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Sweden Beyond Oil: Nuclear Commitments and Solar Options

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Having no domestic oil, gas, or coal, Sweden depends for 70 percent of her energy on imported oil. This will have to change in the next several decades because of resource depletion, world production capacity lagging behind demand, or oil-rich countries limiting exports for political reasons. Thus there has to be a transition, but to what? And what factors will shape the energy path of Sweden? To answer these questions it is necessary to look into the alternatives that exist for replacing oil on a major scale.

Summary. The project "Energy and Society," sponsored by the Swedish Secretariat for Futures Studies, has studied different indigenous energy sources as alternatives to imported oil in Sweden. One alternative is nuclear energy, another is renewable energy. Large uncertainties are associated with both alternatives today. The main characteristics of an energy policy for the rest of the century that does not foreclose either of these options have been identified. Such a policy will have to be based on an understanding of similarities and differences between the alternatives. A nuclear and a solar energy system have been outlined as a basis for an analysis of technical, economic, and institutional issues.

Several decades are needed for major changes in the energy system to take place. Most energy policy studies are based on the need to ensure supply in the short and medium term. Longer-term development thus tends to be determined more through an incremental series of short-term decisions than as a result of any overall strategy or vision. Since we believe that such an approach is inherently biased toward existing technologies and the institutions behind these technologies, we have decided to work differently.

We have therefore identified two different long-term energy systems based on indigenous Swedish resources and deduced the steps that are necessary in the short and medium term in order to make these longer-term developments possible (*1*). One such system is based on indigenous uranium. Sweden has some 15 percent of the world's uranium reserves in low-grade shale deposits that are as yet unmined. The other system is based on renewable energy. Sweden enjoys a solar energy influx close to 1 megawatt-hour per square meter per year on a horizontal surface.

Up to the middle of the 1970's, events clearly moved in the direction of large-scale adoption of nuclear energy. Various decisions taken between 1955 and 1965 led to the establishment of a Swedish reactor industry during the 1960's and to a major nuclear investment program during the 1970's. By 1973, 11 reactors were licensed which will provide 8.4 gigawatts of power, and the utilities planned for 25 GW by 1990. This would have made the Swedish nuclear program the largest in the world on a per capita basis. Since then, nuclear energy has been the most important issue in Swedish politics, contributing to bringing down one government in 1976 and forcing one to resign in 1978. The political fallout in Sweden from the accident at the Three Mile Island nuclear power plant in the United States included a decision to hold a referendum about the role of nuclear energy in 1980 (the first referendum in 20 years and the fourth during this century). Nevertheless, important groups (including utilities, industry, and some trade unions) argue that nuclear energy is the only realistic large-scale substitute for imported oil in Sweden. Others hold that alternatives probably do exist and should not be discarded until they have been given at least as much consideration as nuclear energy. These views are backed by a relatively large but dispersed constituency including environmentalists, women's organizations, and several youth organizations within political parties.

However, there seem today to be major uncertainties with both the solar and nuclear options—technically, environmentally, economically, institutionally, and socially. Swedish society therefore has to start on a transitional path, but without having a clear consensus on where to go. Except for relatively small groups who have already made up their minds about nuclear and solar energy, a fairly large majority on the Swedish political scene favor a strategy of preserving (and creating) freedom of action (*2*). Our work has been directed toward understanding the technical and economic characteristics and the political dynamics of such a strategy.

The starting point for a discussion of these issues has to be the characteristics of nuclear and solar energy systems. In this article we discuss their technical and economic properties and potentials. Their similarities and differences and their social and institutional implications are the main theme of our study.

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Assumptions About Energy Demand and Supply

Some basic data on Sweden are given in Table 1. We have chosen for the year 2015 a model in which Sweden has roughly the same societal and industrial structure as today. The number of inhabitants is assumed to remain about 8 million. The production of goods and services in the country is assumed to be twice the present level. It should be noted that the Swedish level is already one of the highest in the world and that Sweden, compared to the United States, for example, is also relatively energy-efficient (*3*). The level of production assumed (Table 2) would permit giving everyone about the material standard now enjoyed by the top 10 percent of the population.

Other mixes of goods and services are, of course, likely but do not greatly affect the gross features of the energy system. The assumptions therefore cover different developments of Swedish society; they even include more emphasis on resource conservation than was necessary for the purpose of this study, as well as a general raising of the standard of living.

An outline of economic activity and final energy demand values for 2015 are shown in Table 2. The assumptions about specific energy use must be regarded as conservative. Figure 1 relates this demand to current Swedish energy policy.

