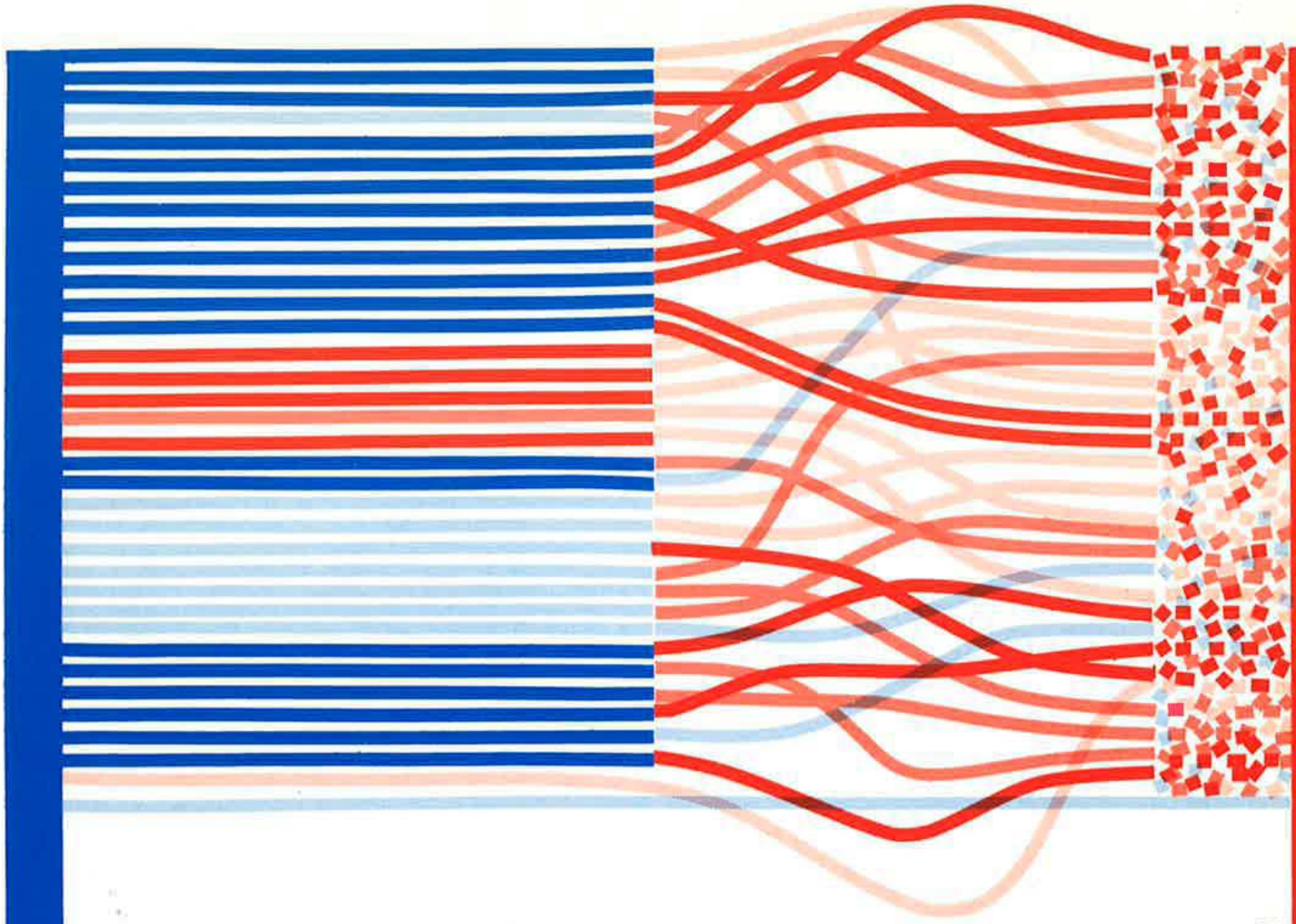
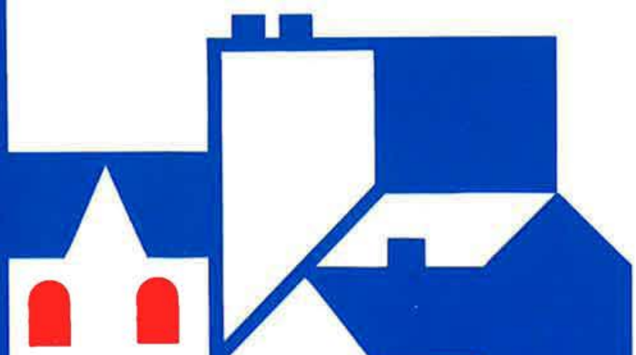
