Nuclear power as sustainable energy?

Paper issued within the

"Bilateral Winter and Summer School on Energy Systems in Austria and the Czech Republic 2007"

Organised by the "Wegener Center for Climate and Global Change"

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INTRODUCTION

AIMS OF PAPER

In this paper we would like to discuss the question to which extent and under which conditions nuclear energy can contribute to meeting the goals of sustainable development.

The idea of working on this subject arose from the recent discussion about the theme in the media:

In order to be able to fulfill the share of 20 % of sustainable energy, which the countries of the EU agreed upon to reach by 2020, France had the idea of numbering nuclear energy among sustainable energies. They argued that nuclear power had the lowest lowest CO_2-emissions and therefore was able to contribute to stop climate change.
Germany, although operating nuclear power plants as well, advanced the opposite view.

However, the discussion is not entirely new:
There exist several detailed reports, which discuss this question - here follows a list of the most established ones:

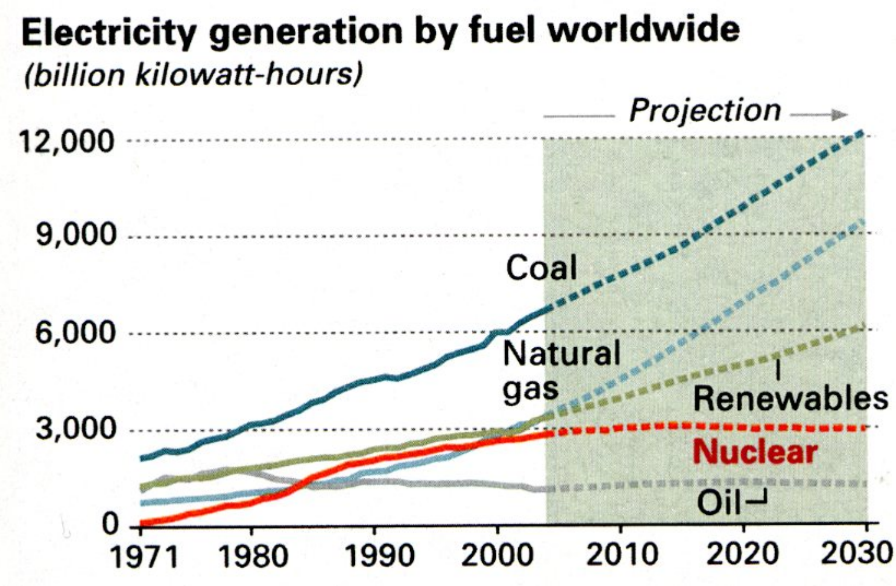
Sceptic of nuclear p. as sustainable E	In favour of nuclear p. as sustainable E
Brundtland-report (1987)	Voß-Report (Alfred Voß, Stuttgart) calculates total costs of different energy types
UBA (Umweltbundesamt Germany) 1997	Keßler-report (2001), argues for nuclear plants of a higher security level than the present plants have so current security and final storage problems could be solved
SRU 2000 (Sachverständigenrat für Umweltfragen, D)	NEA-report (nulear energy agency of OECD) 2000

These studies give different criteria an energy source has to fulfill to be regarded sustainable. We selected the criteria which seemed most reasonable to us and tried to answer the question.

But first we’d like to give a short overview about the current energy situation – in order to see why the discussion is of importance.

