consumption (per kg recovered uranium).

<14> energy quality of uranium resources

The physical qualities of the known uranium ores of the world vary widely. The extraction of 1 kg of uranium from one type of rock may require 1000 times as much energy as from another type of rock.

Uranium is almost exclusively mined for use as an energy source. The amount of useful energy which can be generated from 1 kg of natural uranium has a fixed value. The energy consumed by a mine for recovery of 1 kg of uranium from deposits in the earth's crust increases exponentially with decreasing ore grades.

The energy quality of a given uranium resource is defined here as the energy which can be generated from one kilogram of uranium *minus* the energy input of the extraction of 1 kg of uranium from that resource.

<15> coal equivalence

At a grade of about 200 ppm, 200 grams of uranium per tonne rock, uranium ore has the same energy potential as coal. That means that to feed a nuclear power plant with uranium from that ore as much ore has to be mined and processed as the amount of coal needed to produce an equal amount of electricity.

<16> energy cliff

As pointed out before, the recovery energy per kg uranium rises exponentially with decreasing ore grade. Consequently the net energy from 1 kg uranium as found in the earth's crust drops steeply with decreasing ore grade. This phenomenon is called the *energy cliff*. Beyond the energy cliff, corresponding with an ore grade of about 100-200 ppm uranium, a uranium resource cannot be a net energy resource anymore, but becomes a net energy sink. The energy consumed by mining plus all other processes of the nuclear chain would be more than the energy production of the chain using uranium from those lean ores.

This diagram shows the energy return on energy investment (EROEI) as function of the uranium ore grade. From the definition follows that an energy system with a value of 1 does not deliver net energy. Below EROEI = 1 the system is an energy sink.

<17> energy cliff over time

Usually the mining industry mines the richest and easiest accessible ores first, for these offer the highest return on investments. If no new deposits are discovered of equal E quality, the world average ore quality of the remaining resources will decline over time. This is exactly what is happening at the moment in the world uranium industry. The easiest discoverable and the highest quality ores are already known for some 20 years. There is no evidence of new discoveries of major high-quality uranium deposits.

As a result the net energy production of nuclear power, the EROEI, is declining over time at an ever increasing rate. This slide shows that decline as function of time for two scenario's: scenario 1 is based on a constant nuclear generating capacity at the current level, scenario 2 is based on the assumption of a constant nuclear share of 2% of the world energy supply. Nuclear power would fall off the energy cliff within the lifetime of new nuclear build.

<18> CO_2 trap

As pointed out before, the nuclear process chain emits substantial amounts of CO2. Under the current conditions some 100 grams CO2 per kWh, assumed that all electricity consumed in the process chain is generated by the nuclear power plant itself. Higher energy consumption per kg extracted uranium means higher consumption of fossil fuels and consequently a higher specific CO_2 emission (gram CO_2 per kWh) of the nuclear chain.

Due to the exponentially rising energy consumption with declining ore grade, the specific CO_2 emission of nuclear power will rise sharply and surpass that of gas-fired power stations when the poorest ores have to be mined: nuclear power runs aground in the CO2 trap.

<19> CO_2 trap over time

The specific CO2 emission of nuclear power rises over time and will surpass that of fossil fuels by the years 2050-2070, within the lifetime of new nuclear build, if no new large and high-quality uranium resources will be found. From a geologic point of view the chances of such discoveries are very low.

<20> outlook of uranium resources, economic view

The nuclear industry holds an economic point of view regarding uranium resources:

- The market price is the criterion of uranium mining.
- Higher prices will lead to more intensive exploration.
- More exploration will lead to more discoveries of new uranium deposits, that will be larger than the already known deposits.
- At higher price more and larger deposits are economically recoverable. Ergo: world uranium resources are practically inexhaustible.

The nuclear industry denies that the uranium supply could become a problem. They are right: there will always be uranium left in the earth’s crust. Unfortunately not the quantitative *uranium* supply is at issue, but the qualitative supply, the *net energy supply* from uranium is at issue.