Energy use in Sweden has been broken down into several energy quality groups for the energy demand in 1971. The same distribution is assumed for 2015, although a small adjustment has been made for increased efficiency in space heating. The resulting breakdown of energy quality is included in Figs. 2 and 3.

Table 1. Some basic data for Sweden (1975). Electricity is traditionally counted as 1 kWh electric = 1 kWh thermal because of dominating hydropower production.

Area	450,000 km^2
Population	8,200,000
Gross national product	$52,000,000,000
Gross national product per capita	$6,400
Energy, total	415 TWh/year
Energy per capita	50 MWh/year
Electricity	80 TWh/year
Hydropower	57 TWh/year
Nuclear	12 TWh/year

Both the nuclear and solar options for Sweden employ the indigenous energy sources that are used at present. Hydropower is assumed to contribute 65 terawatt-hours electric per year, which is slightly above the present level. Installations supplying a further 25 to 35 TWh/year are technically and economically feasible, but have so far been viewed as too damaging environmentally and socially (*2*). Biomass (bark and lye) presently supplies 36 TWh/year in the paper and pulp industry, and we assume that it will also be used in solar and nuclear Sweden.

A Nuclear Sweden in 2015

In designing a uranium-based energy system, we have used technologies now available or planned by the nuclear industry. Light-water reactors (LWR's) thus play a major role. However, since known reserves of uranium in Sweden would suffice for only 30 years operation of a large-scale nuclear program based on LWR's (without uranium and plutonium recycling), more uranium-efficient fuel cycles have to be used. Breeder reactors of the type now under intensive development in several countries have therefore been introduced. The full fuel cycle is also assumed to be established in Sweden (although pilot studies of reprocessing have been conducted in the past, no present studies or plans exist for the fuel cycle).

The main energy carrier to the industrial, commercial, and domestic sectors will be electricity, produced mainly by 67 nuclear power stations supplying 1 gigawatt electric each. Peak load is supplied by pumped storage and fuel cells. District heating is assumed for the larger metropolitan areas from six 1-GWe reactors operated in cogeneration and an additional ten smaller reactors for heat production only. This saturates the possibilities for nuclear-based district heating. Transportation is based on methanol or hydrogen (used, for example, in fuel cells). The system is shown in Fig. 2 and the components are listed in Table 3 together with estimated costs. Breeder reactors are introduced from the year 2000.

Uncertainties in the outline of nuclear Sweden include technical and environmental issues, land use, and political controversy. Technically, prototypes of breeder reactors are being built in other countries. Licensing requirements and therefore costs are still very uncertain. Reprocessing technology is at an early stage of industrialization and has yet to be demonstrated on a commercial scale. Reprocessing of breeder fuel is at an even earlier stage. Swedish land use will include 10 to 20 new sites for reactors and space for a large additional transmission grid (800 kilovolts).

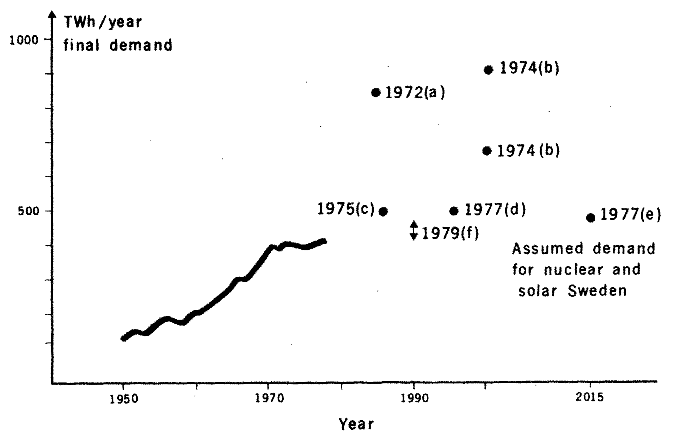

Fig. 1. The curve shows energy demand up to 1978. The points represent various official demand estimates and illustrate how projected levels of energy demand have been reduced during the last 5 years as a result of increased understanding of energy demand, lower economic growth, and conservation efforts: *1972(a)* is a forecast presented by the power utilities; the points labeled *1974(b)* are based on assumptions of 6 and 4 percent annual growth in industrial output, respectively; *1975(c)* is the level assumed by the government plan of 1975; *1977(d)* is a forecast made by the National Swedish Industrial Board of Industries, based on 3.3 percent annual growth of industrial output; *1977(e)* is the figure used for solar and nuclear Sweden; and *1979(f)* is the level assumed by the government plan of 1979.

