History of nuclear power in Sweden

TOMAS KÅBERGER

Summary

This paper is an attempt to outline the history of Swedish policies towards the energy system and to describe how the country's economy dealt with management costs and accident risks of nuclear reactors.

When reactors supply marginal electricity, nuclear power may provide electrical energy at low costs, as it has high investment costs but moderate personal costs and low fuel costs.

The support given by the Swedish electricity consuming industry to nuclear power may be understood as efforts to create and defend a situation of overcapacity in the electricity production sector, rather than a support for nuclear power as such.

The external costs of routine emissions of radioactive materials are difficult to internalise because they, like carbon dioxide, have global long-term effects. However, like the air pollutants already regulated, costs of reactor accidents, as well as the motives for taking on management costs of nuclear waste are regional and within a generation in time. The market evaluation of accident risks has deliberately been destroyed by legislation set to favour nuclear reactors.

Societal economic rationality may be successfully applied in the energy sector. Climate change risks have been internalised through the establishment of carbon taxes. The resulting development of biofuels was surprisingly successful, indicating a potential for further modernisation of the energy supply system.

Possible ways to restore the nuclear risk market so that the legislation may internalise nuclear reactor accident risks and waste costs are described. This may be done without the difficult quantification of environmental costs. Appropriate legislation may internalise the costs while creating conditions for market evaluation of these uncertain costs.

Background

Sweden is a country in northern Europe. Winters require house heating, while summers are warm, but rarely hot. It has an energy-intensive economy. Although oil dependence has decreased since 1970, oil is still the largest source of energy. There are only a couple of countries using more hydropower per capita than Sweden. Moreover, no other country has a higher per capita use of bioenergy. Nevertheless, more electricity is produced per capita by nuclear reactors here than in any other country in the world.

Reducing oil dependence is generally a popular goal of national energy policy. The nuclear opinion has been divided and nuclear policy has become a hot topic dividing the major political parties.

Anti-nuclear arguments have been based on considerations surrounding: reactor accidents, long-term human health effects of exposure to routine emissions of radioactive materials, nuclear waste, and the links between civilian nuclear power and nuclear weapons.

Nuclear policy was the major domestic policy issue during the mid and late1970s. It acted like a lightning rod for much of the political opposition, and brought an end to nearly forty years of uninterrupted Social Democrat governments. However, the most powerful industrial organisations have been strongly supportive of nuclear power.

Nuclear investments were started as a part of a weapons project [Larsson, 1985]. The process continued with industrial ambitions, but as the cost of nuclear power was far higher than electricity prices, the nuclear power project became a not only environmental and political problem but also an economic problem to the owners during the last 15 years of the 20th century [Johansson, 1986; Jasper, 1990; Kaijser, 1992].

As a political problem, the nuclear power issue could not be resolved in the parliamentary process, as parties were divided. Instead, a national referendum on nuclear power was held in March 1980. The wordings of the referendum ballot options were ambiguous, to say the least, although unwritten meanings were well understood by the voters. There were three alternatives to vote on. All of them stated that nuclear power should be decommissioned. The winning alternative stated a maximum of twelve reactors should be built and all of them should be closed. According to a plan published by the campaign, all reactors should be closed within an estimated twenty-five years of operation.

The politics of nuclear power in Sweden is difficult to describe in a consistent way. Many have tried to describe the whole political process from sociological or political science perspectives, focussing on the processes [Lindquist, 1997 (Sociology); Lundgren, 1978 (History); Lindström, 1991 (Political Science); also Anshelm, 2000; Leijonhufvud, 1995; and, in English: Sahr, 1985; Jasper, 1990].

The following is an attempt to outline some of the economic interests and rationalities that influenced nuclear power policy in Sweden. However, there is also an attempt to describe a framework for market economy in the energy sector that may serve a socio-economical purpose. Such policy options are described in the latter part of the text.

Swedish electricity sector development

Electricity production and distribution companies were established in several Swedish cities and industries during the period from 1880 to 1900. Some were based on thermal electricity generation, while others relied on small hydropower plants build in the minor rivers in the more populated southern half of Sweden. As competition was hard to sustain, the electricity act was developed and local electricity companies often became municipality-owned monopolies

Exploitation of the large rivers, mostly in the less populated northern parts of Sweden, began in the early 1900s. Power companies with economic capacity to take part in this exploitation were formed by industries, by municipalities, and by the state. The exploitation was aided by a special Waterpower legislation.

Transmission lines connecting the large hydropower plants of the north and the population gathered in southern Sweden were built by the state. The local, often municipal, electricity companies, one by one, gave up electricity production and became distributors of electricity bought from the power companies. The local electricity companies turned into pseudo-independent retailers with little or no power of their own.

The hydro-expansion came to an end in the late 1950s. The rivers that could be exploited at low cost had been utilized. Those that were left required too large investments in relation to the electricity that could be produced. In addition, a rapidly growing public opinion was opposing the exploitation of the last few rivers flowing into the Baltic Sea, increasing the political cost of every new project. As a consequence, the increasing demand for electricity could no longer be met by new hydropower and attention turned to thermal power generation again.

