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Nuclear Power in Sweden, Finland and Europe

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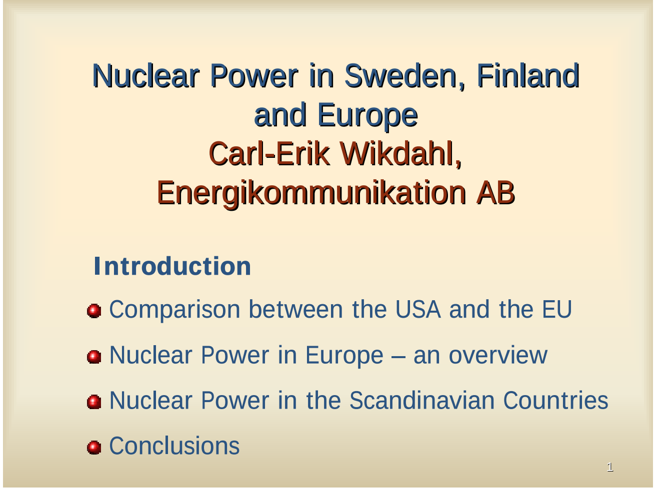
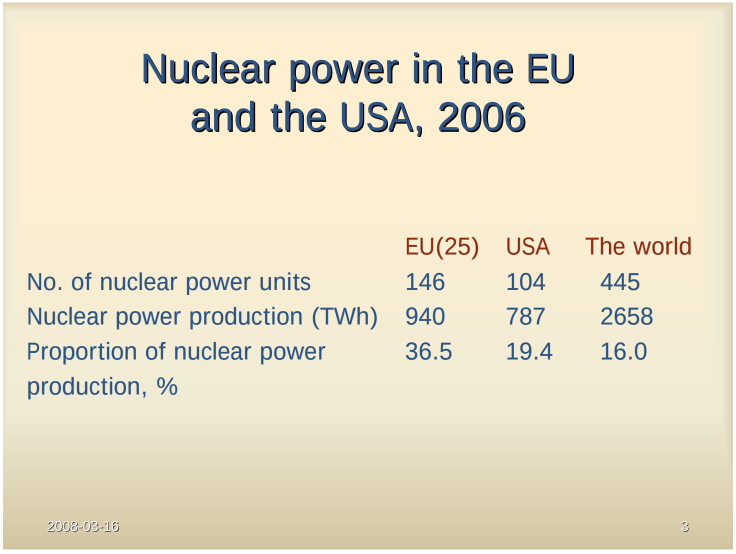


There is a particular significance in presenting a lecture on nuclear power in Chicago.

I would like to start by remembering the pioneer, Enrico Fermi who, in December 1942, achieved the first self-sustaining chain reaction in Chicago Pile One. It marked the start of an enormous technical development, which has made it possible for the world to produce electricity on a large scale in a manner that does not affect the climate.

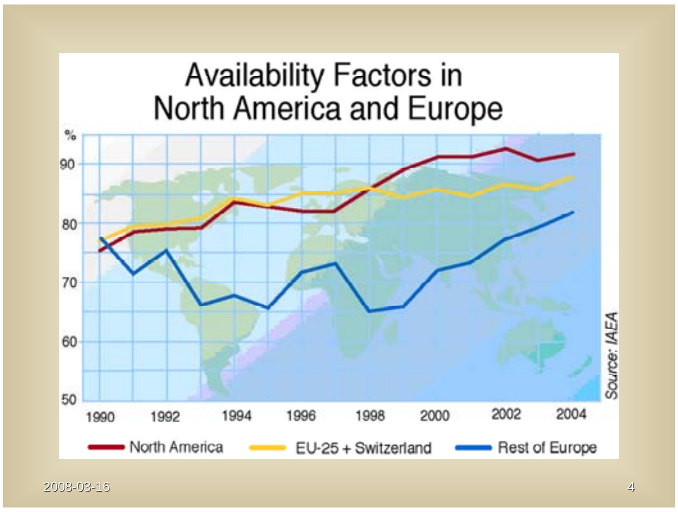
My presentation starts with a brief description of the status of nuclear power in Europe, but then I will concentrate on the Scandinavian countries in more detail, and particularly on Sweden and Finland, which have successful records of nuclear power operation going back many years.



However, I would like to begin with an up-to-date comparison between the USA and the EU. The EU 25 refers to the existing European Union which was expanded to 25 member countries in 2004.

The European Union includes a major nuclear power contribution, to the extent that more than a third of electricity production is from nuclear power. In the US about 20 % comes from nuclear.

Quality of nuclear power is normally measured by means of safety record and availability factors. The availability of a reactor or all reactors in a country is measured as the actual operation time during a year in % of a calendar year.



Both the EU and the USA have seen a significant increase in the availability of reactors. For the last ten years, the USA has been a leader in this respect, with average values over 90 % for several consecutive years. The rest of Europe, i.e. mainly Russia, has a clearly lower availability.

Nuclear power in Europe: an overview

Most European countries today employ nuclear power production, with the exception of Norway, Denmark, Poland, Portugal, Turkey, Italy, Greece and some other countries.

In historical terms, there are major differences in quality and political support for nuclear power between countries. The typically strong and successful programmes are those of France, Sweden and Finland. The earlier Italian programme was not tackled seriously, and showed major shortcomings. All the reactors are now closed. The British programme has largely been based on small gas-cooled reactors, with poor operating economics. The German programme was originally strongly technical, but has lost some of its edge in the face of political opposition.