A Solar Sweden in 2015

The solar energy influx in Sweden is 800 to 1000 kilowatt-hours per square meter annually. The potential for wind energy, biomass production, and solar heating is rather substantial. A possible supply system for the year 2015 (*4*) matched to the same level of final use as in the nuclear case is described in Fig. 3 and Table 4. The biomass contribution dominates, but other large contributions come from photovoltaics, hydropower, wind power, and solar heating. Energy is delivered to end use as electricity, methanol, solid fuels (wood), and heated water at various temperatures.

Biomass is produced mainly on land but also in marine areas. Research carried out recently in Sweden indicates a yield of 100 to 200 MWh per hectare annually (1 ha = 10^4 m^2) in small, carefully managed areas planted with selected willow (*Salix*) and poplar (*Populus*) species. The average yield is likely to be lower as more realistic large-scale conditions are achieved. Further research, however, may increase the maximum yield above the present preliminary results.

Energy plantations are assumed to contribute 260 TWh and to require 2.9 million hectares, giving an average yield of 90 MWh/ha-year. This land area is large, roughly of the same size as that now used for agriculture. It is 6 to 7 percent of Sweden's total land area. However, it is much less than the 23 million hectares presently used for ordinary forestry mainly supplying the paper and pulp industry.

Solar heating contributes 71 TWh/year, mostly as space heating. Heat has to be stored seasonally in district heating systems using low-temperature heat and, for example, in large reservoirs of water or directly in the ground. A number of pilot projects based on this technology are now under way. District heating by cogeneration plants using biomass for heat and electricity production is important for the larger cities.

Wind power is expected to contribute 30 TWh/year. It will be supplied by 3700 units with a capacity of 4 MW each and which are located in areas of Sweden with median wind speeds above 6 m/sec at the 50- or 100-m level. A large demonstration program is under way.

Solar photovoltaic cells, with an area

Table 2. Assumed production of goods and services and specific energy use in the year 2015 based on the figures for 1975.

Energy use	1975 TWh	2015: Production level compared to 1975 (%)	2015: Specific energy use compared to 1975 (%)	2015: TWh
Production of goods	165	+100	−20	264
Services				
Transportation	75	+100	−50	75
Others	70	+100	−50	70
Housing including household electricity	80	+ 40	−30	80
Subtotal	390			489
Conversion losses	25			58 to 79
Total	415			547 to 568