The thermal power development provided the municipal electricity companies in the cities of southern Sweden with an opportunity to recover independence. Electricity generation using steam turbines offered the opportunity to use district-heating systems to utilise the cooling water. Revenues from district heating would give these municipal systems a competitive advantage over the power companies that did not have the same opportunity to develop district heating grids and would have to set their electricity price high enough to cover all the power-plant costs. The local electricity companies saw an opportunity to become energy companies, and take back market-shares lost during the hydropower era.

Such new competitors would threaten the position of the power companies, that could control the national power grid as well as the electricity price. In the battle that followed, the State-owned power-company Statens Vattenfallsverk, now Vattenfall, had significant market power. Vattenfall could stop municipal companies from selling surplus electricity to neighbouring cities, and demanded exorbitantly high rates for power to be supplied in case of power shortage in a city that had dared to build cogeneration plants [Steen & Kaijser, 1990; Sintorn, 1990].

At this stage, the nuclear power option got an important role in the battle for power over the electricity market. If the power companies could present nuclear power as being able to produce electricity cheaper than cogeneration from fossil fuels, it would discourage investments by municipal power companies.

But nuclear power has never been a low cost option. As the first reactors were built in the USA, and the first small Swedish reactor Ågesta was built, investment costs appeared too high to discourage competitors from offering conventional cogeneration. The Ågesta-plant should have been ready in 1961 at a cost of 40 M SEK. It was only ready in 1964 at a cost of 205 M SEK. It operated at a loss until it was closed in 1974 despite the government writing-off most of the investment cost [Leijonhufvud, 1994, p. 47].

The electricity intensive industry developed in Sweden under market conditions set by hydropower, with high investment costs and low marginal costs. Nuclear power also appeared to provide low marginal costs despite the high investments. For industrial customers, such technology may provide low power prices if, and only if, there is overcapacity. Once the plants are built, electricity will be produced and sold to prices as low as the short-term marginal costs.

The greater the number of power plants built, the cheaper nuclear plants were expected to be. In particular if a series of identical reactors could be build, the costs were expected to be lowered enough to make nuclear power plants economically competitive. In order to build series of reactors, perceptions of a large future demand for electricity were needed.

When asked by the power companies, industrial customers had an interest to provide exaggerated estimates of future energy demand in order to create overcapacity, and thereby to get low electricity prices. Power companies, on the other hand, did see such estimates as signs in support of their visions with large series of nuclear reactors. During the period around 1970, projections were made that turned out to be far from the real future. In 1972, CDL, a body coordinating the projections for the electricity producing industry, projected a need for 24 reactors by 1990.

Another factor encouraging electricity industry to provide high estimates of future energy demand was the environmentalist opposition to nuclear power in the beginning of the 1970's. The anti-nuclear movement favoured wind power, solar energy, and biomass. Wind power and biomass were within economic reach. But, if projected electricity demand was high enough, the nuclear industry could claim that only nuclear power could meet the demand.

Strong actors in favour of high electricity scenarios set the scene for the debate. In 1974, a governmental commission on energy projections [SOU, 1974:64], relying heavily on information provided by the industries producing and consuming electricity, predicted an electricity consumption of 350 TWh by the year 2000. Actually, despite expanded nuclear power, real use turned out to be less than 145 TWh.

The over-investments in nuclear reactors that followed may be understood in this context of individually rational responses given economic situations and interests. Electricity intensive industry gave too high figures of future electricity need. The managers of the power companies did not critically analyse their figures, because the resulting projections fitted their political aims so well: The projections justified the idea to build large numbers of reactors to bring down investment costs, and the rapid demand growth showed that renewable energy was not sufficient.

Even before the last Swedish reactors were built after the referendum in 1980 it was clear to many people that the demand would not create electricity prices that would pay the total production costs of the reactors previously planned [Kågeson, 1979; Millqvist, Wallin & Sterner, 1979]. Some years later, researchers concluded that the low–power energy plan of the antinuclear movement fitted real demand better than the official projection, despite none of the measures to reduce energy use had been adopted [Tengström, 1985].

The reactors built after the referendum, most clearly Oskarshamn III and Forsmark III, commissioned in 1985, have not recovered their capital costs to their owners. But, at least before competition was introduced, all reactors appeared to cover their avoidable costs, (fuel, staff and maintenance). Even before competition was introduced, electricity trade included markets for marginal power offered at prices much below average price. Assuming all such sales, priced around 0,1 SEK/kWh, to the older nuclear reactors, one may construct an analysis yielding the opposite result. Despite low priced marginal electricity, reactor operation was limited to prices above the short-term marginal costs of nuclear fuel alone. Often demand was too low even at that price, forcing operators to turn down output of the reactors.