France

France has the highest proportion of nuclear power production of any country in the world, obtaining more than 75 % of its electricity production from nuclear power. The country has 59 reactors in operation, and a further one under construction. Much of its nuclear power production, amounting to almost 20 %, is exported to other countries, such as Italy, Portugal, Belgium and the UK.

The most recent nuclear power unit, a PWR of French design with a power level of 1600 MW, was ordered in 2006 and is expected to be ready for start-up in 2012. A large number of new reactors are planned in France, partly as replacements for the oldest reactors, which have been in operation since the middle of the 1970s.

The new type of reactors is called EPR – European Pressurized Reactor - is designed and marketed by Areva, which is a joint operation between French Framatom and German Siemens. EPRs have also been sold to Finland (in 2005) and recently to Saudi Arabia. EPRs will also be marketed on the British and American markets.

By far the largest power utility in France is EdF, which is wholly owned by the French state. Framatom is the main owner of Areva, and is in turn 90 % owned by the French state.

France has its own facilities for uranium enrichment and for reprocessing of used fuel.

There has been extensive development work of advanced reactors in France for many years, with the aim at present of starting a prototype of a sodium-cooled breeder reactor in 2020. The detailed design of this reactor will be settled in 2012.

Germany

The nuclear power situation in Germany is at present opposite to that of France. Germany originally had a strong nuclear power programme, concentrating mainly on light water reactors. It also invested at an early stage in development of gas-cooled high-temperature reactors, HTGRs. This work is continuing now in South Africa, where a prototype of the so called pebble bed reactor is being constructed.

With the reunification of Germany in 1990, all the reactors in the former East Germany were closed, as they were not regarded as meeting basic safety requirements. There were five PWRs (VVER-440), originally designed in the Soviet Union.

Germany now has 17 nuclear power reactors, producing 33 % of the country's electricity. 55 % is produced from coal, and 5 % from wind power. All reactors have been built by Siemens-KWU, and no new nuclear power plants are under construction or planned.

There was originally political agreement on an ambitious nuclear power programme. However, the Chernobyl accident resulted in loss of this unity. The Social Democratic Party (SPD) - then in opposition - decided in 1986 that German nuclear power production should be phased out.

In 1998, the Social Democrats and the Green Party achieved a majority in parliament, and formed a coalition government. There was extensive opposition to nuclear power in Germany during the 1990s, at times with a militant element, with the grass roots resistance increasing after the change of government. Fuel transports from overfilled spent fuel pools in the nuclear power plants to the French reprocessing plant at La Hague were stopped many times by nuclear power opponents who chained themselves to the rail tracks.

Against the background of a real threat of several nuclear power plants being forced to close, the German nuclear power industry reached an agreement with the government. It was very much a last-ditch agreement, involving the progressive closure of nuclear power production facilities on 'market terms'.

The agreement meant that the nuclear power industry itself determines which reactor is to be closed, and when. However, the entire phase-out must be achieved within an overall time frame. The only reactor that has been closed in accordance with this agreement is Obrigheim, a small PWR, which started operation in 1965, and was closed in May 2005. No compensation has been paid by the State to the power utility.

The power companies are now hoping that the average permissible life of 32 years will be increased to 40 years, and then why not to 60 years, as in the USA.

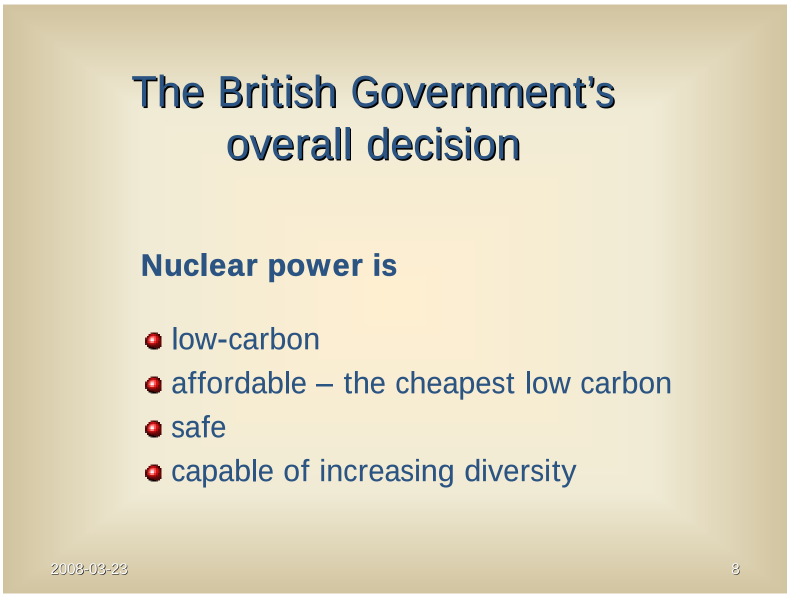
Unless German nuclear power policy is changed, the final power station is due for closure in 2022.

For an outsider, like me, pressure of climate considerations would seem to make it impossible for Germany to phase out one-third of its power production within the next 15 years, while at the same time also reducing power production from coal. To this must be added the fact that public opinion now is against the phase-out policy: in 2007, 61 % were against phase-out of nuclear power production, while 34 % supported the government's nuclear power policy.