Need for the Discussion

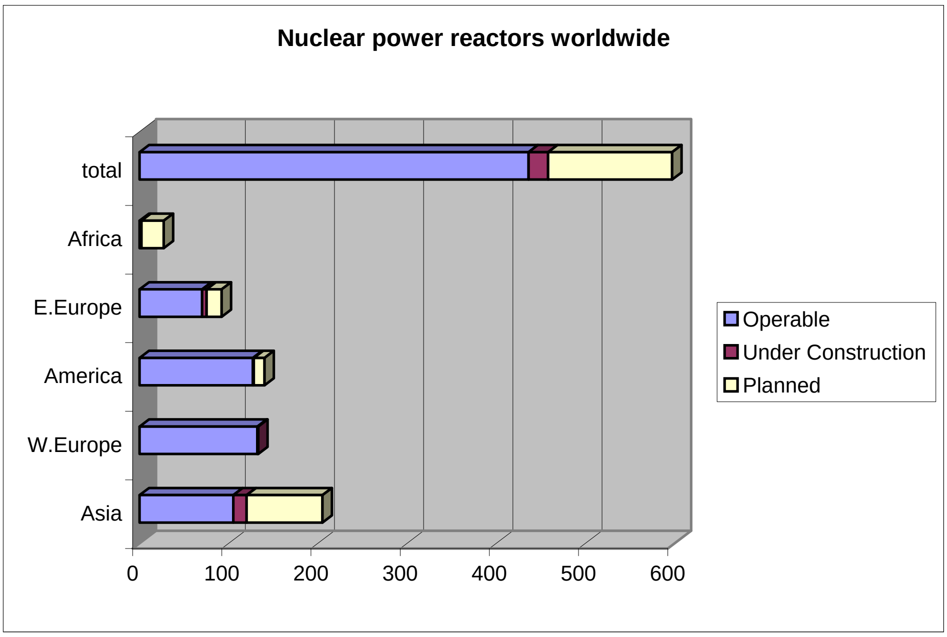
We all know about the energy problem: The need for energy rises along with the consumption and the world's population – and somehow this need has to be supplied.



Source: National Geographic April 2006

In addition we have to face the problem of climate change and take immediate actions against it. The question is whether nuclear energy should be part of the solution.

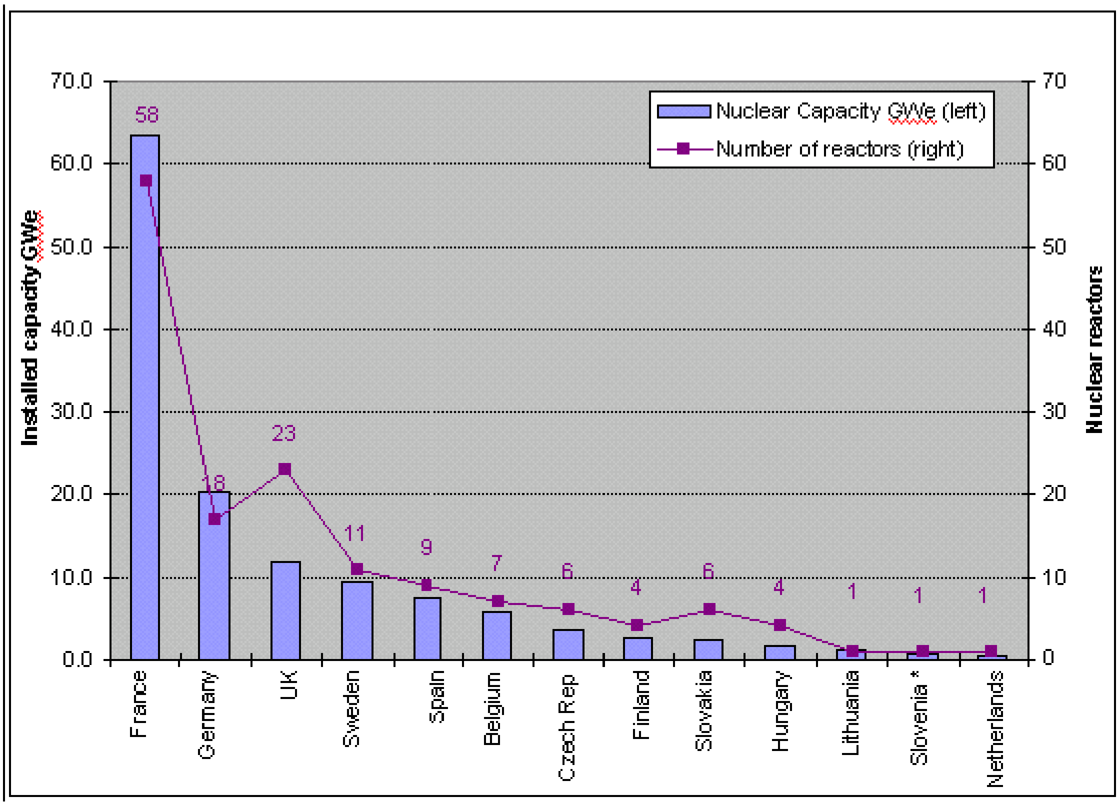
Today the number of nuclear powerplants is distributed worldwide as follows. If the decision is made to focus on nuclear power, the numbers will certainly rise.