This was the situation in the early 1990's, when the oldest reactors approached 25 years of operation, and were to be shut down according to the promises before the referendum and the parliamentary decision thereafter. The minister for Energy and Environment, Birgitta Dahl made an "irrevocable" commitment to close the first reactors in 1996. A well-funded campaign against her and the commitment was launched. In the campaign, the method was to mobilise the industrial trade unions against the social democratic government. The role of the nuclear reactor industry and the power companies was limited to providing "low-key information" [Wikdahl, 1991], leaving the battle to the electricity intensive industry and trade unions [Hibbs, 1992]

Electricity intensive industry in the mining, steel, chemical and pulp- and paper industry were key actors in this campaign. There were few companies involved and they perceived their economic interest to be strong. Thus they were easily organised and formed the Swedish Electricity Refining Industry (Sveriges El-förädlande Industrier) to run the campaign.

They used 31 TWh of electricity per year altogether. Overcapacity of electricity generators made it possible for them to buy electricity at 0,15 SEK/kWh (approximately 2 UScent/kWh). The belief expressed, by industry as well as government reports at the time, was that if two reactors were shut overcapacity would disappear and the price would rise until it became economically justified to build new power plants. Electricity from any new power plant that could be built was said to cost the double, 0,3 SEK/kWh. The business offer by the campaign was the following: If the campaign just managed to delay nuclear decommissioning by one year, the price increase would also be postponed by one year. Electricity intensive industry, buying 31 TWh per year, thus would save 31 TWh * (0,3-0,15) SEK/kWh = 4,65 GSEK ≈USD 650 million. The possibility of delaying decommissioning would justify large investments in political campaigning.

From the visible activities organised and publications made, the campaign budget appears to have been in the order of 10 –20 % of this amount.

Fogelström, who was executive director of the reactor producer Asea-Atom at the time, described the success of the campaign at a meeting with the German Atomic Forum [Hibbs, 1992]. He concluded that the trade union leaders, among them Rune Molin, were impressed by the arguments and that Rune Molin himself was given a post in government as minister of industry and given the energy portfolio from Birgitta Dahl who was left with only the environment. The irrevocable decision became a vague ambition, and the economic result of the industry campaign appeared satisfactory to those who financed it.

The power companies failed to recover their investments, and they lost expected profits of their hydropower plants because of the low electricity prices. At the time, the power companies were about 80% owned by taxpayers and retirement funds.

In 1995 the electricity market was re-regulated in order to introduce competition between producers. The result of the reform was a visible and falling electricity price. From 1998 to 2000, the price was around 0,12 SEK/kWh. The production costs reported by reactor companies were all well above the market price. With the newest reactors this was due to remaining capital costs, but the oldest reactors were not even able to cover avoidable costs at market price.

In 1997 a negotiated parliamentary majority made the decision to close one of the oldest reactors, Barsebäck I, and pay compensation to the owner, Sydkraft. At the same time the decision to close all reactors after 25 years of operation was revoked. The second reactor at Barsebäck would be closed when renewable electricity and efficiency improvements would have compensated the loss of the capacity of the first. In the days following the decision share, values of all power companies increased, but the value of Sydkraft increased more than the others [Kåberger, 1997].

In the economic settlement that followed, taxpayers paid more than USD 1 billion to the reactor owners.

To understand the political success of this settlement we must see how the decision affected the interested parties:

The power companies only profited. One of several reactors that had avoidable costs far above the electricity price was closed. No power company lost anything due to the deal. All electricity producers expected to benefit from a marginally increasing electricity price. The nuclear power companies won. The decision to close all reactors at 25 years of age was removed and, most important, they where given compensation for closing reactors (even for the first oldest reactor with avoidable costs above market price).

Shortly afterwards the vice minister for energy who handled the decision, Peter Nygårds, was given the job of managing director of SKB, a waste management company owned by the Swedish nuclear reactor owners. This appointment indicates that the power industry was at least not disappointed by the political settlement.

The power intensive industry may have disliked the risk of a short-term marginal price increase due to reduced over-capacity. However with the integrated electricity market including more countries than Sweden, the effect of closing one minor reactor was small. Revoking the decision to close all the other reactors after 25 years of operation was more important. The capacity loss would have been large enough in relation to transmission capacity in northern Europe to have an effect on prices in Sweden.

Many active nuclear opponents celebrated that the decommissioning started, and in political rhetoric statements, government spokesmen made successful efforts to support this image of the deal.

The taxpayers who had to pay the compensation to the reactor owners are a large number of individuals, who each lost a moderate sum of money. Such an interest is difficult to organise enough to even understand, and less to be able to defend their interests.

Barsebäck I was closed in 1999. In order to continue the decommissioning of the other reactor at Barsebäck, electricity production of the first reactor was to be substituted by renewable supply or improved efficiency. This was achieved in a few years. The reactors produced an average of 3,5 and 4 TWh each while in operation. Between 2000 and 2005 annual electricity production from bioenergy alone increased more than 4 Twh. In addition, wind power increased by half a TWh. See diagram 2 and 3.