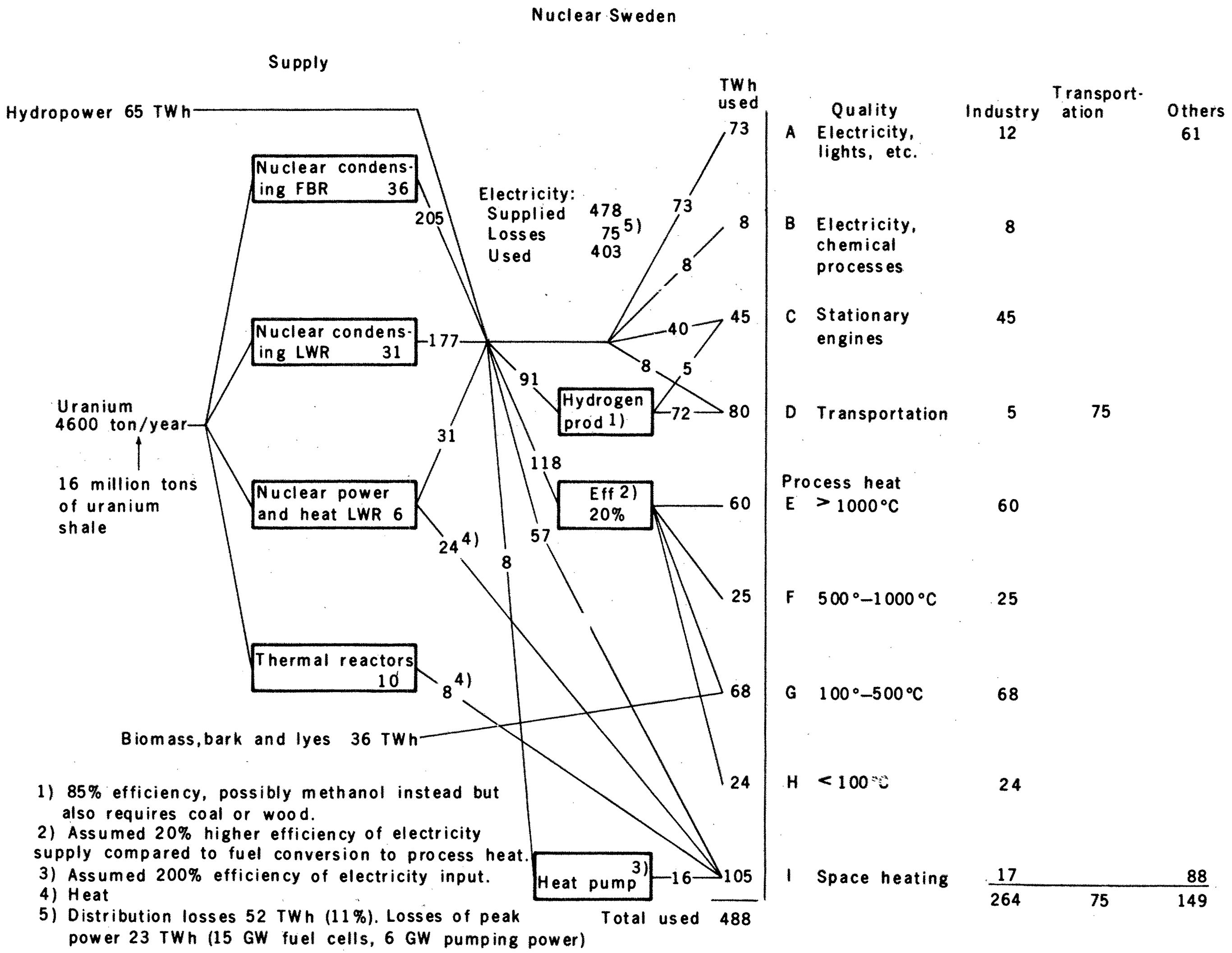

Fig. 2. Energy system in nuclear Sweden in 2015. (Left) Supply of energy in the system; (right) energy consumption divided into different categories of energy quality; (middle) linkage between supply and consumption. The number of terawatt-hours represented by each line is shown.

on the order of 50 m^2 per capita, located on roofs and walls, could be used in various ways. They could be directly connected to the load or used for the production of methanol (with biomass as feedstock), which may be a way to provide seasonal storage.

Fuel cells play an essential role in both the electricity system and the transportation sector. Methanol is used as fuel in the transportation sector. A large fraction of the cars and trucks are assumed to be powered by electric engines, through either fuel cells or electric batteries.

As in the nuclear system, there are uncertainties in several areas, and extensive research and development efforts are needed before any major commitment to the solar option can be made. In particular, the success of energy plantations and solar heating and storage is crucial. The environmental effects of energy plantations are not well understood, and there may be limitations due to nutrient leaching, insect attacks, diseases, or land-use competition. Solar cells are still much too costly to be considered, although costs are expected to drop rapidly. The public acceptability of large-scale wind energy is unknown.

The implementation rates assumed for the 1990's are somewhat lower than those considered possible by the National Board for Energy Source Development. The contribution from renewable energy sources is now around 25 percent and is not assumed to increase much until the 1990's (see Fig. 4). Considerable efforts are needed in the 1980's to facilitate the rapid expansion of renewable energy after 1990.

Comparisons of the Two Systems

The main object of these studies, we stress again, is not to make long-term predictions but rather to analyze the requirements of a medium-term energy policy designed so that none of the long-term options are foreclosed. Such an analysis has to be based on a detailed study of the similarities and differences between the options.

There is no technical reason why the two systems could not be combined. However, a number of economic and (above all) institutional factors, some of which we will address, would probably lead to a dominant role for one system or the other.

Areas of uncertainty. These are large in both cases. Technologically, there seem to be uncertainties about the performance of fast-breeder reactors (FBR's) and reprocessing of FBR fuel as well as about several solar technologies. The environmental impacts are potentially large (but different) in both cases. These and other uncertainties, which also propagate themselves into uncertainties about economics, are important reasons for not foreclosing either of the two options at present.

Economic comparison. In this respect, the two alternatives seem (from the cost estimates in Tables 3 and 4) to be roughly equivalent, although the uncertainties are obviously large. This conclusion is based on a calculation of the total amount of resources needed to implement and operate the alternative energy system from 1990 to 2015. The total costs are two to three times as large as today's. However, given conventional assumptions of economic growth, this increase in the cost of energy is compatible with a higher material standard of living.

If labor productivity increases by 2 percent overall and by 5 percent in good production, the doubling of the total Swedish economy assumed by the year 2015 is compatible with an increase in the cost of energy by a factor 2 or 3. Costs are not uniform, however. The cost of electricity is higher in the solar system than in the nuclear system; but the cost of biomass energy in the solar case is much lower than the cost of nuclear electricity when the function for which it is used is considered.