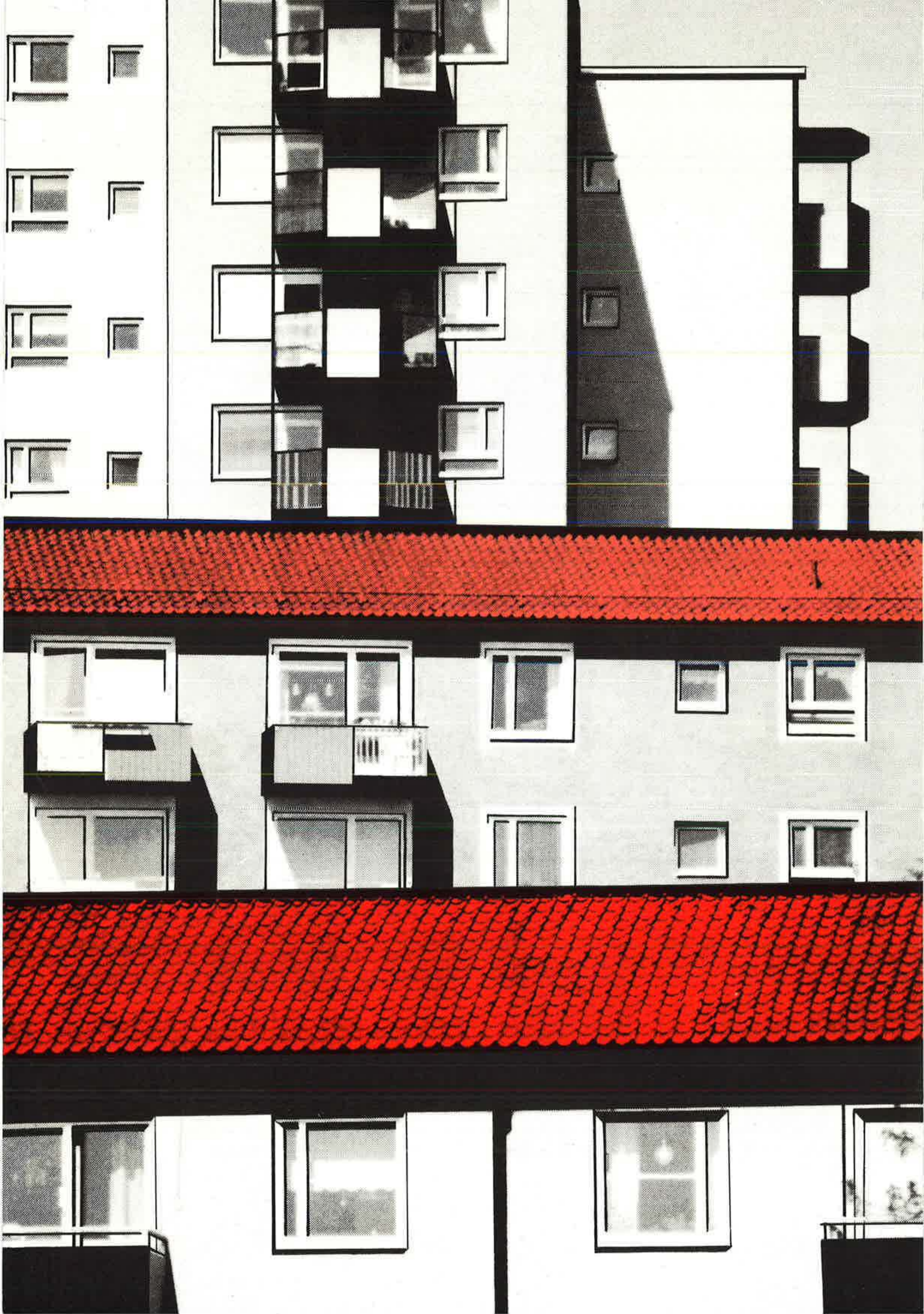
Swedish Council for Building Research