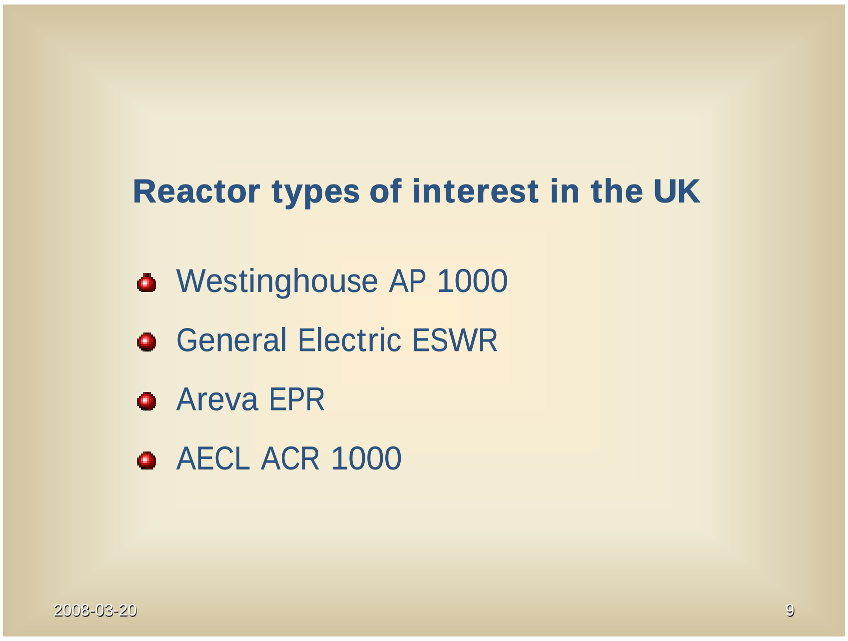
The UK

The development of nuclear power production in the UK started at an early stage, with the first power station being started up in 1956. This was a gas-cooled reactor, using natural uranium as the fuel and graphite as the moderator. A large number of reactors of this type have been built since, although most of them have now been closed. All the reactors were small, with outputs of about 300 MW, and with poor operating economics. An advanced gas-cooled reactor was developed, and about a dozen such reactors are now in commercial operation. The most recent reactor to be commissioned was a PWR with an output of 1200 MW.

A fundamental political review of the British energy programme was carried out in 2007, in response to the climate threat, and the result was presented in a White Paper in January 2008. The front page of the report can be seen on the picture.



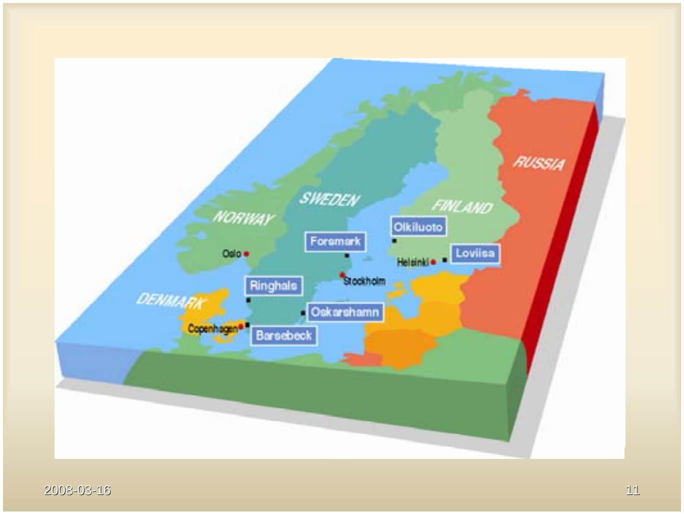
The British Labour government's new decision represents a complete U-turn from the earlier attitude towards nuclear power. The Government now says that nuclear power is low- carbon, affordable, safe and with advantages in a long perspective.



The first reactor order under the new programme is expected to be placed in 2009, for start-up in 2015. This means that the programme is parallel to that of the USA in time terms. Two American reactors, one French and one Canadian are of interest.

Spent fuel has previously been reprocessed in the UK, but the new policy means that all the spent fuel from new reactors will be sent directly to a final repository.

The Scandinavian countries



Nuclear power programmes and political attitudes towards them are controversial in the Scandinavian countries as well. Sweden was the first of these countries to have a commercial nuclear power programme, with the first unit started up in 1972, after which a total of twelve have been started. There has been strong political opposition to nuclear power since 1979, when the Three Mile Island accident occurred.

Finland started later, building up a strong and successful nuclear power programme based on four reactors. A further unit was ordered in 2004. At present, further orders are being discussed.

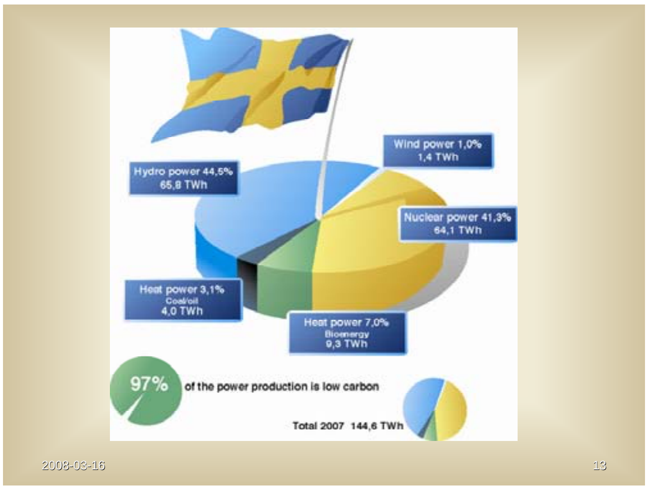
Denmark has never had any plans for nuclear power production: on the contrary, the country has constantly and severely criticised Sweden's two reactors close to the Danish border.