<21> outlook of uranium resources, energy view

Nor the quantity, nor the uranium price, but the energy quality of the uranium resources determines the energy potential of nuclear power. The E quality of uranium resources defines a uranium deposit being either a net energy source or a net energy sink.

During the last two decades no new high-quality uranium resources of any significant size have been reported in the open literature. The chances of such discoveries in the future are utterly unknown. Besides the development of a large new mine may take at least 10 years.

The known uranium resources recently added by the IAEA and OECD/NEA (Red Book) are the result of an economic reclassification of already known deposits. These added deposits are of signifcantly lower energy quality than the previously published resources, due to greater depth, lower grade and less favourable mineralogy.

<22> Part 2 human-made radioactivity

In this part I will address some basic facts concerning human-made radioactivity.

<23> human-made radioactivity

The fission process in a nuclear reactor generates an amount of human-made radioactivity a billion times the content of the fresh nuclear fuel that is placed into the reactor. These amounts are represented by the sphere with a diameter of 10 m and the pea with a diameter of 1 cm.

<24> radioactivity

Each nuclear reactor generates an amount of radioactivity equal to about the amount of 1000 exploded nuclear bombs of 15 kiloton (Hiroshima bomb).
A nuclear reactor produces relatively more radionuclides with long halflifes so it is more dangerous and remains longer dangerous.

<25> radioactivity

The world inventory of human-made radioactivity is about 10 million nuclear bomb equivalents, that is still not safely isolated from the biosphere.

<26> radioactivity

The generation of radioactivity is irreversible.
Radioactivity cannot be made harmless to humans and to all other living organisms.
Radioactivity cannot be destroyed by any means.
Radioactive decay cannot be accelerated, nor delayed. Each kind of radionuclide has its specific halflife, which is unchangeable.

<27> just one option

There is just one option to deal with the human-made radioactivity from nuclear power stations. All radioactive materials should be immobilized and isolated from the biosphere in the best possible way, to prevent contamination of humans. This concept is symbolized in this slide. A geologic repository is a storage facility deep in a geologically very stable formation. The radioactive materials would be packed and stored in such way that migration of radionuclides back into the biosphere, for instance by groundwater flows, is retarded as much as possible.

<28> concept of a deep geologic repository

Probably the most detailed concept of a deep geologic repository is the Swedish KBS-3 concept. The spent fuel elements from the reactor would be packed in a heavy copper canister. The canisters, which generate heat during centuries, would be stored in holes in the floor of galleries deep in a stable formation, for example granite bedrock. The holes and the galleries would be filled up with bentonite, a clay mineral that is nearly impermeable to migration of radionuclides dissolved in water. The canisters will go leaking, sooner or later. Despite the age of the KBS-3 concept of about 25 years, not a single repository has been constructed in the world up until this moment.

<29> nuclear chain: practice

This brings us to the present situation in the nuclear world. Slide 11 showed you the nuclear chain as it ought to be: including the definitive isolation of all radioacive wastes. In practice the back end portion of the nuclear chain is chiefly absent. All radioactivity ever produced by military and civil nuclear reactors, many millions of nuclear bomb equivalents, has accumulated in cooling ponds and other non-permanent storage facilities. Unsafe locations, more or less vulnerable to accidents, terrorism and other exceedingly unpleasant events. Some barrier seems to obstruct the safe management of the human-made radioactivity. To use the metaphor of slide 11 again: the dishes and mess are piling up in the kitchen and dining room. Why?

<30> paradigm barrier

The barrier that obviously prevents the nuclear world from tackling the hazards left from the nuclear meal is not a technical one, but turns out to be a paradigmatic barrier. Main elements of that paradigm are:

- culture of short-term profit seeking
- habit of living on credit
- culture of privatisation of the profits and socalisation of the costs
- belief in unproved technical concepts, only possible in cyberspace.

This attitude can be summarized by the famous statement of the French king Louis Quatorze:

> *après nous le déluge*, or: after us the flood.