Consequently, Barsebäck II was closed in 2005. A similar compensation arrangement to the owner was applied.

The remaining nuclear power plants, comprising 10 reactors in total, are currently in operation. No further decisions have been made on continued decommissioning. The present government has explicitly stated that no decisions will be taken during their term in office.

Partly due to carbon emission constraints, electricity prices have increase in Europe. As a result nuclear power plants are no longer an economic burden on the owners. The owners are instead investing in modernisation of the plants and some have been allowed to increase their generating power. If all plans are carried out, the increased power of the remaining reactors may be as large as the capacity lost when the two small Barsebäck reactors were closed.

This appears to be economically rational. One may see the operation costs of the older and smaller reactors as to high too justify continued operation, while the newer and larger ones were too expensive to build but possible to operate with defensible operating costs. New reactors are not profitable investments, but a marginal increase in the best existing reactors may appear profitable.

So the decision by the political leadership to close Barsebäcks reactors may appear economically rational in a narrow sense. But there are other relevant factors.

Barsebäck is situated near Sweden's third largest city, Malmö, and just across the Öresund straight from København, the capital of neighbouring Denmark. A reactor accident in Barsebäck could have greater economic and social consequences than around other Swedish nuclear plants situated further away from large population centres.

Secondly, Barsebäck staff showed safety related behaviour that raised concerns from the safety authority for many years.

While no other nuclear power plant in Sweden is as badly located, another plant is beginning to catch attention for similar problems with safety culture among its staff. Forsmark nuclear power plant that used to be seen as the best performing nuclear plant is under investigation for illegal breaking of safety regulation. The plant is now under special surveillance by the authority, and one reactor has been closed for safety reasons.

From planned decommissioning to market solutions

There has been a shift in the focus of monetary transactions from decommissioning to market solutions. However, the energy sector has significant external economic effects that are lost in such analysis. The extended operation time of the remaining reactors will lead to a net increase in nuclear operation and associated costs:

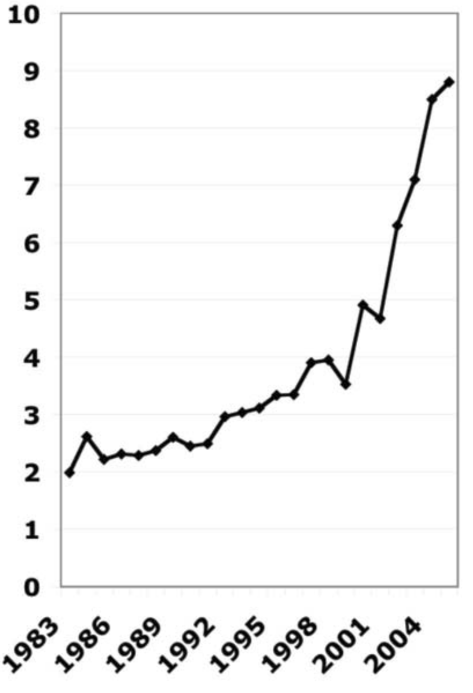

Diagram 1. Bioenergy use in Sweden from 1970 to 2006, in TWh. Most of the bioenergy is used for heating industrial processes or houses via district heating grids. In the last five years electricity and automotive fuels have increased significantly.

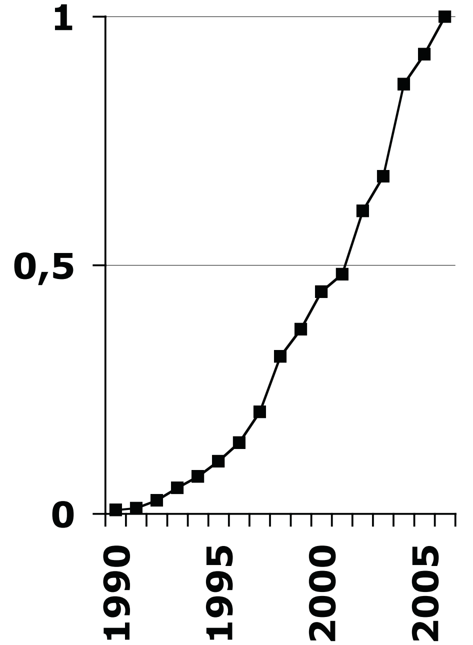

Diagram 2. Electricity production from biomass in Sweden from 1983 to 2005.

An increased number of expected cancer cases and genetic risks will occur due to routine emissions of radioactive material, mostly from uranium mining. These costs affect mainly people in other countries and in future generations. Cancer is nowadays often possible to treat successfully for those who are able to detect it early and who have economic resources to pay for treatment.

Rational economic men of power in present industrial societies may undervalue these effects. However, a socio-economic analysis giving equal appreciation of cost regardless of where and when people suffer from such effects may assess these costs as significantly larger.