The oil nation of Norway has had a research and materials testing reactor for many years, but has no need of nuclear power production in a country where production is dominated by hydro power and some gas power.

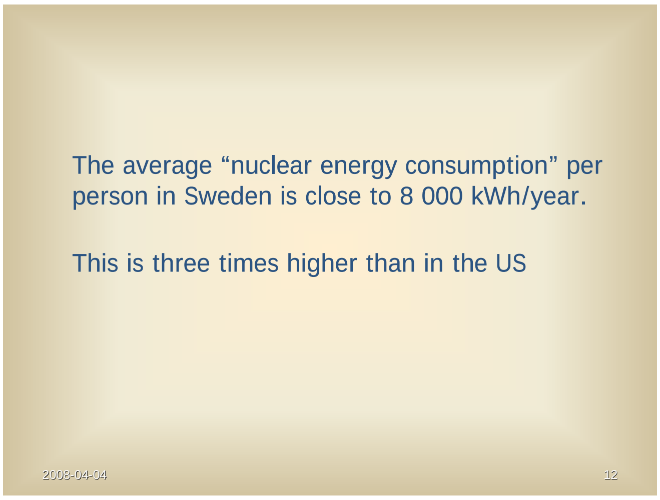
However, Norway has very large deposits of thorium, which could be used as a nuclear fuel. There is at present a discussion on thorium for a new export item when the oil starts to run out. As a result, nuclear power is a hot topic in the present energy debate in Norway. As yet, no decision has been made on any future concerning nuclear power.

I'd like to describe the situation in Sweden and Finland in more detail.

Sweden



As you can see on the picture almost 90 % of Sweden's electricity is produced from hydro power <u>and</u> nuclear power, with both producing about equal amounts. The remainder is produced by fossil power, biofuels and wind power. Thus, power production is almost carbon dioxide-free in Sweden.

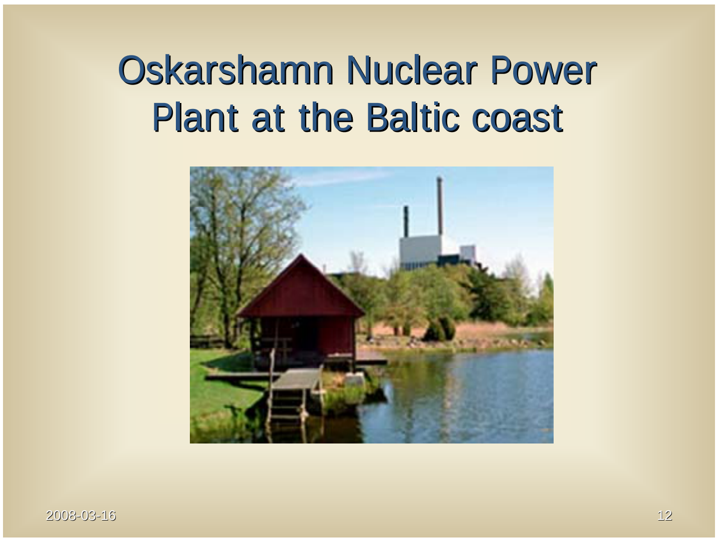


With almost 50 % nuclear and a very high specific per-capita electricity use, Sweden has the highest per-capita use of nuclear energy in the world – almost 8000 nuclear kWh/year. This is somewhat more than in France, and three times as much as in the USA.

Research and development in the nuclear power sector in Sweden started at the beginning of the 1950s. The first experimental reactor was commissioned in 1954, followed by the first power-producing reactor in 1963. The reactor was a heavy water type, fuelled by natural uranium. It was followed in a few years by an advanced boiling heavy water reactor for power production. However, it never started up, as it was found that the design included weaknesses which would be too expensive to rectify, and at the same time it was realised that this type of reactor would never become competitive against light water reactors.

It is obvious that there was political interest in planning the development of Swedish nuclear weapons during the 50s and early 60s. This interest concentrated attention on the combination of natural uranium, which could be mined in Sweden, and heavy water, which could be imported from Norway. It must be emphasised that no decision was ever reached on the manufacture of nuclear weapons. However, detailed technical and scientific knowledge was built up, showing how plutonium produced in heavy water reactors could be used as a weapons-grade material.

In 1964, the American government offered for the first time to perform toll enrichment of uranium for use in commercial power reactors in other countries. This decision was of decisive importance for the orders for BWRs in Sweden in the following year and a death blow to the Swedish Line, which included an ability to develop the country's own nuclear weapons.