<31> spontaneous degradation

After us the flood. This photograph shows what irrevocably will happen to all human-made structures in a *Après nous le déluge* scenario. Without investments of dedicated effort and energy, materials will deteriorate and structures will decay. If we postpone the necessary actions long enough, we can be sure that millions of nuclear bomb equivalents of radioactivity will disperse into the biosphere. The laws of nature are relentless.

<32> Part 3 hazards of nuclear power

This official warning sign symbolizes the potentially deadly effects of nuclear radiation: alpha, beta and gamma radiation.

In this part I will briefly mention the possible health effects of radioactivity and the ways people can get contaminated with radioactive materials. In addition the questionable role of the International Atomic Energy Agency and the World Health Organization in downplaying the health hazards of radioactivity is discussed.

<33> health effects of radioactivity

It makes a big difference if you are exposed to radiation from radioactive sources outside of your body or from radioactive atoms inside your body. Gamma radiation is very penetrating. Alpha and beta radiation do not penetrate your skin. That is one reason why usally only gamma-emitting radioactive substances are measured to assess health risks posed by radioactivity. The other reason is that only gamma radiation can be detected by portable radiation counters.

However, alpha and beta emitters are highly dangerous inside the body. Alpha emitters inflict serious biological damage inside living cells, due to the high energy of the alpha rays, but beta emitters can also be highly dangerous when incorporated in essential biomolecules.

Damage to the biomolecules in living cells can cause a wide variety of diseases, such as:

- cancers,
- lethal and non-lethal non-cancer diseases,
- premature ageing
- stillbirths
- genetic malformations
- inheritable diseases.

The latency period of these diseases are long: often the diseases become observable only after years or even decades. A point is that most of these diseases can be induced also by non-nuclear causes: the diseases are anonymous. For that reason it is not possible on an individual scale to unambiguously attribute a given disease contracted by a given individual to radioactive contamination at a given moment. Only statistical investigations involving large numbers of persons can prove the relationship between the exposure to radioactivity and the incidence of diseases.

<34> pathways exposure to radioactivity

Alpha and beta emitting radionuclides can enter the body via inhalation of radioactive dust or via ingestion of dissolved radionuclides in food and drinking water. This slide shows how insidiously radioactive contamination can occur. Each nuclear power plant discharges large amounts of radioactive hydrogen (tritium), as radioactive water HTO, and radioactive carbon-14, as CO2. Both compounds enter the food chain and drinking water. Both radionuclides are biologically very active inside the human body and are incorporated in biomolecules, such as DNA. The biochemical mechanisms and their medical consequences are poorly investigated and poorly understood.

Health effects with young childern near nuclear power plants are proved by epidemiological investigations in Germany and France.

Very little is known on chronic exposure to a variety of radionuclides via the food chain and drinking water.

Little is known on the biological behavior of radioactive substances inside the human body.

Very little is known on the combined action of a number of different radionuclides together in the body.

<35> detection

Common radiation detectors (radiation counters) can only detect radionuclides that emit strong gamma rays, for example cesium-137. Alpha en beta emitters with weak or no gamma emission are not detectable. Many biologically dangerous radionuclides are only measurable by means of special equipment and laboratories. A common detector cannot see tritium and carbon-14 discharged by a nuclear power plant in the cooling water.

<36> dose-effect models

The nuclear world uses computer models to estimate the health effects of exposure to a given dose of nuclear radiation. Note that this not the same as exposure to radioactivity. The official models are hardly understandable, are based on studies from the 1940s and 1950s, with often arbitrary assumptions, and on effects of external radiation sources (X-rays and gamma-rays).

The models do not include biochemical mechanisms of radionuclides inside the body, do not include chronic exposure to a number of different radionuclides via air, water and food, do not include the cumulation of radionuclides in specific organs. Empirical evidence from the past decades is hardly or not incorporated.

<37> standards allowed exposure to radioactivity

The standards, which are based on the official dose-effect models, are flexible and can easily be adapted to economic and/or political needs.

The standards are not based on unambiguous scientifically sound medical investigations.

