NUCLEAR POWER AND SUSTAINABLE DEVELOPMENT

Mr. Stig Sandklef

President Vattenfall Fuel
SE-162 87 STOCKHOLM

INTRODUCTION

Nuclear Power is a new, innovative technology for energy production, seen in the longer historic perspective. Nuclear technology has a large potential for further development and use in new applications. To achieve this potential the industry needs to develop the arguments to convince policy makers and the general public that nuclear power is a real alternative as part of a sustainable energy system.

This paper examines the basic concept of sustainable development and gives a quality review of the most important factors and requirements, which have to be met to quality nuclear power as sustainable.

This paper intends to demonstrate that it is not only in minimising greenhouse gas emissions that nuclear power is a sustainable technology, also with respect to land use, fuel availability waste disposal, recycling and use of limited economic resources arguments can be developed in favour of nuclear power as a long term sustainable technology.

SUSTAINABLE DEVELOPMENT

World population is projected to grow to 10 billion people in 2050. Most of this growth will occur in developing countries where the future generations have a right to improve their quality of life, have enough food, clean water, clean air and an environment which is not polluted to the extent it is today. Releases of greenhouse gases must be reduced even from current levels to avoid climate change. Developing countries will suffer disproportionately from the affects of climate change, as it will cause problems in basic areas such as their ability to grow enough food to take care of their growing population.

Agenda 21, adopted at the Rio Conference on the Environment and Development in 1992 notes that "energy is essential to economic and social development and improved quality of life.etc. All energy sources will be needed to use in ways that respect the atmosphere, human health and the environment."

Preparing the Ground for Renewal of Nuclear Power, edited by
Kursunoglu *et al.* Kluwer Academic / Plenum Publishers, New York 1999.

We all realise that these prospects pose enormous challenges on sustainable development and particularly on the systems for energy production, distribution and use that will be needed in the future. We need to examine the requirements for future energy systems in this context and within the concept of sustainable development. In 1987 the Brundtland Commission gave the generally accepted definition of sustainable development as follows:

"Development that meets the needs and aspirations of the present generation without compromising the ability of future generations to meet their own needs"

When measuring sustainability for energy production against this principle the following factors should be considered:

- Fuel availability and use
- Land use
- Environmental effects of waste disposal
- Recycling possibilities
- Availability and competitiveness, including external and social costs
- Climate change

Let us examine these factors applied to nuclear energy:

FUEL AVAILABILITY

Uranium is the basis for nuclear fuel. There are abundant reserves available and they have no other constructive use. The natural biological cycles rely on hydrogen, oxygen, carbon and nitrogen. The use of uranium does not interfere with any of these natural cycles and therefore leaves these valuable resources for other uses. Today estimated reserves of uranium equal about 250 years of consumption, with recycling of uranium and plutonium this figure can be extended to 10,000 years.

There are known and estimated additional reserves of uranium which would extend this figure even further allowing for significant increases in nuclear programmes and still maintain, what is in practice an unlimited fuel resource base.

Table 1. Fuel Availability. Estimated Uranium reserves

Category	Mio tU	Years of present consumption
Stocks	0.2	3
Weapons materials	0.6	9
Known in ground	4.5	70
Estimated in ground	11	170
Estimated in phosphates	22	340
Sea water	4 000	60 000

We can conclude from these figures that uranium availability does not restrict the use of nuclear power now or in the longer term even with significant increases of nuclear programs. Even if costs for uranium would increase by a factor of 10 it would still be less expensive than any of the competing fuels.

Uranium is found in abundance in a number of politically stable countries such as Canada and Australia. Trade with uranium producers is very stable, and most European utilities have long term contracts with very little price fluctuation, and maintain inventories of one to three years worth of nuclear fuel, preserving security of supply.

The energy intensity of uranium is beneficial from an environmental point of view:

* 1kg of firewood produces about 1 kWh(e).
* 1kg of coal produces 3 kWh(e)
* 1kg of oil produces 4 kWh(e)
* 1kg of uranium produces about 50,000 kWh(e)

The volume of nuclear fuel, its transport, land use, storage and quantity of waste, are all much smaller than for fossil fuels.

One tonne of uranium produces as much energy as 17.000 tonnes of coal. CO_2 equivalent emissions for the entire nuclear fuel cycle - from uranium mining to waste disposal - range from 10-50 g/kWh which is about the same as for wind power. Comparable factors for the fossil fuel cycle range from 450 to 1200 g/kWh.

Nuclear power plants can make a future contribution to sustainable development by burning nuclear weapons material to generate electricity. The incorporation of weapons material into nuclear fuel in civil reactors will reduce the risks of proliferation and global security is improved. The material would no longer have weapons potential, because in the commercial fuel cycle it is mixed with uranium and surveyed by IAEA and in Europe by EURATOM safe-guards.

The costs of nuclear fuel for an operating nuclear power plant are only about 8 to 12 percent of total generating costs, a minor expense when compared to the 60 percent of the cost of natural gas in gas fired power plants.