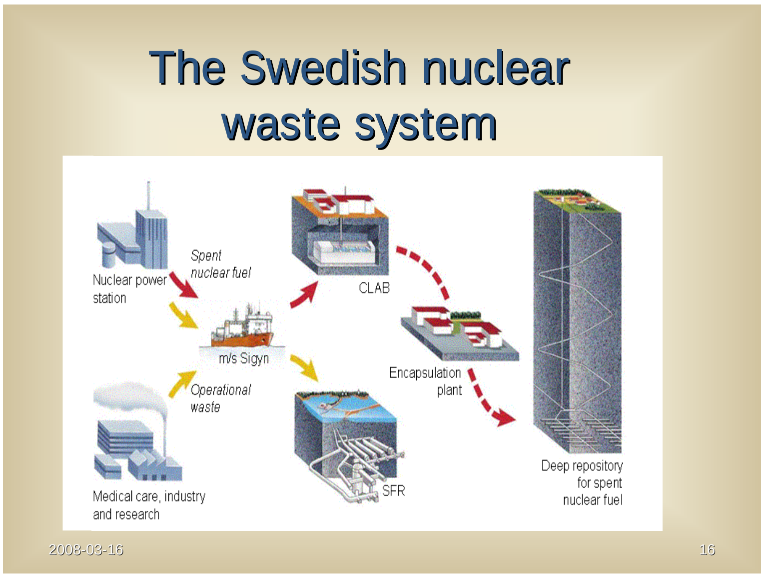


In parallel with the state's efforts to establish what was known as the Swedish Line, i.e. reactors based on natural uranium and heavy water, a private power utility was working on a project including the first BWR in Sweden. ASEA Atom, later under the name of ABB Atom, and now owned by Westinghouse, designed its own BWR, without requiring any license from General Electric. In 1965, the privatised utility OKG AB signed a turnkey contract with ABB Atom for a 440 MW BWR at the Oskarshamn site for delivery in 1972.

In total, ABB Atom built eleven BWRs, of which nine are in Sweden and two in Finland. All had high availability as long as they were in operation. However, two of the Swedish reactors were closed in response to political decisions. It is likely that the remaining BWR reactors - seven in Sweden and two in Finland - will have lives of 60 years.

At the Ringhals Nuclear Power Plant there are three PWRs of Westinghouse design.

Sweden was the first country in which nuclear power became an important issue among the political parties. This started prior to the 1976 elections, just when a very large nuclear power expansion programme was in full swing. Before the election, the leader of the opposition called for a stop to the fuelling of any further reactors until the question of disposal of nuclear waste had been solved. The post-election result was a compromise, which allowed all the power stations then under construction to be started up but the programme was somewhat delayed.

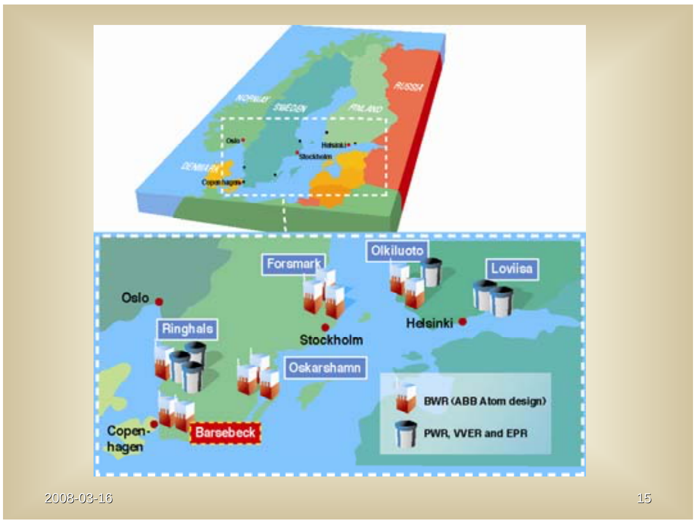


The power industry, for its part, started a very wide-ranging technical development work in order to identify acceptable methods for final storage of spent fuel. The result was KBS-3, a project that was presented for the first time in 1983. A major programme of research has been carried out since then, with the most recent report being submitted to the reactor safety authorities in the autumn of 2007.

The waste project includes a central intermediate storage for spent fuel (CLAB) in operation since 1986, a final repository for operational waste (SFR) in operation since 1988 and a 500 m deep final repository for spent fuel to be built in the future.

Two possible sites for a final repository have been investigated in detail. Both are in the vicinity of existing nuclear power stations: one in Oskarshamn and the other at Forsmark. During 2009 the power industry will indicate which of these two sites has been selected.

It should be added that public opinion surveys in the towns in the neighbourhood of the two plants, indicate widespread acceptance of the project. The percentage of residents who say that they are in favour of a final repository has increased in both municipalities during the site investigation period. In the 2007 survey about 80 % of the population were in favour of a final repository in their own municipality – or in other words in their own back yard.



Nuclear power stations were political dynamite in Sweden during the second half of the 1970s, with divisions appearing along party dividing lines in Sweden long before they appeared in other countries. The main emphasis of the debate was on disposal and storage of nuclear waste, although reactor safety also came into the picture. A particular problem was presented by the fact that the two Barsebäck reactors on the south coast were only about 20 km from Denmark's capital of Copenhagen. This remained a constant problem over the years, with opposition to nuclear power steadily increasing in Denmark and focused on Barsebäck.

The planned nuclear power programme in the end of the 1970s consisted of twelve reactors, of which six were in operation and two were almost completed. The remaining four had been ordered, and some work had started. Opposition was gradually declining, until the Three Mile Island accident occurred in March 1979. A referendum on nuclear power had been discussed for several years, but after the accident it was no longer possible to put it off, with the result that a referendum was held almost exactly a year after the accident, in March 1980.