summary of ENERGY IN THE BUILT ENVIRONMENT



The way forward to the 1990s



Energy use in the built environment

- A summary of key data in the run-up to the 1990s

This brochure presents a summary of the changes that have occurred in energy use in residential and commercial premises since the beginning of the 1970s, together with the potential offered by the built environment for realising the growing demands for efficient use of energy, modernisation and good future environmental conditions. Strategic aspects of the built environment that are important in determining energy policy are also discussed.

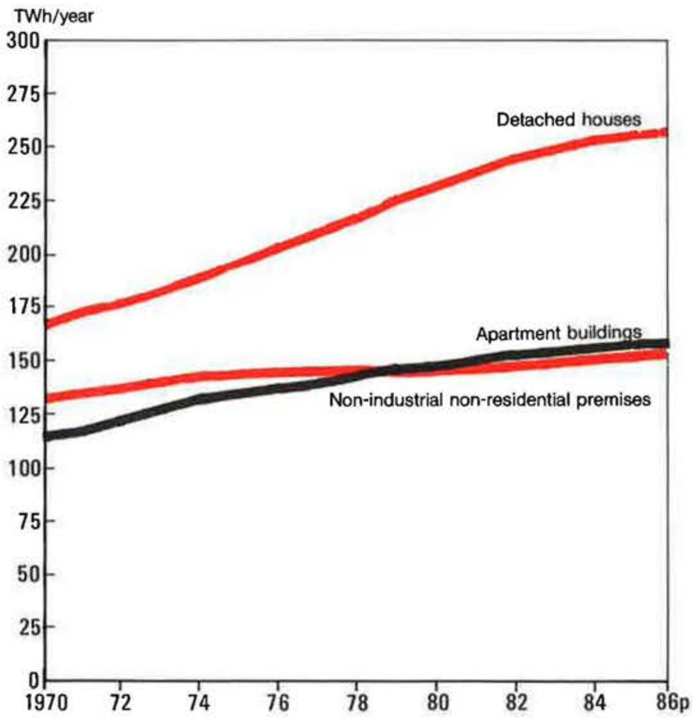
The results are based on a large number of completed research, development and experimental building projects.

The complete report is published by the Swedish Council for Building Research as G16:1987 in Swedish and G16:1988 in English.

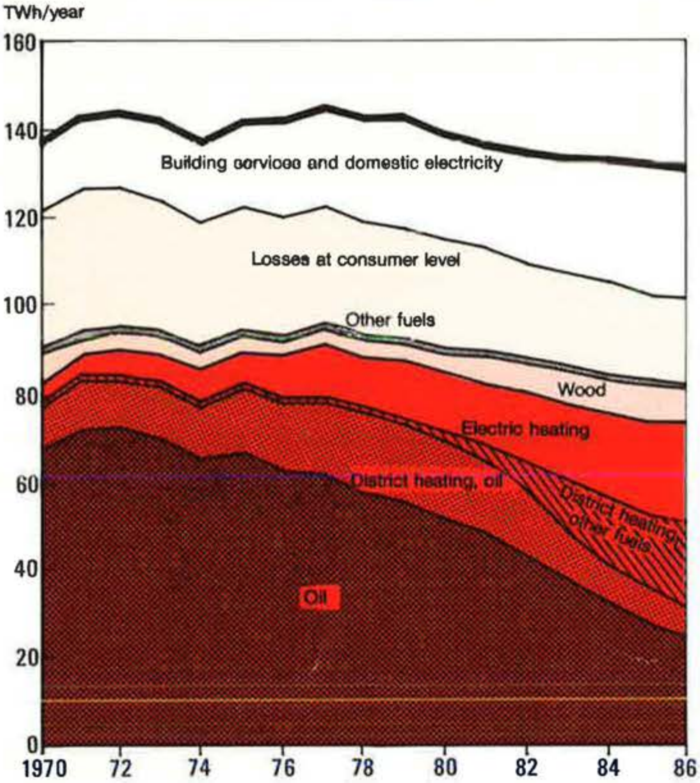
The built environment

Not including industrial buildings, the built environment accounts for about 40 % of Sweden's total energy use, which means that any changes in the sector may have a considerable effect on the country as a whole. Efficient and rational energy conservation affects not only the country's trade balance, but also its environmental quality and strategic vulnerability. Changes in the building sector also influence energy use in other sectors.