Longer periods of reactor increase the risks of accident. The significance of such risks is difficult to quantify. The costs have been lifted off the shoulders of the operators and placed on tax-payers and potential accident victims by the special legislation on nuclear liability. In this case, a large number of people carry a low probability of a significant cost.

More nuclear waste will be produced. Nuclear waste management is believed to pose external costs only to coming generations. Members of these generations cannot influence present decision-making. However, in economic theory, though not necessarily in politics, consequences are important even if they do not have well organised interest groups to give them attention. The general principle is that those who cause environmental costs also shall pay the costs. If they do not pay the victims directly, they shall pay the cost as a tax [Pigou, 1920]. This is the position taken not only by environmentalists but also by economists and by international organisations in documents like Agenda 21 [UN, 1992, eg article 4.24] and WEC [WEC, 1995].

In the following, we shall briefly look at how internalisation of external costs of fossil fuels by environmental taxation was done in Sweden. This policy was successfully implemented and it favoured nuclear power interests. Finally, we shall look at the potential for applying economic theory to the regulation of nuclear power itself.

Pricing carbon dioxide emissions from fossil fuels

From the time of the first oil crises in 1973 there has been a genuine policy to reduce oil dependence in Sweden agreed by all political parties. Subsidies and support for oil have been systematically removed and energy taxes on fossil fuels were increased.

As climate policy added another driving force to reduce fossil fuel use, a carbon tax on fossil fuels was introduced in Sweden in 1990 [Jonsson et al., 1997]. Diagram 1 shows the most significant effect of this policy, the increased use of bioenergy. Bioenergy corresponds to about a quarter of all energy use in Sweden in 2005.

Since the introduction of the carbon tax, bioenergy has been a more competitive alternative to oil and coal in all new large plants. As the use of

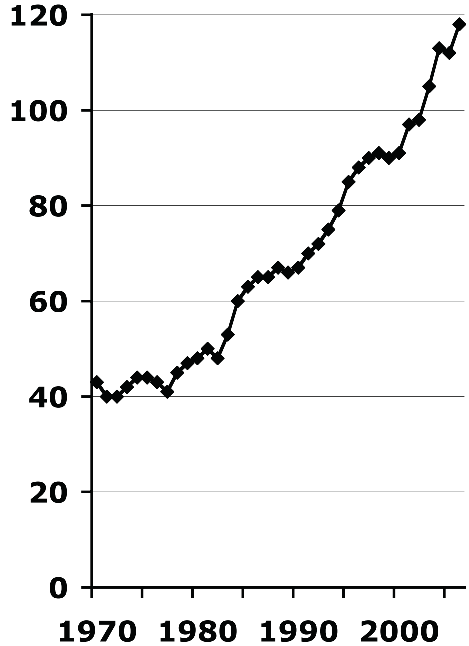

Diagram 3. Electricity production from wind in Sweden from 1999 to 2006.

bioenergy increased, surprisingly to some, prices of solid biofuels fell. There appeared to be no shortage of resources while the methods of preparing and transporting biomass for energy purposes improved significantly.

During the following decade, bioenergy use increased by about three TWh per year. And in 2006, preliminary data from the energy authority says bioenergy contributed 118 TWh in Sweden, significantly more energy than the 65 TWh of electricity produced in the nuclear reactors.

Sweden is one of the countries in the world where new technologies to produce and use refined bioenergy have been developed. Wood pellets to be used in small pellet burners have increased in popularity, and technologies for integrated biomass gasification and combined cycle electricity generation has been developed and demonstrated in Sweden [Ståhl & Nergaard, 1998].

While much of the planning for more bioenergy were projecting energy plantations and competition with forest industry supplies, market conditions stimulated supply of residues from the timber industry and residues from forestry [Kåberger, 1997].

In this case there was a clear policy to reduce the use of fossil fuels and increase the use of bioenergy. Removing subsidies and imposing environmental tax on competing fossil fuels created conditions for growth, a demand for research results and information on bioenergy was well received, as using bioenergy was profitable.

Behind the introduction of the carbon tax in the period around 1990, there were mutually supporting interests of the nuclear reactor-owners and the environmental movement. As described above, nuclear power in Sweden suffered from over-capacity. Reactors were operating at reduced power because the electricity they could produce was not in demand even at short-term marginal cost prices. The power companies were looking for ways to increase demand for electricity. The only option that could provide a large demand increase in a short period of time was to increase electric resistance heating. At the time, oil and coal were the competing sources of heat that electricity could win market shares from as a result of fossil fuel taxation.

Environmentalists had asked for a general carbon tax on all carbon emitted from fossil fuels. However, from the point of view of the electricity producers who wanted to increase the sales of electricity for heating purposes, this would not be attractive. Heating demand peaks in winter when hydro and nuclear capacity cannot satisfy power demand. With a carbon tax on the fossil-based electricity production, marginal cost pricing would make electric resistance heating very expensive.