<38> radioactive discharges

There are three ways along which human-made radioactivity is entering the human environment:

1 Routine discharges by nuclear power plants, reprocessing plants and other nuclear installations. These discharges are authorized according the standards valid at the particular place and time.

2 Unintentional discharges, caused by leaks and accidents. These discharges, often into the groundwater or sea, could involve large amounts of radioactivity and could go on for long times before they are noticed. When noticed these discharges are often concealed.

3 Large disasters, such as Chernobyl and Fukushima.

<39> risk enhancing factors

Nuclear safety is not just a matter of technical quality of nuclear installations, numerous factors are enlarging the chances of inadvertent events involving radioactive materials.

The safety margins of nuclear installations are very narrow. Failure of a component, only a nuisance in a conventional plant, may have serious consequences in a nuclear power plant.

The cradle-to-grave period of a nuclear power plant is extremely long. If you start building an NPP in 2014, it will come online in 2024 and will be closed down by about 2070. Finishing the back end processes, including the dismantling of the NPP may take another 60-100 years. So by the year 2130-2170 the chain may be finished in an appropiate way.

Human factor: sloppiness, incompetence, shortage of skilled personnel.
Degradation of materials en structures by unavoidable ageing processes, see one of the previous slides.
A culture of secrecy and conflicts of interest may provoke late or wrong decisions.
Not all radioactive flows and inventories can be adequately measured and the used computer models have their limitations.
I'll return later to economic pressure. The other four factors may be obvious.

<40> nuclear disasters

Violent disasters with dispersion of huge quantities of radioactivity are possible in facilities containing spent nuclear fuel. Spent nuclear fuel generates much heat during tens of years after discharge from the reactor and has to be cooled actively. If the cooling fails for some reason, the fuel melts and violent explosions are unavoidable. A large part of the radioactive inventory, many hundreds of nuclear bomb equivalents, is expelled out of the reactor or cooling pool and dispersed into the air, water and soil.
The molten mass may become critical again, resulting in uncontrolled fission and production of heat and new radioactivity.
This scenario occurred at Chernobyl in 1986 and Fukushima in 2011.

<41> nuclear disasters: explosion

One of the explosions of the Fukushima disaster occurred in the spent fuel cooling pool of reactor 3.

<42> nuclear disasters: dispersion of Cs-137 from Chernobyl

This map from a French institute shows how large areas can be contaminated with radioacive materials by the explosion of a nuclear reactor. The map is based on de spread of cesium-137, an easily detectable radionuclide (strong gamma-emitter). Not known are the spread and distribution of other, probably more dangerous radionuclides. Each radionuclude has its specific physical and chemical properties, so the spread of cesium-137 is most likely different from other radionuclides.

<43> nuclear disasters: dispersion of Cs-137 from Fukushima

This map from the same French institute shows the dispersion of cesium-137 from the Fukushima disaster. Most radioactive material is deposited into the ocean. Significant regions of the United States and Canada are contaminated. A large part of Japan it heavily contaminated with Cs-137 and dozens of other radionuclides.

<44> nuclear disasters: dispersion of radioactivity from Fukushima

Most radioactive material from the exploded reactors and cooling pool are dispersed into the ocean. This process is still going on. Some American institutes prepared this map a year after the disaster.

<45> nuclear disasters: rising risks

The chances of large nuclear disasters are increasing with time due to the increasing trend of a number of risk factors.
Time is also an increasing risk factor due to the ongoing and unavoidable deterioration of materials and structures. The degradation processes follow from a fundamental law of nature: the Second Law of thermodynamics. I am not going to explain this law here, my intention is to let you know that these processes cannot be prevented by some kind of advanced technology.