The main conclusion of this economic comparison is that when the present uncertainties are taken into account, it is too early to state that one alternative is more economical than the other. A sec-

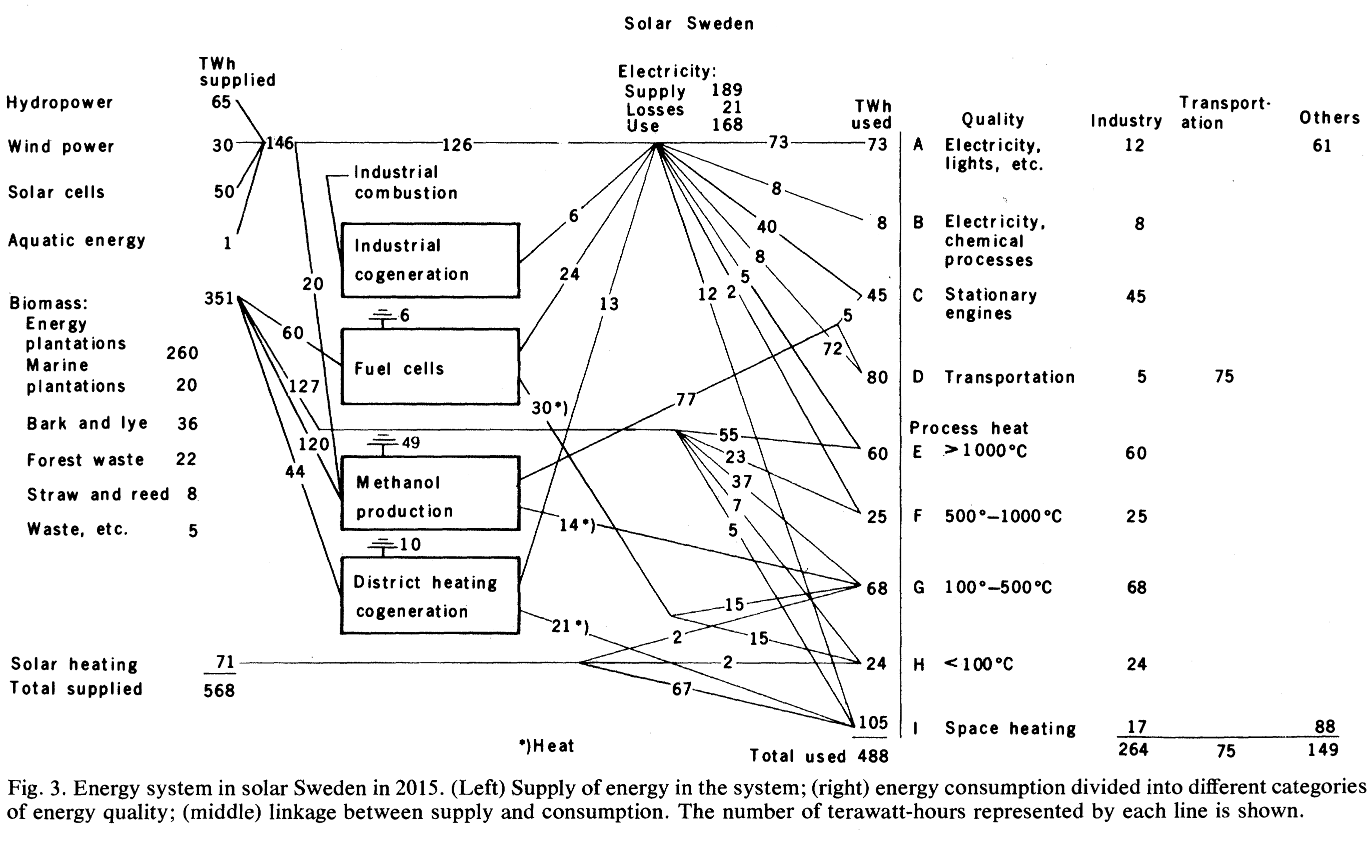

Fig. 3. Energy system in solar Sweden in 2015. (Left) Supply of energy in the system; (right) energy consumption divided into different categories of energy quality; (middle) linkage between supply and consumption. The number of terawatt-hours represented by each line is shown.

ond conclusion is that neither of them needs to be a major obstacle to increasing the material standard of living.

Technical comparison. There are large differences between the solar and nuclear alternatives in the choice of energy carriers and distribution systems. The way present systems are designed will therefore have important effects on later costs of connecting new supply sources.

It takes decades to establish large district heating systems. Thus present policies on district heating operating characteristics (such as design temperatures) will have to be adjusted to facilitate the later introduction of solar heating. In the same way, policies with respect to direct electric space heating will have to be adjusted.