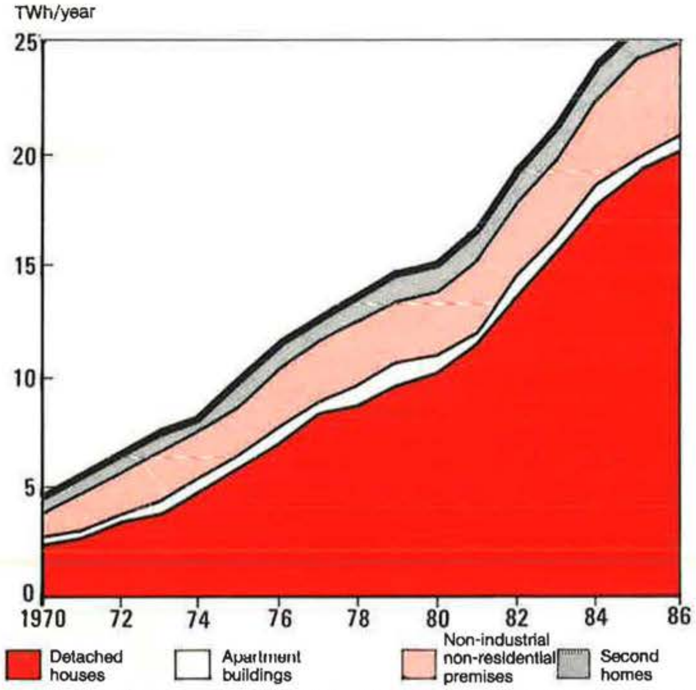
IN 1985, Sweden's total building stock amounted to about 780 million m² of heated floor area, representing an available area for each of the country's inhabitants of over 90 m². The number of dwelling units amounted to about 1.8 million in detached houses and about 2.1 million in apartment buildings. In recent years (up to 1987) investment in new residential construction has fallen by one-third, while investments in repair, conversion and extension projects have more than doubled.



Breakdown of total heated floor area, 1970-1986



Total energy use in residential and non-industrial non-residential premises, classified by energy carrier. Energy use for heating purposes is corrected for a statistically normal year. Oil is used in small individual boilers, in group heating plants and also to produce district heating. The sector indicating losses at consumer level represents the difference between gross and net energy use for heating purposes. Addition of electricity for domestic purposes and operation of building services systems gives the final gross energy use.

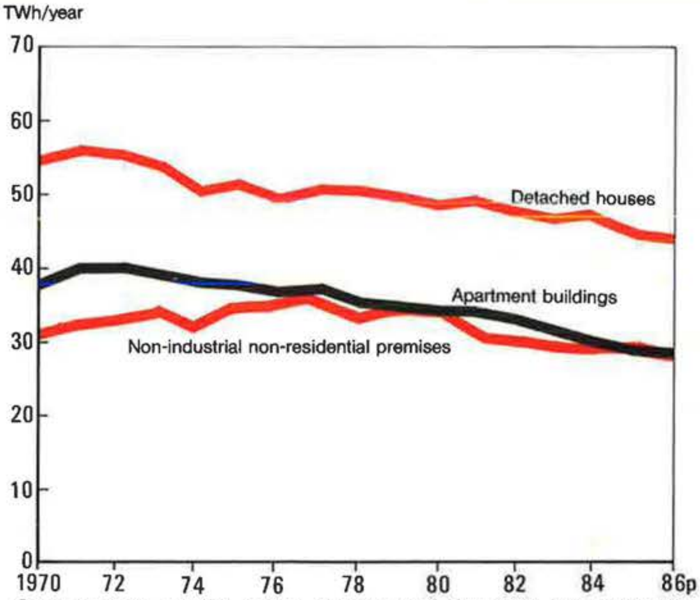


Gross use of electricity (statistically average year corrected) for space heating and domestic hot water production, classified by type of buildings.

29 TWh lower energy use

Gross energy use for space heating and domestic hot water production in residential and commercial buildings and premises has falllen from about 143 TWh/year in 1977 to about 130 TWh/year in 1986. However, as the total heated floor area increased by about 15 % during this period, these figures do not tell the entire story.

If, instead, we consider the changes that have occurred in the building stock that was in existence in 1978, when the first energy conservation plan was presented, the picture becomes clearer. We can see that within this stock the gross energy use for heating and domestic hot water production has fallen from about 120 TWh/year in 1978 to about 91 TWh/year in 1986. This means that, after seven years of the ten-year energy conservation plan, nearly 70 % of the savings target of 43 TWh/year (gross) was achieved, representing an average annual rate of reduction of about 3.8 TWh/year over the period. The 1985–86 period is an exception, for wich preliminary figures indicate a poorer result, with the rate of annual decrease falling to about 2.0 TWh/year.



Gross energy use for space heating and domestic hot water production in the still existing 1978 stock of residential buildings and non-industrial non-residential premises, corrected for a statistically average year.

A reduction in energy conservation rate

The willingness of property-owners to invest in energy conservation measures or improvements seems to be on the wane. This applies not only for cooperatively or privately owned property, but also for public buildings. At the same time, there has been a marked reduction in the number pf heat pumps installed. Metering in apartment buildings also indicates that indoor temperatures are increasing, with the result that energy use in such buildings is not falling as intended.

Dependence on electricity a growing problem

While oil consumption in the built environment has been halved since 1974, the use of electricity for heating, operation of building services, domestic purposes and office equipment has tripled. This, of course, has the effect of complicating the problems associated with the phase-out of nuclear power.