The Parliament’s interpretation of the result of the referendum was that the planned programme of expansion of nuclear power to twelve units could be completed but that, in the longer term, nuclear power production should be phased out. With a calculated technical life of 25 years, it was decided that the entire Swedish nuclear power programme should be phased out by not later than 2010.

Nuclear power continued to be a political hot potato during the 1980s and 1990s. However, in the middle of the 1990s, Parliament decided that the previous decision, of total phase-out by 2010, no longer applied. Instead the political focus was on closing some units as soon as possible. The result was that Barsebäck 1 was closed in 1999, and Barsebäck 2 in 2005.

The two Barsebäck reactors were closed as a result of a government decision, therefore the government was forced to pay full compensation to the owner of Barsebäck. This was a very expensive decision for the Swedish state.

I believe that the remaining ten nuclear power units will be allowed to continue in operation as long as the power utilities regard it as economically justifiable to continue their operation, probably to an age of 60 years.

Outputs of Swedish nuclear power reactors

Reactor	Type	Original power level MW	Current power level MW	Planned power level MW	Total uprating % by year 2012
Forsmark 1	BWR	900	1014	1134	20
Forsmark 2	BWR	900	1014	1134	20
Forsmark 3	BWR	1100	1190	1360	25
Oskarshamn 1	BWR	460	487	487	6
Oskarshamn 2	BWR	580	623	840	35
Oskarshamn 3	BWR	1100	1197	1450	29
Ringhals 1	BWR	750	880	880	12
Ringhals 2	PWR	785	870	920	9
Ringhals 3	PWR	915	1010	1110	14
Ringhals 4	PWR	915	915	1160	19
Total		8440	9240	10465	24

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To date, the total output from the Swedish nuclear power stations has been increased by 800 MW, or 9 %. Projects are at present in progress in all the power plants for further increases in output. Over the next few years, installed nuclear power capacity will increase by a further 1200 MW, or 13 %, which is almost as much as was lost through closure of the two Barsebäck reactors. The total power uprating by 2012 at the ten reactors now in operation will be almost 25 % compared to the originally installed capacity.

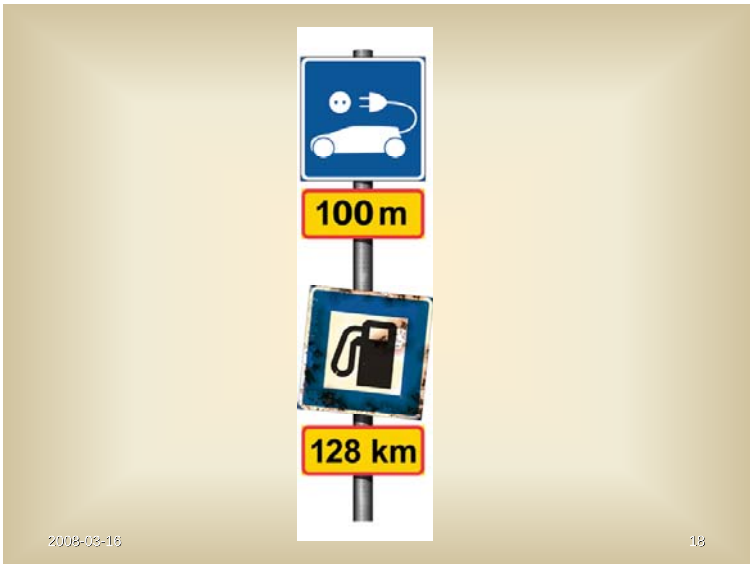
This means that the expected increase in the use of electricity in Sweden over the next few years can be met by increased production from carbon dioxide-free nuclear power.

Swedish legislation bans the construction of new nuclear power stations. The Social Democratic Party, which is now in opposition, is still committed to a progressive phase-out of the present nuclear power production capacity as increasing production from renewable energy sources (wind and bioenergy) allows reactors to be closed.

There are some signs today that some of the larger political parties might modify their views on new nuclear power capacity prior to the Parliamentary election in the autumn of 2010. This includes the Social Democratic Party, which is essentially deeply divided in its attitude towards nuclear power.

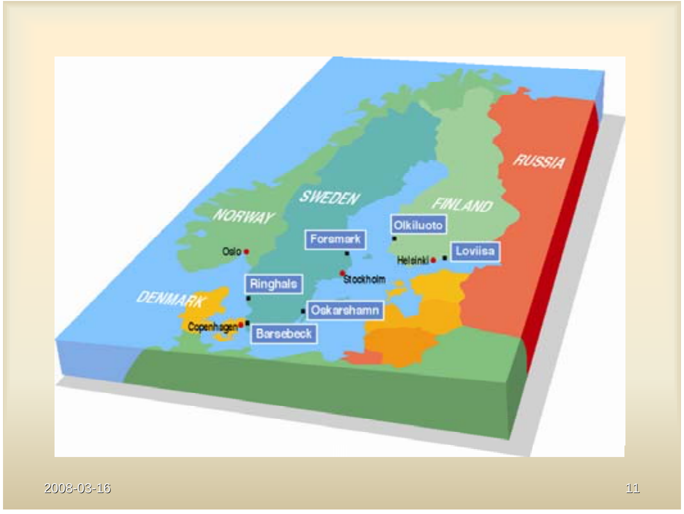
My own political analysis is that it is possible, verging on probable, that there will be a change in the attitude to nuclear power within one or two years. One of the reasons for my optimism is that public opinion surveys show a clearly favourable view of nuclear power, and an increased awareness that nuclear power is a sustainable energy source with low carbon dioxide emissions.