The two alternatives differ considerably with respect to industrial energy use. In the nuclear case electricity is used for process heat, while in the solar case direct combustion of biomass would supply the heat. The equipment necessary in the two cases would differ greatly and ways would have to be found to reconcile the differences.

Electricity production in solar Sweden is located closer to the user, is less predictable (wind and solar), and is more frequently connected to co-use of waste heat than is the case in nuclear Sweden.

Table 3. Cost estimates used for components in nuclear Sweden (price levels at the turn of the year 1977–1978) in Swedish crowns (kr) (U.S.$1 = 4.40 kr; 1 Mkr = 1 million kr; 100 öre = 1 kr).

Component	Description	Capacity	Investment cost*	Operating cost*
Uranium mines	Ranstad mine supplying 1300 tons of U per year plus ten smaller mines producing 400 ton/year located in the Billingen area and in northern Sweden. A shale processing industry of 16 Mton of shale per year would be built. For comparison, the large iron ore industry in Sweden processes 35 Mton/year today.	5200 tons of U per year	1.7 Mkr/ton per year	260 kr/kg (natural U)
Enrichment	A Swedish plant by 1990	3.6×10^6 SWU†	2115 kr/SWU per year	300 kr/SWU
Fuel fabrication	Light-water reactor			600 kr/kg (enriched) U
	Fast-breeder reactor			5000 kr/kg (fuel)
Reactors	Light-water reactor	37 of 1000 MWe	3500 kr/kW	0.7 öre/kWh + 45 kr/kW per year
			4375 kr/kW‡	0.7 öre/kWh + 45 kr/kW per year
	Fast-breeder reactor	36 of 1000 MWe	5250 kr/kW	0.7 öre/kWh + 45 kr/kW per year
			6500 kr/kW‡	
	Nuclear heating stations	10 of 200 MW	2000 kr/kW	
Reprocessing	Light-water reactor fuel	2×1100 tons	10 Mkr/ton per year	0.85 Mkr/ton per year
	Fast-breeder reactor fuel	360 tons	30 Mkr/ton per year	2.55 Mkr/ton per year
Waste isolation	Waste from 1500 tons of U per year, corresponding to one repository of 10^4 KBS-size canisters every 6 years§	As for reprocessing	3.1 Mkr/ton per year	0.1 Mkr/ton
Distribution	5000 km of 800-kV transmission lines on 40-m-high transmission poles 400 m apart, totaling 13,000 poles plus additional lower-voltage power lines	340 TWh	0.25 kr/kWh per year	Information not available
Hydrogen production		45.5 GW	550 kr/kW	4 percent of investment annually
Pumped storage		6 GW	800 kr/kW	4 percent of investment annually
Fuel cells		15 GW	2000 kr/kW	4 percent of investment annually

*Costs are from various Swedish studies, referenced in detail in (*1*). †SWU, separative work units. ‡Underground siting in rock; 75 percent of the reactors are assumed to be sited underground. §As proposed by the Swedish Nuclear Fuel Safety Project (Kärn Brènsle Säkerhet, KBS).

Table 4. Cost estimates for a solar Sweden in 2015 in Swedish crowns (U.S.$1 = 4.40 kr).

Energy supply	Installed capacity by 2015	Investment cost*	Operating cost*
Wind power	15 GW	4000 kr/kW	2 percent of investment annually†
Solar cells	50 GW 500 km²	~ 2.5 kr/W (peak) plus 100 kr/m² installation; total, 400 kr/m²	2 percent of investment annually†
Solar heating	71 TWh/year	2 kr/kWh per year	2 percent of investment annually†
Methanol production	16 Mton	1100 Mkr per 750,000 tons per year	4 percent of investment annually†
Pump storage plant	15 GW	800 kr/kW	4 percent of investment annually†
Fuel cells	8 GW	2000 kr/kW	4 percent of investment annually†
Biomass			
Energy forest plantation	260 TWh/year		300 kr/ton (dry weight)
Other biomass (except bark and lye)	55 TWh/year		230 kr/ton (dry weight)

*Costs are from various Swedish studies, referenced in detail in (*1*). †For maintenance and service.