LAND USE

Regarding land use, for comparison purposes a 1000 MW plant was selected. A nuclear site requires 1-4 km^2, a solar or photovoltaic park requires 20-50 km^2, a wind field 50-150 km^2 and for biomass 4000-6000 km^2. Even then a solar or wind park will only have availability factors ranging between 20-40% while Swedish nuclear plants are averaging around 78% in 1997.

Apart from the fact that solar and wind can only be used in places where conditions are favourable and consequently require investments in back up production capacity, the enormous land requirements of biomass make its use in a large scale possible only in countries sparsely populated and with favourable climatic conditions. Many developing countries simply can not afford to set aside large areas for biomass production when the highest priority for land use is food production.

There are projections that in 2050 half of the world's population will live in large cities. This emphases the need for concentrated energy production systems and in practice the large scale use of wind, solar and biomass for the energy needs of these large cities are ruled out. Large-scale use of biomass will be restricted to countries where climate and low population density allow the extensive land requirements (Sweden, Canada, Russia and a few more). The fact that nuclear energy requires a minimum of land will be a strong factor in favour of nuclear power in the future.

ENVIRONMENTAL EFFECTS OF WASTE DISPOSAL

A comparison of the amounts of waste generated by the operation of 1000 MW-nuclear and coal fired power plants results in the following figures:

7.000 tons of coals are need per day or about five trains loads. The nuclear plant will use about 80 kg of uranium per day. Even with sophisticated clean coal technology the coal plant will emit per year about

* 900 tons of SO_2
* 4500 tons of NO_x
* 6.5 million ton of CO_2
* 400 tons of various heavy metals including arsenic and mercury.

The nuclear plant will produce about 20 tons of spent fuel per year. The industry always works to contain any radiation, whether in the fuel rod, in the reactor during operation, or in an engineered barrier system for waste.

If, throughout the lifetime of an average citizen of an OECD country, all of the electricity he or she used were to be generated by nuclear fuel, the vitrified high level waste produced is about the size of a kiwi fruit. Radioactivity decays over time, toxic materials like heavy metals last forever.

Waste is generally managed in two ways, it is either contained or dispersed. Because of the large quantities of fossil fuel waste, such as greenhouse gases, most of this waste is dispersed directly into the atmosphere because there is no practical alternative. Nuclear waste quantities are sufficiently small that our industry can to manage its waste through containment. The principle-disposal options are in surface-based engineered facilities or in previously mined areas or in deep geological repositories.

In many countries, the industry needs to convince the public and politicians that major progress in handling, treatment and storage of nuclear waste has been made in recent years. It is the view of the European nuclear industry that there are no outstanding technical issues to be solved in the industrial management of radioactive waste. European industry has the technological lead in this area, as both reprocessing and direct disposal methods have been demonstrated.

Economically our waste management programmes should give nuclear a competitive advantage over other forms of electricity generation. The nuclear industry's waste has always been accounted for and taken care of. It has never just been released into the air.

An OECD/NEA study which as assessed the costs of waste management concluded that costs ranged from 0.4 to 1.8 mills per kWh compared with total nuclear generation costs for new plants, in the same countries, ranging from 28 to 54 mills per kWh. Therefore we can conclude that waste generation is both minimal and not a determining factor in total generation costs.

In the UK which was the first country in Europe, using nuclear power, all the radioactive waste produced from all sources by 2030 will be equivalent in volume to about three weeks' worth of British garbage. 90 percent of this nuclear-related waste is low-level waste material, which is only slightly contaminated.

Financial reserves are accumulated for decommissioning and waste storage facilities, through electricity prices in most European countries, as part of the provisions of the industry to finance both the handling and treatment of waste as well as the later decommissioning and dismantling of the nuclear facilities. This practice is based on another criteria of sustainability: that the people who have benefited from the electricity should also be responsible for the waste management.

Technically the industry has demonstrated its ability to condition all forms of nuclear waste for storage and to complete geological repositories needed for the final disposal of nuclear waste.

RECYCLING POSSIBILITIES

Industry recycling of its spent fuel contributes to waste reduction. Even though spent fuel from power plants can be safely disposed of, as high level waste, it contains large amounts of energy. 97 percent of the total volume may be recycled, thereby replacing the need for a corresponding new production of uranium fuel. By recycling uranium and plutonium as reactor fuel up to 60 times as much of the energy content can be utilised in fast neutron reactors. This technology is available and already used on a large scale in some countries. The industry is also committed to reducing waste volumes by compacting, drying and burning in incinerators.

AVAILABILITY

Nuclear technology is not only available today and demonstrating its environmental and cost benefits in many countries, there is also a dynamic development of evolutionary and new reactor concepts in several countries.

There are 428 reactors, representing 344 774 MWe in operation in the world today and 30 reactors under construction, making nuclear power the third largest electricity generation technology in the world.

New reactor designs have been or are being developed to meet the needs of future nuclear power expansion. The EPR (European Pressurised Reactor)' and similar developments for a European Boiling Water Reactor, the ABWR (Advanced Boiling Water Reactor) in Japan and the US and CE 80+ (an advanced pressurised water reactor) in Korea and the US may serve as examples of a dynamic development.