Instead, a carbon tax that applied to fossil fuels used to produce heat, but not to fossil fuels used to produce electricity, was introduced. As described above, it was successful in introducing bioenergy-technology and increased the use of bioenergy sufficiently to bring down its costs. But there are unintended consequences that deserve to be mentioned:

If electricity is produced from steam and the waste heat is dumped into the sea, no carbon tax is paid on the fuel. However, if the waste heat is supplied to the district heating grid, then a carbon tax is assessed for the fraction of the fuel ending up as commercial heat. As the carbon tax on coal is higher than the price of coal, this was a disaster for fossil fuelled cogeneration plants that competed with less efficient fossil-based electricity production. Recalling the battle between local energy companies, attempting to expand cogeneration and the power companies, this appears as another political victory for the power companies.

Since 2003 a system of green certificates on renewable electricity has supported the use of bioenergy for electricity production ensuring no fossil fuels are used in cogeneration plants [Kåberger et al., 2004].

Potential regulation of the economic liability for nuclear reactor accidents

In 1957, studies at the Brookhaven national laboratory in the USA on behalf of the Atomic Energy Commission described catastrophic consequences of an accident in a civil nuclear power plant [Beck et al., 1957]

The nuclear industry in the US came to the conclusion that if the nuclear industry had to carry the economic liability for reactor accidents there would be no commercial nuclear power. To avoid these costs, the industry asked a group of legal experts to provide a proposal for a legislation that would make nuclear power profitable by socialising the costs of potential accidents. The proposal, [Murphy et. al, 1957] and the resulting law called the Price-Anderson Act after the two politicians that brought it forward, has served as blueprints for nuclear accident legislation in all countries that have private nuclear power reactors. The key elements are:

1. In case of a nuclear reactor accident there is only one company or person that can be held liable and that is the operator.

This is important, as all suppliers are relieved of the risk that faulty equipment or mistakes during construction could imply economic consequences, were they to cause a reactor accident. Without this component in the legislation all suppliers to nuclear power plants would have to keep higher prices to cover the costs of accident liabilities their mistakes could cause.

2. The economic liability of the operator in case of a major reactor accident is strictly limited to an amount far below the potential costs of a major accident.

This component in the legislation has two important aspects. Without a limited accident liability the operator would face bankruptcy in case of a major accident. To banks considering lending money to an operating company, that risk of bankruptcy would be a reason to increase interest rates to compensate for their risk of loosing the money in case of an accident. Increased interest rates would lead to higher costs and less competitiveness of nuclear power.

In Sweden, the law was based on a government commission on nuclear liability. They justified the subsidy by arguing "that it is necessary to utilise nuclear power – at any cost – if we are to avoid economic decline" [SOU, 1959:34 p.25].

The introduction of the liability legislation is an expression of decisive energy policy. The law has immediate and significant economic implications for the competitiveness of an energy technology.

One can imagine an alternative to this legislation, the kind imposed on automobile owners. It was discovered, when automobiles became popular, that there were people who could afford to buy and drive a car, but who were unable to pay for the costs resulting from car accidents they might cause. Allowing the drivers to escape paying caused a societal problem of deciding how to compensate the victims of the accidents. As a result, most countries have introduced a legislation of compulsory insurance for cars to be allowed on the streets – an insurance that should cover the total cost of very rare accidents that may cost from 100 to 10 000 times the price of a car.

A country with a desire to establish a fair competitive electricity market may choose to impose similar legislation for nuclear reactors. The maximum amount of money that is necessary to compensate all victims of a nuclear accident may be in the order of several thousand billion US dollars (1 000 000 000 000). According to public statements by the governments of Ukraine and Byelorussia, the costs of the Chernobyl accident are in the order of some hundred billion dollars.

A thousand billion dollars cannot be easily paid by any state budget. Not even in a large country in which cost is easily distributed. The Chernobyl accident was a good reason for the relatively rich Russia to withdraw from the Soviet Union when costly consequences of the accident occurred in the poorer parts of the Union: Ukraine and Byelorussia.

It is possible to find insurance-like solutions to share such risks via the international capital markets. Radetzki & Radetzki [2000] describe how this could be done. Operators could be forced to sell catastrophe bonds to collect enough capital to compensate victims of large accidents. Such bonds would lose all their value in case of a reactor accident, and in order to find voluntary capital, the reactor operator would have to pay an extra premium interest on the bonds.

By compulsory arrangements of this kind there would be a market value created for nuclear accident risks. This risk cost would have to be paid by nuclear power operators, reducing their competitiveness in relation to new energy technologies.

Anti-nuclear policy in Sweden has gone as far at to close down a working reactor by law. But the parliament has not gone on to withdraw the accident liability subsidy in the legislation.

Economic liability for nuclear waste costs

When a nuclear reactor is taken into operation and is contaminated by radioactivity, decommissioning the plant and storing the radioactive components will generate future costs. If we include the cost of managing used nuclear fuel of thousands of generations into the future, the cost of waste management, the back-end cost of a nuclear reactor may be higher than the cost of building the power plant.