Source of data: National Geographic April 2006

In the following graph we can see to which extent the European countries use nuclear power this day. We will discuss the reasons for these shares of use later on.

Total number installed (net nuclear capacity in GWe) versus the number of nuclear units by country for EU-25 as of December 31st, 2004



Source: World energy council report 2007, p. 12

Before beginning the acutal discussion it is necessary to define what "sustainability" means – in order to be able to assess what is sustainable and what isn't.

DEFINITION OF SUSTAINABILITY

The Brundtland Commission defined sustainable development as development that "meets the needs of the present generation without compromising the ability of future generations to meet their own needs."
(In this context a "generation" means all individuals that live at the same time - not like in other definitions the parent–child generation).

This definition is widely used and accepted, although it raises some open questions:

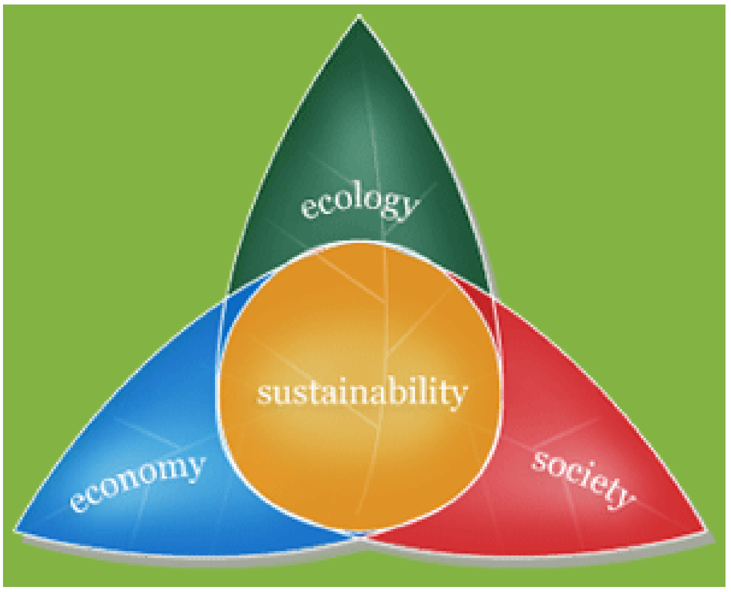
- What exactly are the needs of a generation? Who defines them?
- To what extent should intragenerational justice be considered (or don't all people have the same needs?)?
- Where should we draw the boundary between meeting people's needs and considering the "needs" of the environment?

The criteria for sustainable development can be divided into three main topics: the three columns of sustainability.

THE 3 COLUMNS OF SUSTAINABILITY

The 3-column model of sustainability will be used as thread leading through this paper.

The 3-column model of sustainable development has the following fundamental idea: Sustainable development can only be achieved when environmental, social and economic aims are realized equally and simultaneously.



source: http://www.loretobay.com

Each of these columns has indicators that measure the grade of sustainability. We selected categories and indicators particularly applicable for energy "generating" systems.

COLUMN 1: ENVIRONMENTAL SUSTAINABILITY (ENVIRONMENTAL COMPATIBILITY)

THIS COLUMN FOLLOWS THE FOLLOWING FUNDAMENTAL PRINCIPLES:
(source: Pearce and Turner 1991)

1. Don't use up the renewable resources faster than they are regenerated.
2. Don't use up non-renewable resources faster than the rate of creation of renewable substitutes.
3. Don't pollute the environment with more waste emissions than it can naturally assimilate (Pearce and Turner 1991).