Dependence on electricity is particularly marked within the detached house sector, where the use of direct electric resistance heating is considerably more common than in other types of buildings, and where there has also been large-scale conversion of boilers from oil firing to electricity.

A total of about 525 000 detached or semidetached houses, containing about 560 000 dwelling units, is more or less dependent on direct electric resistance heating, with about 380 000 of them being entirely dependent on electricity for their heating.

Direct electric heating in apartment buildings is only used in a total of about 60 000 apartments.

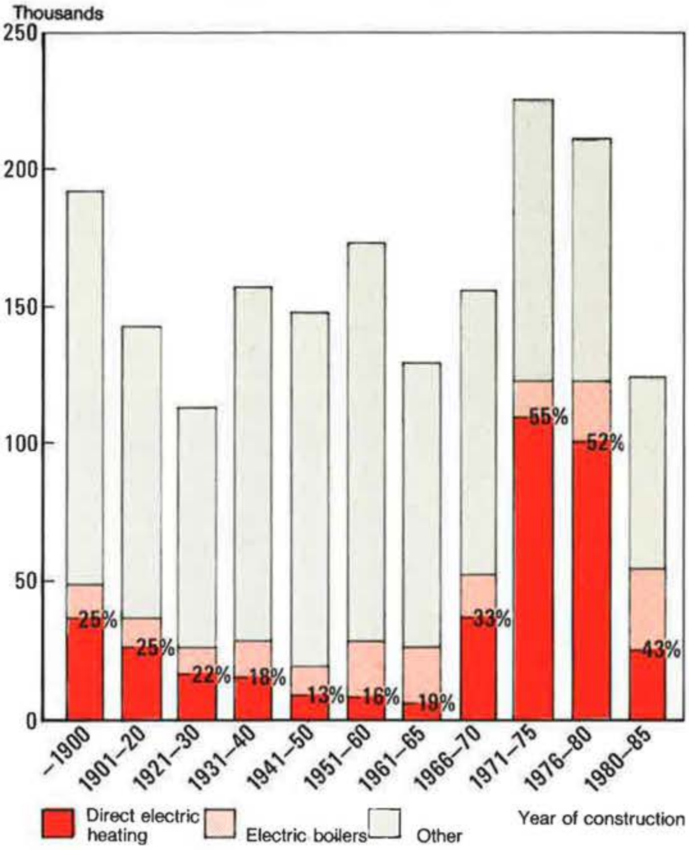
Uneconomic conversion

Research and development that has been started in the field of conversion of electric heating systems needs to be intensified and in due course crystallised in experimental and demonstration projects. However, there is no cause for panic. As the majority of directly electrically heated detached houses (over 70 %) are modern and built to good standards, no major improvements will be needed before the early years of the 1990s at the earliest. And thus, of course, also energy conservation improvements may wait.

The remaining third of electrically heated houses, on the other hand – those that were built prior to 1940 – are often in need of modernisation. Unfortunately, too, such houses are seldom grouped closely together, which would be helpful when converting them to some form of collective heat supply system.

In recent years, it has also become apparent that more and more electricity is being used for building services systems – e.g. for ventilation fans and for pumps. Even in relatively conventional apartment buildings, such systems use about the same amount of electricity as is used for domestic purposes, i.e. about 25–30 kWh/m², year.

Reduction of power demand – as opposed to energy demand – is becoming increasingly important, primarily because the power demand in all kinds of electrically heated buildings tends to vary with the ambient temperature. Energy conservation measures reduce not only the total level of energy use, but also the power demand on the "Coldest day".



Number of detached houses using direct electric heating only, electric boilers only or any other form of heating system, classified by age.

Buildings can be constructed with lower energy demands

Based on experience from experimental building projects, it is the opinion of the Council that energy demands in the built environment can be significantly reduced as a result of improvements in building design and in building services systems.

Experience from the Council's experimental building work indicates that it is possible to reduce the annual level of use of purchased energy for space heating, domestic hot water production and domestic electrical purposes in **newly-built detached houses** – with a floor area of about 110 m² – to about 10 000–12 000 kWh in the climate of central Sweden, using known and well-proven technology.

In **existing detached houses,** economically viable improvements based on tried-and-tested methods can reduce the total demand for purchased for heating, domestic hot water production electricity for a building in the climate of central Sweden with a floor area of, say, 110 m² to about 15 000 kWh. At present, the statistical average demand of such buildings is about 23 000 kWh, with a very wide spread.