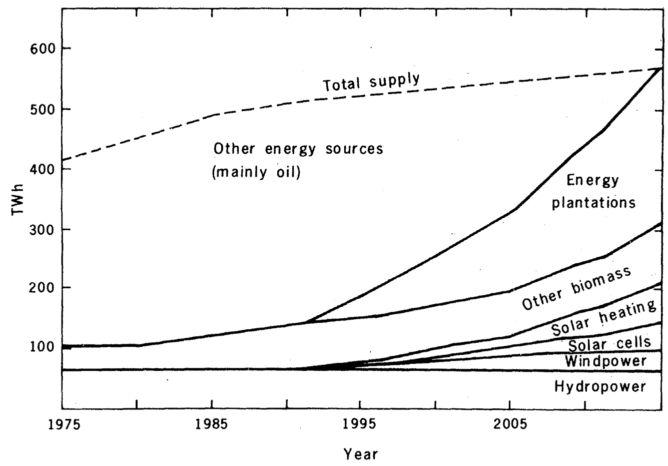

Fig. 4. Contributions of renewable energy forms to energy supply in solar Sweden. The broken line shows the assumed development of total energy supply.

It thus requires different load management practices.

In sum, the technical differences are large. To ensure freedom of action on the supply side it is therefore necessary to develop distribution and end-use systems so that they can be connected to different supply alternatives in the future. This poses problems of institutional adaptation, which may well be greater than problems related to the economic and technical aspects of the alternative systems.

Institutional differences. The large technical differences noted above imply large differences in institutional arrangements. A nuclear Sweden can only be implemented through a strong central authority; this is true not only for the fuel cycle but also for the total electricity supply system. Locations of fuel cycle components, reactors, and transmission lines have to be based on national decisions, implying that local authorities will have to give up their present right to veto siting decisions.

A solar Sweden, on the other hand, requires more integration between end use, distribution, and supply. Land-use plans for buildings, biomass plantations, and wind energy have to be developed and implemented.

Thus it seems that both the nuclear and solar cases compared to today's conditions, imply increased public planning. The nuclear system cannot be implemented without strengthening planning on the national level and the solar system cannot be implemented without giving more power to both local and central authorities. Other differences between nuclear and solar Sweden are to be found in the capital market. In the former, the typical recipient (or customer) is the national government or a large utility; in the latter, a large number of individuals, small firms, local authorities, and regional and central governments are the customers.

The overall conclusion is that the social organization, in particular the institutional infrastructure, is very different in the two cases. Thus, medium-term energy policy has to be directed toward establishing institutions that, in an overall sense, are unbiased toward different technologies. This is no small task in itself.

Controlling the Nuclear Momentum

It is now possible to combine the medium- and longer-term perspectives. A number of studies of medium-term supply show—and this has also been the conclusion of various large political majorities—that nuclear power should not be rejected in the medium-term perspective. The government plan of March 1979 indicates that the present nuclear program of 12 reactors, together with some more hydropower, cogeneration of electricity, conservation, and possibly wind power, is sufficient to satisfy electricity demand through the end of the century. Also, during the medium term oil could be replaced in part by other energy sources, such as wood, natural gas, peat, and coal. However, the long-term studies also show that a medium-term policy, apart from securing supply for the medium term, has to include specific steps designed to create freedom of action in the longer run.

During the last 20 to 30 years, the view generally accepted by the political parties, industry, and the electric utilities has been that the use of nuclear power should be increased. Research and development has been strongly oriented in this direction, in Sweden as well as internationally (*5*). A reactor industry in need of further orders, the organization of the electricity distribution system, the expectations underlying planning in different sectors of society—these and other factors have contributed to building up a momentum in continually expanding the role of nuclear energy. If our call for freedom of action as a component of medium-term energy policy is to be taken seriously, the mechanisms behind this momentum have to be identified and controlled.

One such set of mechanisms has to do with a forecast overcapacity in the electricity supply sector during the 1980's. The Swedish power industry used a similar overcapacity during the 1960's to discourage cogeneration by industries and local authorities (*6*). This overcapacity makes the utility sector and the nuclear industry resist measures that tend to reduce demand for electricity, and it also makes investments in other supply alternatives, such as cogeneration, very uncertain. There is a related and marked tendency among utilities to advocate end-use patterns that are highly inflexible, such as direct electric resistance space heating, thus ensuring the market for nuclear-generated electricity (roughly half of the nuclear power planned for 1990 is, in fact, to be used for electric space heating). Without electric space heating it would hardly have been possible to establish an indigenous Swedish nuclear reactor industry.

Another set of mechanisms tends to favor electrification over other secondary energy carriers. This is again most notable in the space heating market. The medium-term alternative to electric space heating is district heating, both when oil-based furnaces in newly constructed buildings and in existing buildings are replaced. District heating could be achieved with different fuels in large or small plants and it is favored by many local authorities. It does not, however, have the same privileged position in the capital market as electricity supply.