COMPETITIVENESS

A key factor to achieve sustainable development is the economic use of available resources including financial resources.

There are risks associated with any industrial activity. There are also risks associated with a lack of sufficient energy production sources. In the poorest countries 25.000 children die every day because of a lack of clean water, a problem which could be remedied with pumps, purification facilities and the energy to operate them. There have been a number of studies of the comparative risks of electricity production. A recent example by the OECD/NEA demonstrates that the latent risks of disease or accident from coal based electricity generation is 100 times more dangerous than the operation of a light water reactor in normal conditions.

The full external and social costs of any energy production technology should be taken into account, thereby including environmental effects for the entire fuel chain and occupational as well as public effects on a local, regional and global scale. Extensive studies are carried out to quantify these external costs and even if results are still uncertain the assessments can highlight the basic characteristics of different energy production technologies. The comprehensive ExternE project, carried out by the European Commission in collaboration with the US Department of Energy examined externalities for complete energy chains and the results are shown in the following table.

Table 2. Total costs of electricity production in cECU/kWh

Technology	External costs	Operating, fuel, financial costs	Total
Coal	2.0	5.0	7
Oil	1.6	4.5	6
Gas	0.36	3.5	3.9
Wind	0.22	6.0	6.2
Hydro	0.22	4.5	4.7
Nuclear	0.04	3.5	3.5

The operating and financial costs of the different technologies vary in different countries depending on local conditions, assumptions on interest rates etc.

The external costs of nuclear power cover the potential costs of large accidents taking into account the low probability of such accidents.

In general hydro and natural gas with modern technology and nuclear are very close for most scenarios counting only operating and financial costs. Taking into account the external costs given above natural gas and nuclear are the most favourable options.

Estimates of external cost of CO_2 emissions (climate change effect) are very uncertain and range from 10 to 25 USD/ton coal. Assuming 15 USD/ton coal gives an external cost of 0.5 cECU/kWh for coal and 0.3 cECU/kWh for natural gas (included in table 2). The upper value would increase these figures with more than half. This leaves nuclear power as the most economic alternative when all costs are taken into consideration.

CLIMATE CHANGE

Up to 75% of the CO2 emissions from human sources in the atmosphere are caused by the burning of fossil fuels; coal, oil, and gas and the main remaining component is the deforestation in the large rain forests.

As stated above, the use of nuclear energy results in a release of CO2 equivalents comparable to those of wind power and orders of magnitude less than the burning of fossil fuel.

Nuclear energy and hydropower are the only major sources of essentially carbon-free, economic electricity generation, which could be expanded today at a significant scale.

While our scientific understanding of global warming continues to grow, it is important to rely increasingly on those sources of electricity which do not contribute any greenhouse gases to the atmosphere, like renewables and nuclear energy. In the European Union and other developed areas of the world, continued reliance on electricity must be a key component of any sustainable development policy. A balanced energy policy, involving the reduction of fossil fuel use, a focus on energy conservation and efficiency improvements, and an increasing reliance on non-greenhouse gas emitting energy sources, will lead to fewer environmental hazards, while maintaining our standard of living.

ENERGY SCENARIOS

Any projection for long term energy use must take into consideration the large unbalance between industrialised and developing countries of today and the strong driving forces, both in terms of population growth and demand for improved living conditions. Any projection for the longer-term future will predict significantly higher figures for energy consumption.

The World Energy Council/IIASA has recently published scenarios, which are summarised in table 3.

Table 3. Energy Scenarios until 2050

	Unit	Today	2050
World population	billions	5.7	10
World primary energy	Gtoe	8.4	20-25
Share of fossil fuels	%	90	59-73
World electricity gen.	Twh	13 000	31 000-42 000
Share of nuclear	%	17	11-38
Carbon dioxide Emissions	GT	24	34-55

The scenario with the lowest emission rate for greenhouse gases (34 GT compared with to-days 24) does not meet any of the objectives set in Kyoto. In the high nuclear scenario (38% of 42000 Twh) there is a growth of a factor of 6 while the low nuclear scenario practically maintains to-days capacity. An increase of nuclear power capacity by a factor of 6 is not in itself enough to reduce climate change. But it must be clear to everyone that a significant increase in the use of nuclear energy is a vital part of any long term energy policy. And it can be done. The industry has the capacity to expand.

CONCLUSIONS

I have demonstrated that nuclear power is in all aspects a sustainable technology, which could serve us in the long term with minimal environmental effects and at minimum costs to the society. And the challenge can be met.

But to achieve it we need political leadership, to support and develop the institutional and legal framework that is the basis for a stable and long-term energy policy. And we need industry leaders to stand up for nuclear power, to create a new industry culture of openness and communication with the public that is necessary to get the public acceptance that we have failed to do so far. The basic facts are all in favour of nuclear power. We should use them!

I want to acknowledge the valuable help from Linda Gunter, FORATOM and Carl-Erik Wikdahl, Swedish Atomic Forum in preparing this paper.