As far as **newly-built apartment buildings** are concerned, the Council feels that it should be possible to reduce specific energy use levels for space heating, domestic hot water production, domestic electricity and electricity for common purposes in buildings in normal production at the beginning of the 1990s to about 100–120 kWh/m², year. However, two important considerations must be noted, both of which have been indicated by experience. Even with relatively conventional technology, the standard of commissioning of building services systems in apartment buildings is an important element in the achievement of low levels of energy use. Secondly, even with conventional systems, electrical energy demand for operation of the various pumps, fans etc. used in the building services systems tends to be of the same order of magnitude as the total internal electrical power requirements of the apartments for lighting and domestic purposes.

Improvements applied in the form of carefully planned groups of measures in **existing apartment buildings** indicate that it is possible to reduce the level of energy use for space heating and domestic hot water production by 30–50 % from an average specific annual requirement of 250–350 kWh/m² of heated floor area. Further technical development should make it possible to reduce specific energy use for heating purposes to about 100–110 kWh/m², year.

In **new commercial and other premises** – offices, schools and health service buildings – it is possible to cut total energy use by 50 % in comparison with the average present-day level of use. Application of suitable building and building services systems improvements to **existing buildings for office and educational purposes** can achieve viable reductions of almost 50 % in energy use for heating purposes.

However, in all these cases, it is important that design should be detailed and painstaking, workmanship should be of a high standard, inspection and testing should be thorough and operation and maintenance should be in the hands of carefully trained personnel. This applies particularly for commercial premises and large apartment buildnings, which tend to have comprehensive building services systems.

When improving the airtightness of a building – which is normally the result of application of additional insulation – ventilation requirements must be considered.

Attention to design and careful building work is necessary to prevent the occurrence of problems with radon, damp, mildew, reduced internal comfort and defective indoor air quality.

Good development potential for new technology

The contribution made to the country's energy supply by **heat pumps** during 1986 **is calculated** as amounting to a total of 7.6 TWh gross (5.1 TWh net). There is still a considerable potential for the use of heat pumps abstracting heat from natural sources for supply to large apartment buildings, commercial building complexes and group heating plants (i.e. heat plants of various sizes for supplying heat to defined groups of buildings). To this must be added a large, as yet unexploited, potential for exhaust air heat pumps, which can supply up to 70–80 % of the annual energy requirement for space heating and domestic hot water production in the many apartment buildings having mechanical ventilation.

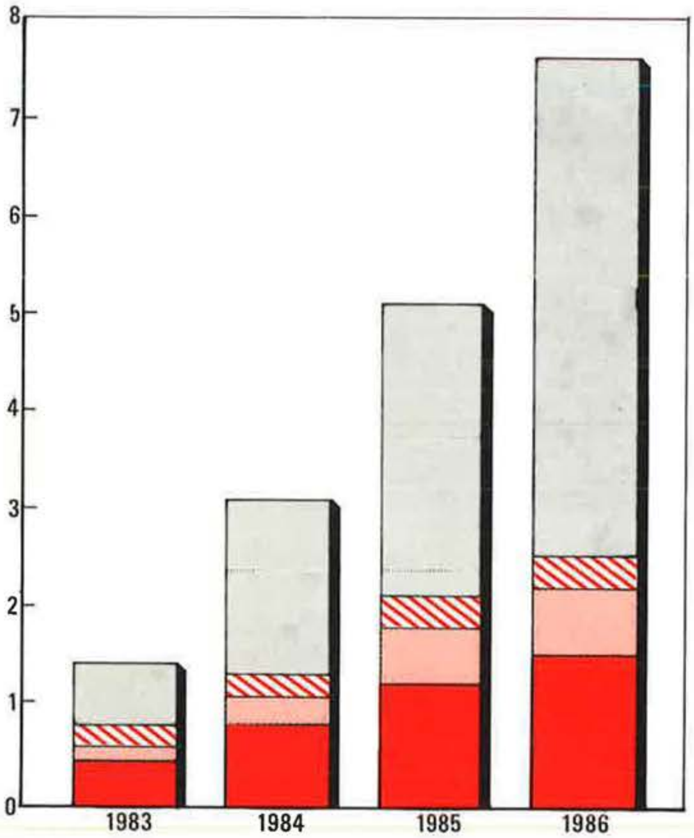
Heat pumps contain chlorinated fluorcarbons (CFC), which have been recognized as contributing to destruction of the world's ozone layer. In the short term, the main method of dealing with this will be careful control of leakage and strict regulations controlling maintenance measures. In the longer term, we can expect to see heat pumps using non-hazardous working media.