A third set of mechanisms is related to the conditions under which local authorities work. Many long-term solar technologies and the medium-term distribution systems that make solar competitive in the long term require considerably more planning by local authorities than most of these authorities are yet capable of. Moreover, the financial situation of local authorities in Sweden has to be improved, but this will require considerable legislative work because of the interdependence of different systems of rules. The present situation favors either technologies that fit well into existing rules or those that are being pushed by very powerful entrepreneurs. Wind power, solar heating, cogeneration, fuel cells, photovoltaics, heat pumps, and many other technologies close to the consumer may pose serious threats to the utilities' plans for expanding base load in general and nuclear plants in particular. Differences in lead times tend to reinforce these problems.

A fourth set of mechanisms favors large-scale, utility-operated electricity production over small-scale, dispersed production, regardless of whether the latter is done by local authorities with cogeneration plants or by industries or other means. This again depends partly on how the capital market works, but it also depends on the power to determine existing principles of rate setting. As long as these reflect the cost structure of utilities they tend to create barriers to dispersed electricity production and, for that matter, conservation.

Having already invested in nuclear plants, electric utilities set rates that protect their investments and dissuade consumers and local authorities from investing in more dispersed technologies for producing and conserving electricity. The Swedish federation of electric distributors has considered rates for electric heat pumps that have special penalties for peak power demand. These rates would depress the market for the heat pump industries. Rates could be set in such a way as to stimulate these and other dispersed solar technologies, but they would then reduce the market for nuclear power.

Measures to create a solar industry therefore threaten the nuclear industry. And conversely, measures to protect the nuclear industry and the demand for nuclear-generated electricity may very well create an insurmountable barrier to a nascent solar industry.

A Medium-Term Energy Policy

Steps that ensure long-term flexibility are thus likely to challenge short- and medium-term industrial policy and to threaten the medium-term financial stability of the present utilities. Balancing and reconciling these conflicts is therefore one of the primary aims of a medium-term energy policy. A policy attuned to freedom of action must therefore cover broad areas. Under Swedish conditions, some of the main points would be:

1) Strengthening local authorities in the field of energy. Many local authorities are now in charge of the distribution of electricity and the production and distribution of district heating. These tasks should be the responsibility of all local authorities, who should also be responsible for conservation of energy. Moreover, local authorities should be encouraged to become as self-reliant in energy as possible.

2) Regulatory and financial reform of the energy sector. This reform should ensure adequate financing on the local level and a rate structure that stimulates conservation and implementation of dispersed and capital-intensive supply alternatives. It should also include financing of conservation efforts and require that conservation and supply be balanced explicitly and on the local level. Technical design parameters, which are now almost exclusively the responsibility of professional organizations, should become subject to political scrutiny (with subsequent regulation as well as some deregulation).

3) Increased control of large-scale energy users by the national government. The main aim is to ensure that markets are established for biomass production and that end-use and conversion devices are compatible with several supply alternatives. Conservation programs for these users should be monitored by the national government.

4) State-financed development and procurement of new energy technology. This is an important way to create incentives for industry to establish new technologies. It should cover space heating, transport, and small-scale electricity production, where local and central governments could become large consumers.

5) Land-use planning to ensure that land is available for reactor sites, biomass plantations, wind energy plants, solar heating stations, and so on. This requires a combination of local and central initiatives.

6) Electric utility reform to encourage the introduction of more dispersed electric technologies. This can be done by giving local authorities exclusive right of distribution and divesting production interests of control of bulk transport (the grid above, say, 130 kilovolts). The bulk transport utility (which should be publicly controlled and preferably publicly owned) would function as a wholesale broker and, through rate setting, could encourage distributors to channel their investments into alternatives to large base-load plants.

There is no question that this kind of program is controversial. Circumstances could, of course, be imagined in which these types of interventions would not be necessary—in particular, if the nuclear option were convincingly demonstrated and accepted as superior. The imperative now is to establish a policy for the case where genuine uncertainty remains large.

Some discussions of solar and nuclear futures have focused on the theme of centralization and decentralization. It should be evident from our discussion that a policy directed toward a solar Sweden does not seem to reduce the need for central authority and planning.

Moreover, the challenge to policymakers posed by an open-ended energy policy can hardly be stressed enough. Pressures to make decisions and commitments will be very strong from constituencies favoring particular long-term options. A flexible policy can be seen as a way to reduce overall uncertainty for governments and the public at large, but it appears in exactly the opposite light to groups and industries that are already committed.

A flexible policy will require a balance of interests, which means more control by the national government than is required for clear-cut implementation of either the solar or the nuclear option. But that may be the price that has to be paid in order to have freedom of choice.

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