Addition of German institutions (Enquête –Komission 1998):

4. Avoid dangers and indefensible risks for human health from anthropogenic impact.

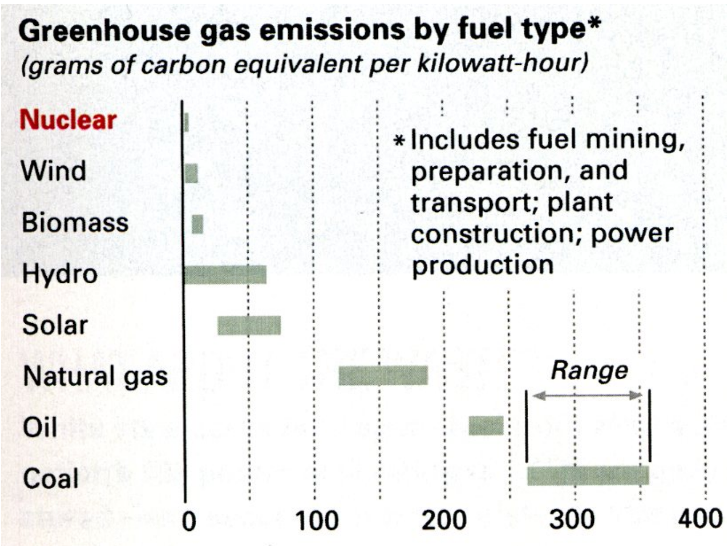
And now I would like to assess to which extent nuclear energy fulfills the indicators of environmental sustainability concerning the energy sector given by the OECD 1993.

1. CLIMATE CHANGE AND AIR POLLUTION:

A) CO_2-EMISSIONS (POINT 1) AND GDP-EMISSIONS

On the 4th of May 2007 the IPCC (Intergovernmental Panel for Climate Change) published it's most recent study: It recommends the use of nuclear power to fight against climate change because it has the lowest CO_2-emissions of all electricity supplies.

To say that nuclear plants are free of CO_2-emissions is not true, but it is true that the emissions are lower than in other power plants.
The given table shows a life cycle analysis of the emissions of a nuclear power plant compared with other power plants.
Life cycle analysis means that not only the operating emissions are taken into account but also the emissions for the construction, disassembling and so on – thus the real CO_2-emissions



Source: National Geographic April 2006

Nevertheless the CO_2-emissions of nukes are low. A nuclear power plant can offset a high amount of CO_2 if it displaces energy got from other sources

Displaced energy source	**Reduction of CO2-emissions (in million tons)**
Coal	1,75
Oil	1,2
Natural gas	0,7

source of data: NEA-report of OECD

Looking at this data it also has to be taken into account that the carbon-emissions of the replaced energy sources are calculated with the emissions of today's technology. If the money that is used for doing research on nuclear power would be used to research on alternative technologies instead the figures might look quite different.

Even if the decision was made to build more nukes, the time necessary for getting the approvals and building them would be rather long, and the reduction of CO_2-emissions would come quite late for the fight against climate change..

B) EMISSIONS OF OTHER AIR POLLUTANTS

Concerning other air pollutants caused by nuclear power industry the SRU warns about radon-emissions from uranium mines. Due to ventilation the radon can get into the ambience. This contamination can last tens of thousands of years, even though the concetrations are small. Radon has a half-life of only 5 days, but the long-time contamination leads to an increase of the probability to get lung-cancer.

2. WATER POLLUTION AND LAND USE

There are several ways where the nuclear power industry can possibly pollute the environment:

- Uranium mining is likely to contaminate ground water as well as air. (SRU-report 2000, 501).
- Accidental leakages pollute the environment as well.
  (In former times the cooling water was taken directly from the river and the polluted water was returned into it - contaminated with sodium, arsenic and zinc. Today these techniques are (hopefully) not practised any more.)