The consolidation of knowledge and technical development resulting from the experimental building of **solar heating systems with seasonal heat storage** that has taken place in Sweden since the end of the 1970s is internationally unique. The cost of solar collectors, suitable for use in Swedish climatic conditions, has been reduced by more than half, while specific performance per m² of collector surface area has tripled. Nevertheless, solar heating system costs are still an impediment to commercial application at present energy prices. The objective of continued R&D work is to bring about a 30 % reduction in the cost of energy supplied, achieving this by a combination of reduced capital costs and higher performance.

Seasonal storage of heat is a prerequisite for the use of solar heating on a larger scale. However, the ability to store heat can also open the way to more efficient utilisation of natural heat sources and waste heat. An interesting aspect in the possibility of being able to use heat stores for both cooling and heating of buildings. This would allow the considerable quantities of internal heat released by lighting and computers in present-day office premises to be utilised in combined cooling and heating systems based on seasonal heat stores.

The establishment and consolidation of knowledge relating to large-scale heat storage can also be seen as an important asset in connection with dealing with the problems of peak loads and the growing need for simultaneous power and heat production that will result from the phasing-out of nuclear power.

Distribution of heat in local collective heat supply systems has been developed in the Council's experimental installations in which the media pipes, insulation and outer sheath are all plastic-based. Excavation, pipe-laying and connection to subscribers are speedy and flexible, with little encroachment on ground area or effect on accessibility while the work is in progress. Preliminary results also indicate that it should be possible to extend the lower limits of viable connection downwards to lower density loads than have hitherto been regarded as feasible on small systems, e.g. as would be needed in connection with conversion of groups of directly electrically heated detached houses.



Total heat energy supplied by heat pumps, 1983–1986.

	Solar collector surface area, m²	Store volume, m³
Installations in operation		
1. Ingelstad Ia	1 300	5 000 insulated concrete tank
2. Lambohov	2 700	10 000 uninsulated rock-pit
3. Torvalla	1 800	–
4. Lyckebo	4 300	105 000 uninsulated rock cavern
5. Ingelstad Ib	1 400	5 000 insulated concrete tank
6. Nykvarn	4 000	1 500 insulated steel tank
Outline-designed installations		
7. Ingelstad II	6 000	16 000 insulated excavated pit
8. Kungälv	120 000	400 000 uninsulated rock cavern

Main data for commissioned and outline-designed solar heating installations

Siting considerations, guide measures and consumer aspects

The growing energy demand of the transport sector is heavily influenced by the location of new residential developments and working zones. Research indicates that, at the beginning of the next century, almost as much energy will be used for transportation in urban areas outside densely built-up city centres as for heating. Coordinated zoning will result in cost reductions and higher energy efficiency for local energy systems.

Energy conservation is also associated with other conservation aspects. Integrated planning of the built environment, transport systems, water supply and sewerage systems and other utility systems can reduce the capital, operating and maintenance costs of local service infrastructures. Reduced energy consumption in the built environment and in transport systems results in a better environment, making it an important element in any local authority's environmental planning work.

Local government resources and firmness in the role of the planning body in determining the balance between the level of energy supply are of considerable importance. By no means least important is the local authorities' role as the planning body in determining the balance between the level of energy use and energy supply. Analyses if energy systems based on combinations of electricity, gas district heating, CHP, waste heat and heat pumps are unavoidably complicated and require skilled personnel.

It is very difficult to evalute the effects of guide measures on energy conservation and management. Which effects are due to market forces and which to guide measures? Research has shown that it is not only individual property-owners, but also organisations and companies, that make irrational decisions.

Energy conservation and the introduction of new heating technology have important effects on those who live and work in newly-built or modernised buildings. We still need to better our knowledge of desirable comfort levels, air quality and lighting. The increasing amount of care and attention associated with improved energy management and new technology means that user behaviour also needs to be studied.

It is important that health considerations should be given a central role in the continued work of energy conservation and management.

How far can we go?

As far as tried-and-tested technology is concerned, the Council's calculations indicate that there is a remaining savings potential of the order of 20 TWh – of wich about 4–5 TWh is accounted for by electrically-heated buildings – in residential buildings and commercial premises. It should be possible to achieve this for an investment of the order of SEK 60 000 million.