Direct costs of nuclear waste management may not be all of, or even the most important part of, total costs. Waste accidents and resulting radioactive emissions, future sabotage or deliberate use of fissile material produced in the reactors to construct nuclear weapons may cause significant consequences thousands of years into the future.

There are uncertainties about what methods may be used and thus on what the real costs of waste management will be. An interesting lesson was learnt as the British government prepared for privatisation of nuclear power plants in 1987. The private investors considering taking over the plants and operating them on a competitive electricity market significantly changed the estimates of decommissioning and waste management. There was roughly a tenfold increase in estimated future costs [see MacKerron, 1991].

When uncertainties are as large, as in the case of nuclear waste management, the conditions under which the cost estimates are made are important. Prior to the attempted privatisation in Britain, the nuclear reactors were operated by a government monopoly. The people of the nuclear department of this monopoly had all interest in producing low cost estimates of waste management. Low waste costs would make nuclear power appear more competitive and increase the chances of more investments and a growing nuclear department. And it was not a problem for them if the estimates proved too low. The monopoly-company could just raise their prices to raise the money necessary to manage the waste. If that would prove impossible they may rely on the owners of the reactors and waste problem: the taxpayers.

The private investors were in an entirely different situation. They had no reason to underestimate the waste cost. They only wanted the best possible estimate to be able to place a bid that was high enough to get the reactors but low enough to ensure future profit. On the other hand, they knew they would face a competitive electricity market. Thus they also knew that they would not be able to increase electricity prices to raise the necessary money to handle the waste in the future. They also knew that they would not like to turn to the owners. The owners would be the investors themselves.

The real management costs in the future will also depend on how dangerous radioactive pollution will turn out to be in the future. During the last few decades of radioactive contamination, knowledge of cancer risks and genetic effects have accumulated slowly. It may prove relevant to distinguish between effects of external radiation caused by distant nuclear explosions or X-ray machines on the one hand and doses caused to a particular cell by a decay chain of ingested radioactive pollution built into the body on the other. Such distinctions may provide an understanding of the mechanisms behind the leukaemia clusters found around reprocessing plants in Europe [Gardner et al., 1990; Guizard et al., 2001].

The established scientific organisations like the International Commission on Radiation Protection, ICRP, has increased their risk estimates step by step, with the cancer risk increasing by the order of ten during the last thirty years.

As the risk estimates increase, more safety measures are required when handling waste. More expensive waste storage facilities are needed, and bringing waste into the storage becomes more expensive as workers protection makes handling waste more difficult.

It is important for the fair competition with new sources of energy that these management costs are not socialised. But that is not enough to assure proper economic management of radioactive waste.

Due to the long periods of time involved, nuclear industry can assume that by the time waste has to be managed or damages from waste missmanagement occur, the nuclear companies will no longer exist. In Sweden the nuclear waste management costs are supposed to be covered by the nuclear reactor operators. The owners of the nuclear power plants have formed limited liability companies owning the reactors and holding all liabilities connected to the power plant. As long as they are profitable, profits are passed on to the owners. However, when the reactors are closed and only waste costs remain, they may file for bankruptcy. Due to the strict limited liability legislation, the owner would be able to escape from the real costs.

The Swedish parliament had previously imposed legislation forcing the owners to contribute to a waste management fund under government supervision that should cover planned costs for nuclear waste management.

In a government commission in 1994, we discovered that this system was insufficient. Cost estimates were so uncertain that there was a need to have the industry provide reliable paying capacity to cover at least the potential management costs during the coming century. As these costs were uncertain they could not easily justify further fund accumulation beyond the planned costs. Instead, the industry was supposed to provide economic securities that could be used if real costs became larger than the planned costs already covered by money accumulated in the fund [Reported in SOU, 1994:107/108]. These economic securities are now in the order of a billion USD.

BIBLIOGRAPHICAL REFERENCES:

Anshelm, Jonas, 2000: Mellan frälsning och domedag: om kärnkraftens politiska idéhistoria i Sverige 1945-1999. Symposion, Eslöv

Azar, C., Berndes, G., Kåberger, T. & Abrahamson, D. 2001: The feasibility of large-scale lignocellulose-based bioenergy production, Biomass and Bioenergy. Vol. 20, pp. 371-383.

Beck, C.K. et al. 1957: Theoretical Possibilities and consequences of major accidents in large nuclear power plants – a study of possible but highly improbable, were to occur in large nuclear plants. United States Atomic Energy Commission. Washington.

Gardner, M. et al. 1990: Results of case-control study of leukaemia and lymphoma among young people near Sellafield nuclear plant in West Cumbria. British Medical Journal. Vol. 300 pp. 423-434.

Guizard, A-V, et al. 2001: The incidence of childhood leukaemia around the La Hague nuclear waste reprocessing plan (France): a survey for the years 1978-1998. Journal of Epidemiological Community Health, Vol. 55 pp.469-474.