3. Nuclear waste and nuclear fuel reprocessing

"Radioactive waste is a product primary of the nuclear power plant operations, but also results from medical, research and industrial applications." (citation World energy council report 2007 p. 25)

The energy density of nuclear power is very high: It is possible to extract 10.000 times more energy per unit mass from uranium than other technologies are able to extract from their source. So also the volume of waste is small, typically about 1 % of the overall toxic waste in countries with nuclear industry. (data: Nea-report p. 34)

"The generation of electricity from a 1000 MWe nuclear power station produces a few hundred cubic metres of low- and intermediate-level waste per year and some 30 tonnes of spent nuclear fuel (SNF). There are three general approaches of managing the spent nuclear fuel: reprocessing, direct disposal and temporary storage (until a suitable choice of disposal is made)."
(citation World energy council report 2007 p. 25)

To give an idea of how big that amount is the table below shows the quantities of spent nuclear fuel in the European countries.
The Czech republic ranks on place three with 29 tons per GWe and year.
The amount of low and intermediate lever waste amounts up to 300 m³ per GWe/a.

Country	Reactor type	Quantity of SNF per GWe/year [tonnes]
Belgium	PWR	20
Finland	LWR	26
France	PWR	19
Germany	LWR	19
The Netherlands	PWR	20
Spain	PWR	20
Spain	BWR	22
Sweden	LWR	21
United Kingdom	AGR	29
United Kingdom	PWR	25
Bulgaria	VVER	28
Czech Rep.	VVER	29
Hungary	VVER	30
Romania	CANDU	145
Slovakia	VVER	27
Slovenia	PWR	22

Source: World energy council report 2007, p. 27

It should be mentioned that this volume isn't the whole nuclear waste that has to be stored: it is only the waste from nuclear industry – it doesn't contain the huge amounts of residual material you get from producing plutonium for nuclear warheads. 52.000 tons of radioactive

spent fuel were left after the cold war in the US from producing 32.000 warheads. Russia had waste in similar magnitude.
The cold war is over, but for nuclear waste a few decades are like a blink of an eye, and the cleaning up of the remainders still takes place.
However, waste of nuclear weapons shouldn't be part in the decision whether nuclear power is sustainable.

The problem of the waste is not only its volume but rather its radioactivity and the special storing measures that are necessary for it.
Long term isolation from the biosphere is necessary. The probably best way to store the waste is deep underground in stable geological formations.
The Swedes plan to use steel containers "coated with copper, which won't corrode in the absence of oxygen, imbedded 1.800 feet in granite and surrounded by impervious clay to inhibit moisture transport. They expect this architecture to contain radioactivity for a million years." (citation from National Geographic July 2002)
The most intense radioactivity part only lasts a short time, that makes further storage easier. But nevertheless it has to be maintained for thousands of years, and it is hard to predict influences of for example wars or natural catastrophes for this long period of time.

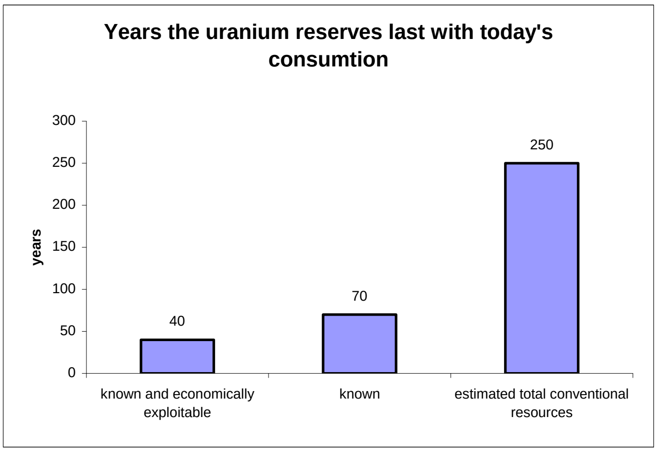
There are different radioactive elements produced in reactors, with different properties and half-lives: for example plutonium, caesium or strontium. The half-life for uranium 238 for example is 4.5 billion years. But also elements with short half-lives are problematic: the longer the half-life the less intense the radiation.