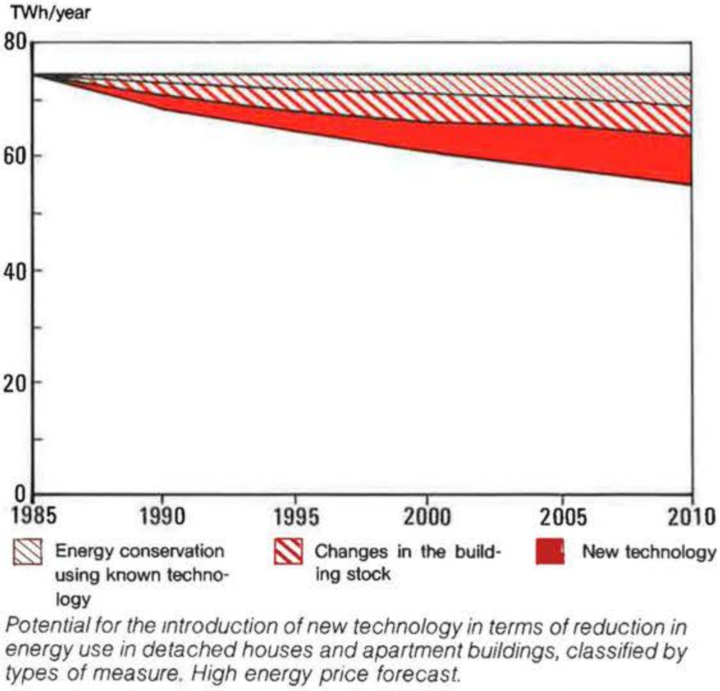
The potential for reduction of fuel consumption and electricity use for heating purposes by application of new technology has also been calculated. This is based on combinations of conservation measures and conventional heating systems in competition with the new types of systems that have been and are being developed, such as heat pumps, solar heating and heat stores. The calculations indicate that a technical and economic improvement of the order of 10–15 % of the new systems could be expected to result in **an increase in savings potential from about 4 TWh to about 14 TWh** by 2010.

In general, the new energy systems have only very slight impact on the external environment, in comparison with present-day conventional technology. They bring considerable benefits, too, in respect of reduction of strategic vulnerability.

Reduced pollution and greater freedom of action

Although application of new technology methods of energy conservation to buildings and building services systems would result in additional benefits in the form of less pollution, greater freedom of choice and reduced strategic vulnerability, it is difficult to quantify these benefits in economic terms. Nevertheless, they are so apparent that there is reason to claim that *energy conservation investments are justifiable in terms of public economics, even though with present-day assumptions their specific costs per kWh may be higher than the cost of supplying an additional kWh from new heating or electric power plants.*

Many measures in the built environment can be undertaken or not undertaken on a particular occasion, e.g. in connection with new building or rebuilding. However, in the event of a change in the energy policy situation, it is not possible to implement or apply them quickly at a later date. Energy policy relating to the built environment must be long-term. The Council feels that measures intended to achieve a good standard of energy quality in the built environment should be applied systematically and aimed at a definite objective. Such measures are often justified in public economic terms far more than would appear from short-term analyses at any particular given time.



Potential for the introduction of new technology in terms of reduction in energy use in detached houses and apartment buildings, classified by types of measure. High energy price forecast.

Greater concentration on research, development and experimental building work

Over ten years' resarch and development work in the energy sector has resulted not only in internationally recognized expertise in technology and system applications, but also in established links between the research workers and the various categories of practitioners in the building and built environment sectors. This has led to a broad and expanding competence across the entire sector. The maintenance and expansion of this expertise is of vital importance if the success of future R&D work is to be assured. Not least important is the provision of facilities and effort for concentration on new areas.

New R&D areas include methods of reducing power demand and development of conversion technologies for electrically-heated houses, advanced heat pump systems and CHP systems for group-heated areas. This also includes the development requirements associated with the future introduction of natural gas.

Continued R&D work must also be concentrated more specifically on the energy aspects of system relationships encountered in every phase of thc building process. A proper understanding of these relationships is vital in determining the efficacy of energy utilisation. New ways of dealing with implementation aspects, including the formulation and effects of energy policy guide measures, form another important R&D area.

In its report **"Energy in the built environment - the way forward to the 1990's, "**The Swedish Council for Building Research sets out the relationship between energy policy objectives and energy-related research, development, experimental building work and demonstration activities between 1974 and 1987. The results achieved in present-day energy conservation are related to future potential for further reduction in energy demand as a result of energy conservation measures and new energy techology.

In the companion publication **"Energy answers '87 - Questions and answers on energy conservation and management in buildings and the built environment"** some of the country's leading research workers in the fields of building, building services systems and building design, together with technicians and property owners, administrators and operators, give their views on energy-related work that has been done to date on the country's building stock. The authors deal methodically with the commonest questions relating to energy use and energy conservation, giving their views on viability and practical implementation.

Both publications are available free of charge from the Svensk Byggtjänst S-171 88 Solna. Telephone, + 46 8 734 50 00: telefax + 46 8 734 50 99.

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