There are at present no concrete plans for expansion of nuclear power in Sweden by the power utilities. However, if there is a change in energy policy, the power industry will start planning new nuclear power stations. They will be needed in the longer term, not only to replace the oldest power stations, but also to permit the export of carbon dioxide-free electricity to Denmark and Germany, where most electricity is produced from coal.



Finally, still on the horizon, the power industry is preparing to meet the need to increase the production of electricity to allow a large-scale transition to electrically powered vehicles.

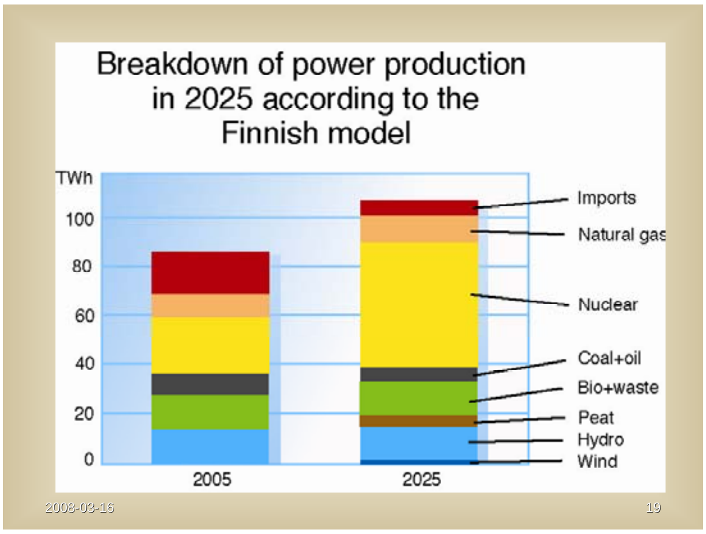
Finland



I would like to conclude my review of nuclear power in Europe with Finland. Admittedly, this is a small country, with only four reactors in operation, but it is where things are happening. The country is building another nuclear power station, and has come a long way in planning for ordering one or two further new plants. Nor is the country afraid of new technology: the first EPR reactor was ordered in Finland.

Per-capita use of electricity in Finland is high, as it is in its Swedish neighbour: More than 15 000 kWh/year in both the countries, somewhat higher in Finland than in Sweden. The use of electricity is about 30 % higher than in the US.

Finland's neighbours are Russia in the east and Sweden to the West. The country's energy policy is to reduce the import of electricity and gas from Russia and other neighbouring countries, to reduce carbon dioxide emissions, and to minimise energy costs. The targets for these aims can be seen in the next diagram. It shows the situation in 2005 and the planned power production system in 2025.



The country now imports about 20 % of its electricity, which proportion is to be reduced to about 5 % by 2025. This will be done by increasing the proportion of nuclear power generation, hydro-power generation and bioenergy, while at the same time reducing energy production from coal. At present, almost 30 % of the country's electricity comes from nuclear power.

Let's go back a few years to the time when nuclear power production was introduced to Finland. The country surprised the Western world at the beginning of the 1970s by ordering two PWRs of Soviet design, the VVER 440. The Finnish nuclear power designers and engineers realised from the start that the control systems were inadequate, and therefore ordered control equipment from Siemens in Germany. The two reactors, Loviisa 1 and 2, started commercial operation in 1977 and 1980 respectively. As early as the 1980s, these two hybrids were exhibiting excellent operational performance, with availabilities of 85 % or more, which was far above the international average of that time. Outputs have subsequently been increased by about 10 %, to about 500 MW.

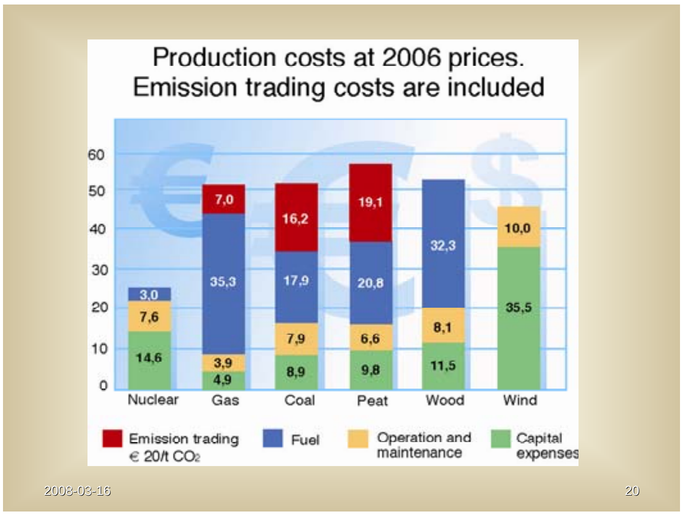
About the same time, two BWRs were ordered from ABB Atom in Sweden, Olkiluoto 1 and 2, and were taken into commercial operation in 1978 and 1980 respectively. These, too, quickly returned very high availability figures, of over 90 %. Outputs have been progressively increased.

2007 was a year of record production for Olkiluoto, with an availability of 95.6 % for the two reactors together. Finnish reactors are still world leaders in terms of availability.