New technologies allow to convert the waste to fissile plutonium. This could expand the resource base by about 30 %. The recycled material then could be used as MOX (mixed oxide fuel) in light water reactors, as already deployed in Japan. (NEA).
But the recycling process of these generation IV systems is controversial:
A study of the German SRU declares that it is likely to make the waste problem even worse: For the recycling process fresh uranium has to be added continuously, and so more fission products than the required plutonium are generated. In addition the effectiveness of the resources declines rapidly with the increase of recycling cycles. (SRU 2000) The recycling also increases the probability of misuse for war purposes (Standard 31st of March 2007).
So the usage of MOX-fuel-elements is no long term solution as well.
In addition high investments would be necessary for these type of reactors – investments that could be used for the advancment of alternative energies as well.

5. Use of exhaustible resources

All nuclear power plants worldwide together need about 60 000 tons of uranium per year. But as crude oil uranium is a non-renewable resource: The proven and economically exploitable uranium reserves supply about 40 years of the current need – the total known reserves could last for 70 years. But if the number of nukes is going to increase, the demand will increase as well.

Like for crude oil the proven economically exploitable resources are not the total resources. Uranium is known to be existent in the earth's crust and these total resource (even though not found yet) are estimated to cover today's demand for 250 years. How much the extraction of these sources would cost is not clear yet.



Source of the data: NEA-report p 35

COLUMN 2: ECONOMIC SUSTAINABILITY

= Part Tomas, see presentation

COLUMN 3: SOCIAL SUSTAINABILITY/COMPATIBILITY

The fundamental idea of social sustainability is the following:
A state should be run in a way that conflicts can be solved peacefully

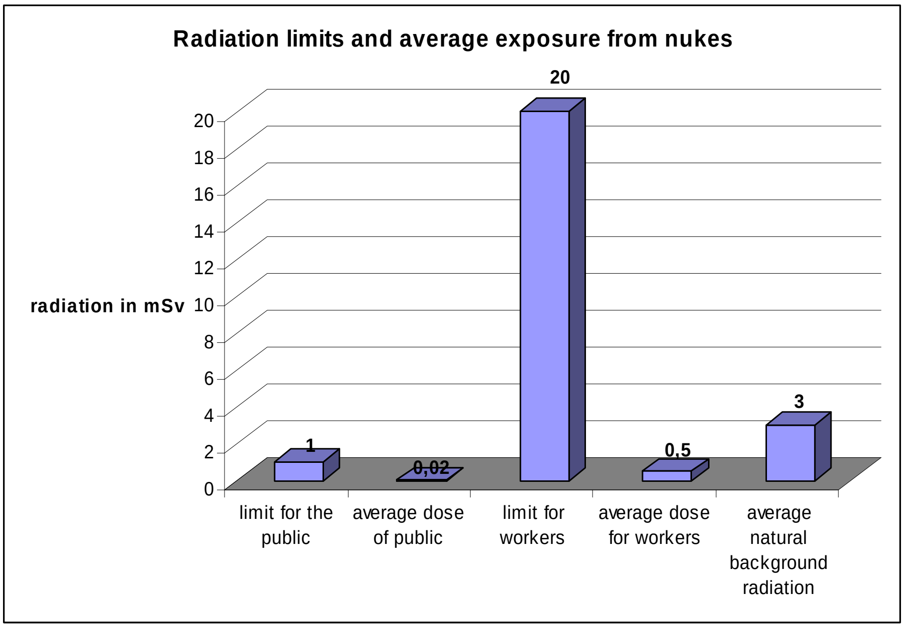
Indicators for social sustainability for nuclear power:
(OECD 1993 and Kopfmüller, Coenen 2000, S. 40 f)

1. RISKS FOR THE SOCIETY

A) RADIOACTIVE EMISSIONS:

Nuclear power plants emit radioactive material, which is harmful – according to the dose one is exposed to (like all other substances – even pure air can kill if breathed in too fast). There are radiation limits which minimize the health-risks – nevertheless they don't eliminate them totally.

Radioactive emissions of the routine operation of nuclear power plants are relatively small – as it can be seen in the graph below: the average doses the workers and the public are exposed to are smaller than the average impact of the background radiation.
There are two different limits for the radiation of nukes: One for workers and one for the public. The limit for workers is 20 times higher, but the average dose for workers is small compared to it.
Abutters of nukes are likely to get more harmful radiation from one day in the sun than from one year next to a nuclear power plant.