Hibbs, M. 1991: Power intensive industry led nuclear comeback, Fogelström says. Nucleonics week, May 23.

Jasper, J. 1990: Energy and the State: Nuclear Politics in the United States, Sweden and France. Princeton University Press.

Jonsson, O. et al. 1997: Environmental taxes in Sweden – economic instruments of environmental policy. Swedish Environmental Protection Agency Report 4745. Stockholm.

Johansson, T. B., 1986: Sweden's Abortive Nuclear Weapons Project. Bulletin of the Atomic Scientists. Vol 42, No 3 pp 31-34.

Kaijser, A. 1992: Redirecting Power: Swedish Nuclear Power Policies in an Historical Perspective. Annual Review of Energy and the Environment 1992, Vol. 17 pp. 437-462.

Kåberger, T. 1993: On the Economic Conditions of Suitability Assessments. Presentation at Endlager Hearing, Braunschweig September 21-23. Niedersächisches Umweltministerium.

Kåberger, T 1997: Barsebäck blev plötsligt lönsamt: Finanstidningen

Kåberger, T. 1997: A Comment on the paper by Roger Sedjo. Energy Policy, Vol. 25 No. 6 pp. 567-569.

Kåberger, T., Sterner, T., Zamanian, M. & Jürgensen, A.: Economic Efficiency of Compulsory Green Electricity Quotas in Sweden. Energy and Environment Vol. 15, No 4, pp 675-697.

Kågeson, P. 1980: Elpriset. Källa No 3, p. 19, FRN Stockholm.

Larsson, C. 1985: Historien om en svensk atombomb. Ny teknik No. 17 pp. 33-83, No. 18, pp. 4-9, No. 19 pp. 4-10 and No. 20 pp. 4-8.

Leijonhufvud, S. 1994: (Parentes? – En historia om Svensk kärnkraft. ABB Atom, Västerås.

Lindström, S. 1991: Hela Nationens Tacksamhet, Svensk forskningspolitik på atomenergiområdet 1945-1956. Thesis, Dept of Political Science, Stockholm University.

Lindquist, P. 1997: Det Klyvbara ämnet: Diskursiva ordningar i svensk kärnkraftspolitik 1972-1980. Lund Dissertations in Sociology 18.

Lundgren, L.J. 1978: Energipolitik i Sverige 1890-1975. Sekretariatet för framtidsstudier, Stockholm.

MacKerron, G. 1991: Decommissioning costs and British Nuclear Policy. The Energy Journal. Vol. 12 pp.13-28.

Millqvist, R, Wallin, G. & Sterner, T. 1979: Kärnkraftens kostnader – en samhällsekonomisk studie. Modin-Tryck AB, Stockholm.

Murphy, A.W. et al. 1957: Financial protection against atomic hazards. Atomic Industrial Forum, Inc. New York.

Nord-pool 2001: as viewed 2001-10-05.

OECD 1994: Liability and Compensation for Nuclear Damage – An International Overview. OECD, Paris.

Pigou, A.C. 1920: The Economics of Welfare. London 1920. 4th edition 1932 Macmillan.

Radetzki M. & Radetzki M., 1997: The Liability of Nuclear and Other Industrial Corporations for Large- Scale Industrial Damages Journal of Energy & Natural Resources Law, Vol. 15, No. 4.

Radetzki M. & Radetzki M., 2000: Private Arrangements to Cover Large-Scale Liabilities Caused by Nuclear and Other Industrial Catastrophes. Geneva Papers on Risk and Insurance, Vol. 25 No 2, April 2000.

Rikskommittén for linje 2 1980: Förslag till avveckling av det svenska kärnkraftprogrammet. Stockholm.

Sahr, R. 1985: The Politics of Energy Policy Change in Sweden. University of Michigan Press Co. Ann Arbour.

Sintorn, J. 1990 Ny Teknik 1990:45.

SOU 1974:64 Energi 1985-2000.

SOU 1959:34 Om atomansvarighet.

SOU 1994:107/108.

Steen, P. & Kaijser Ny Teknik 1990:42.

Ståhl, K. & Nergaard, M. 1998: IGCC Power Plant for Biomass Utilization, Värnamo, Sweden. Biomass and Bioenergy 15, pp.205-211.

Swahn, J. 1992: The long-term nuclear explosives predicament. Thesis. Technical Peace Research Group. Chalmers Universtity of Technology. Götebor, Sweden.

Tengström, E. et.al, 1985: Energin, makten och framtiden. Stem 1989:R165, Stockholm.

WEC 1995: Report of the WEC Tokyo 8-13 October 1995.

Wikdahl, C-E 1991: Sweden: Nuclear power policy and public opinion. IAEA Bulletin 1, pp. 29-33.

Tomas Kåberger is a researcher at the International Institute for Industrial Environmental Economics, Sweden. @ – tomas.kaberger@iiiee.lu.se
Received on 2.22.2007 and accepted on 2.27.2007.