<46> economic pressure

Probably the greatest risk factor is the economic pressure on the nuclear industry to minimalize the investments in actions which do not provide profits, but which are nonetheless indispensable for safety of the public.
Relaxation of the discharge limits allows application of less costly but less effective retainment techniques for radioactive materials.
Inpections are costly, so decreasing their number save costs. As a consequence unsafe situations are becoming more unsafe, and the risks of nuclear criminality are increasing.
Economic viable ‘solutions’ are always conceived with a short time horizon. Chosing a short-term solution most likely will generate much higher costs in the future. In times of a declining economy or even an ecomic crisis the risks for inadequate solutions, or no solutions at all, are greatly enhanced.
Economic considerations are usually the reason for postponement of large and costly acivities of the back end of the chain, for example the dismantling of nuclear installations and the construction of a deep geologic repository.

<47> role of the IAEA

The communication on nuclear power issues, nuclear safety and health hazards, from the nuclear industry to the general public and policy makers is dominated by the IAEA (International Atomic Energy Agency). Policy makers should be aware of the fact that the IAEA is not an independent scientific institute but an organization with vested interests in nuclear power, for three reasons:

- it has the promotion of nuclear power in its mission statement
- it promotes the interests of its 159 member states
- its reports have to be approved by its 159 member states.

<48> WHO-IAEA connection

There is a strong connection between the IAEA and the World Health Organization (WHO) since 1958. The reports of the WHO on nuclear matters are not allowed to deviate from the official IAEA viewpoint. Examples are the reports on the consequences of the disasters at Chernobyl and Fukushima.

<49> downplay of health effects of radioactivity

The IAEA, and with it the nuclear industry and the WHO, systematically downplays the consequences of contamination with radioactive naterials. The IAEA and WHO deny that diseases with long latency periods, as mentioned on slide 33, can be attributed to radioactive contamination. The IAEA blames this kind of diseases on mental illness: radiophobia (fear for radiation), without any scientific investigation. This viewpoint became clear after the nuclear disasters at Chernobyl and Fukushima, despite opposite evidence from independent studies. According to the IAEA the dose-effect models adopted by the nuclear industry are more trustworthy than empirical evidence.

The relationship between adverse health effects and exposure to radioactivity can be proved by large epidemiological investigations, which are undone by the IAEA and WHO. However, independent German and French studies proved a strong connection between the incidence of child cancer and the living distance from a normally operating nuclear power station.

<50> IAEA/WHO assessment of the Chernobyl disaster

The official assessments of the Chernobyl disaster by the IAEA and WHO use a highly questionable method, conflicting with the elementary conventions of science.

The international organization IPPNW (International Physicians for the Prevention of Nuclear War, Nobel Prize 1985) states about the IAEA/WHO reports:

“Unscientific and untrustworthy”.

<51> summary

Here we come to the end of this lecture.

<52> summary 1

From the energy analysis follows that the quality of the uranium ores feeding the nuclear energy system are of crucial importance for the viability of nuclear power as a net energy source. With time the ore quality goes down at an increasing rate. Within several decades nuclear power falls off the energy cliff and becomes an energy sink, producing more CO2 per kilowatthour than fossil fuels, even if the nuclear capacity remains the the current level of less than 2% of the world energy supply.

I briefly discussed the coal equivalence, the energy cliff, the CO2 trap and the energy debt.

<53> summary 2

The back end of the nuclear chain, the safe isolation of the human-made radioactivity, is systematically postponed to the future. However, it has to be done, if we want to keep our countries habitable. The bill comes later.

Nuclear energy does not comply with any sustainability criterion.

<54> summary 3

The health hazards and risks of societal disruption from nuclear power are greatly underrated by the nuclear industry.
Discharges of human-made radioactivity into the environment are rising at an increasing rate and consequently the hazards.
The chances of disasters like Chernobyl and Fukushima are also increasing.

<55> summary 4

The communication on nuclear matters from the nuclear industry to the public and policy makers is dominated by the IAEA and the WHO has to follow the IAEA viewpoints.
Both organizations are downplaying the health hazards of nuclear power and the consequences of Chernobyl and Fukushima to a very high degree, using unscientific argumentation.

Do we have to conclude that health hazards of nuclear power are an economic notion? What are we willing to pay for the health and societal stability of ourselves, our childern, grandchildern and their offspring?
Why do we think to need nuclear power?

<56> world globe

thank you