In 2002, Finland again surprised the world as the first country for over ten years in Europe or the USA to order a new nuclear power station. This surprise was further increased by the fact that the order was for the unproven French EPR reactor from Areva, with an output of 1600 MW. It was to be some years before Areva received a French order for the same type of reactor.

The photograph shows the two BWR Olkiluoto 1 and 2 power stations that are at present in operation. The third unit in the background is only a sketch of Olkiluoto 3, which is under construction.

Olkiluoto 3 was ordered as a turnkey delivery, for start-up in 2010. However, the project is running a year behind schedule, with commercial start-up now expected in 2011.



The decision on Olkiluoto 3 was preceded by an extensive economic comparison. The main results are shown in the diagram.

It shows that nuclear power would give the lowest total costs, even without allowance for emission trading costs for fossil fuels. The cost of nuclear power production is much lower than that of production from wind power or bioenergy. All of these three forms of power production have approximately the same low values of carbon dioxide emissions per kWh. Thus the diagram shows that nuclear power is the most economically efficient way of reducing carbon dioxide emissions from the electricity sector. The same has also been noted in the new UK debate on nuclear power.

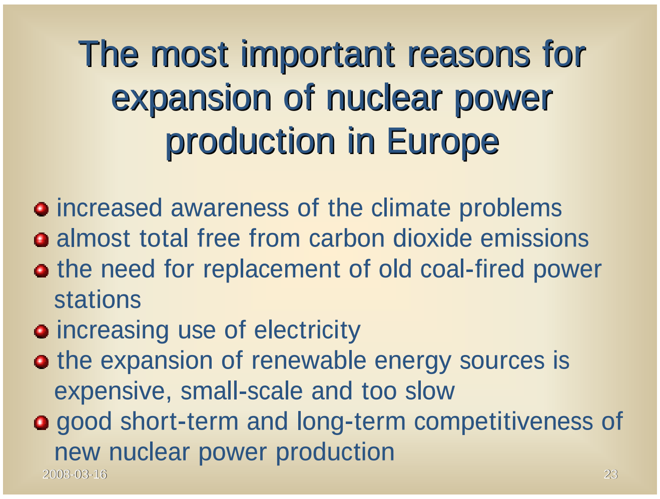
One of the conditions for the order for Olkiluoto 3 was that the power companies should also be able to demonstrate a safe method of, and suitable site for, final repository of spent fuel. This has therefore been based on the Swedish KBS-3 repository, with a suitable storage site in the rock close to the Olkiluoto nuclear power station.

In the spring of 2007, the Finnish power industry stated that it wanted to build another new nuclear power station. An environmental impact assessment for a nuclear power plant was submitted to the government in February 2008, but no final investment decision has yet been made. In the meantime one more new reactor project has been announced. So, it is possible that, within ten years, Finland will have six or seven reactors in operation, with the result that nuclear power will be supplying more than 50 % of the country's electricity.

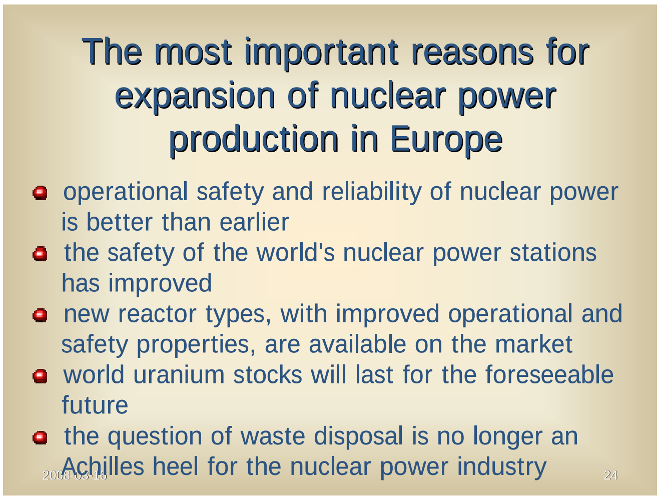
Conclusion

Let me conclude by saying that in 1979, the Three Mile Island reactor accident set a stop to nuclear power construction in many countries. The Chernobyl catastrophe in 1986 further reinforced this attitude in Europe.

Several European countries now have a positive attitude towards expansion of nuclear power production on the part of the public, leading politicians and the industry. As a result, some new reactors have been ordered, and several new orders are being planned.



Many different reasons for the new positive attitude to nuclear power in Europe can be mentioned. The climate change is of course of great importance and the increasing use of electricity. There is a need for replacement of many coal-fired power stations and the expansion of renewable energy sources can not meet the large scale demand. Nuclear power is competitive even for the new types of reactors with better safety conditions.



The safety of nuclear power reactors is better than earlier and new types of reactors with improved safety properties are available on the market.

The uranium resources in the world will last for the foreseeable future and the question of waste disposal is no longer an Achilles heel.

There is still a political opposition to nuclear power production in a number of countries, including Germany and my home country of Sweden. Extensive expansion of nuclear power production in other nearby countries, and a continued global expansion of nuclear power production without any reactor accidents, will probably change the political attitudes towards nuclear power in Germany and Sweden as well. There are already clear signs of such a development.

When returning to Sweden after this conference I hope to be able to spend some time at our country cottage. Out there I prefer to split fire wood instead of atoms.

Thank you for listening.