Source of data: NEA-report p. 35
The unit used is called Sievert, it is the equivalent dose of radiation which includes the harmfulness of radiation to human health as well.

But the standard operation of the plants isn't the only source of radioactive emissions: the main part is released by radioactive waste and its treatment. 59 % of anthropogenic emissions of radionuclides are cause by waste reprocessing – only 5 % by reactor emissions (Eurostat-environment-report 1999, p. 127)

B) RISK OF ACCIDENTS

The risk of an accident with core-damage is estimated to be below 10^{-4} per plant operating year for reactors in operation in OECD countries (that means on average one accident within 10 000 years within this plant). Taking into account the improved accident management the risk for somebody who lives near a plant to be exposed to a significant radiation release would be 10^{-5} per year (so every 10.000 years). (data from NEA-report p. 38)

New nukes are planned for which even in the case of such an emergency case off-site emergency plans (like the evacuation of the public) shouldn't be necessary any more. Human errors are further decreased by continuous training - and self-testing protection systems shall help to decrease the possibility of accidents as well.

But consider this: There are currently about 400 nukes working at the same time – which increases the probability of an accident among one of those by 400. And the security measures spoken above are not in use yet and the value of 10^{-5} per year is only valid for OECD countries. Murphy' law should still be considered: "Anything That Can Possibly Go Wrong, Does" (Sooner or later).

C) PROLIFERATION RISK (ABUSE AS NUCLEAR WEAPONS)

"Proliferation risk" means the possibility that nuclear material is used as supply for nuclear weapons.
In general, there are two types of base materials:

The first is highly enriched uranium, from which you can make an atomic bomb in the conventional meaning out of – thus a mass destruction tool. This material is quite hard to get.

The second possible kind of bomb is the so called "dirty bomb". For these kind of bombs you need only low-grade materials like nuclear waste. They don't have the destructiveness of their sisters but they are bombs as well and could also lead to mass panic. The base materials for this kind of bomb is quite easy to get - and substantial quantities of weapon-grade material already have been offered on the black market (National geographic Oct 2002).

This risk has a political as well as a technological aspect.
The political frameworks have to ensure that owning nuclear weapons is made unattractive to a state. The Non-Proliferation Treaty of Nuclear Weapons (NPT) for example commits 187 countries to renounce of nuclear weapons – in return they get the benefits of nuclear technology.

But the offered civilian military program can make it easier for the states to get the feed material for nuclear weapons. And even if a state holds to these rules, non-governmental institutions may abuse the actually peaceful application of nuclear power.

Another initiative, the "Nunn-Lugar-program" provides the former Soviet nations with assistance to prevent nuclear proliferation.
"Nunn estimates that Russia, working with help and financial assistance from the United States, has secured about 40 percent of the former U.S.S. R.'s nuclear materials in the last decade. The other 60 percent are not yet secured to American standards, but work continues" (citation from National Geographic Oct 2002)

Conclusion

There are some criteria of sustainable development that nuclear power fulfills partly, for example the reduction of greenhouse gas emissions:
The emissions are low but even if the decision was taken to build more nukes, the time necessary for getting the approvals and building them would be rather long, and the CO_2-reduction would come late. And for the fight against climate change it are fast measures that are needed – fast and sustainable measures...
The problems of radioactive emissions and accidents are quite low and could become even lower with technical progress – but especially the risk of accidents can never be wholly eliminated.
Uranium is still available as resource and in higher quantities than crude oil but it is exhaustible nevertheless.

The essential problems with nuclear power in my point of view are the waste and proliferation problems. Also with better storing techniques the waste must remain at its disposal for millions of years and accumulates. More nuclear power plants would make it accumulate even faster. Furhter more the waste is a relatively easy to obtain source for material to build nuclear weapons.

Considering all this I have to conclude that nuclear energy isn' a sustainable energy – the problem of climate change has to be solved in another way, a way that mainly reduces the need of energy instead of only producing more of it – a sustainable way.

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