"ENERGY EFFICIENT HOUSING IN SWEDEN"*:

Lee Schipper

BRIEF SUMMARY

Swedish homes use 30 - 50% less heat, adjusted for climate and house size, than do homes in the US. Swedish technology often saves energy at lower cost per unit of energy saved than the for similar technologies in the US. Moreover, Swedes have saved energy because it was profitable to do so; they were not forced to do so by draconian regulations. Instead a healthy partnership of private initiative, public financing incentives and research and demonstration, and a long time horizon on the part of house buyers, builders, and occupants, combined to provide the greatest indoor comfort in the OECD at the lowest cost. The technical achievements that allowed these savings in Sweden are transferrable to the United States and should be economically attractive in the US as well.

The only fundamental policy difference between Sweden and the US is the greater use of incentives in Sweden to reinforce a national committment towards quality housing, for all Swedes, built for the long run.

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* Summary of a presentation by Lee Schipper, Lawrence Berkeley Lab to the ACEEE summer study on energy efficiency in buildings, "Doing Better: Setting an Agenda for the Second Decade". at the Univ. of California, Santa Cruz, August 15, 1984. Opinions are strictly those of the author and do not necessarily reflect those of the project sponsors, the German Marshall Fund, Washington, DC, through the American Council for an Energy Efficient Economy, and the Swedish Council for Building Research, through VVS Tekniska Foreningen in Stockholm. The full report of the project, Coming in from the Cold is being edited and will be available soon.

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** A description of energy use trends in Sweden is found in Energy and Buildings, Vol. 6, Nr. 1, in an article by the author.

Introduction

During 1982 and 1983 a team led by the author investigated residential energy conservation achievements and policies in Sweden.** The major reasons for the study were:

- Homes in Sweden use less energy for heating, adjusted for climate and house size, than homes in any other OECD country, yet maintain the highest standard of indoor thermal comfort. (Fig. 1 shows energy end uses in Swedish homes over time, while Figs. 2a and 2b show distribution of principal fuels, and Fig. 3 space heating use (in useful energy terms) for a variety of countries.)

- Since 1973 older homes in Sweden have reduced heating needs by between 15 - 25%, primarily through the use of added insulation and other technical changes. In contrast, most of the savings observed in homes in the US and elsewhere have been achieved by reducing temperatures and other short-term, simple measures measures such as caulking. (Figure 4 shows energy use trends in single-family dwellings heated by oil-fired central heating systems in a variety of countries over time.)

- Homes built in Sweden since 1973, and particularly those built since 1978, are considerably more efficient than those that were built before 1973, and world leaders in heating efficiency. (Fig. 5 shows k values for Swedish single-family dwellings as a function of year built, givien both actual practice as surveyed and codes. K-values are calculated taking into account thermal bridges and other factors and are typically only 10% higher than measured values. In US units, R values are obtained by inverting k-values and multiplying by 5.6.)

It appeared that current Swedish housing technologies could save a great deal of energy in the United States at a low initial cost, particularly in new housing. Advanced technologies were pushing energy needs even lower. Therefore, we investigated many aspects of how Swedes keep their heating bills low, the technical reasons as well as the policies that supported technical developments.

TECHNICAL AND ECONOMIC FINDINGS

The technical reasons for Swedish achievements include high insulation levels (even in older homes), multiple glazing, efficient heating systems, good installation and upkeep of components, and more recently, use of heat pumps and other new heating technologies. Houses built today use levels of insulation equivalent to nearly twice those found in walls and windows in the colder parts of the US and 25-35% greater than those used in attics in the US.

By contrast, lifestyle per se only plays a minor role in achieving energy savings in Sweden. Indoor temperatures in Sweden are the highest in the OECD, and hot water consumption is almost as high as in the United States. Exhaust air hot-water heat pumps have entered the market in Sweden to reduce hot water costs considerably.

The Swedish building industry, and homeowners/occupants have achieved these savings at lower costs than the cost of obtaining energy. Data from ABV, one of Sweden's major builders, showing consumption in similar houses built to ever-improving thermal standards, show that the investments required to reduce energy use over the 1970s have been about $750 US per house (at 7.6 Swedish Kronor [SEK] to the dollar). Compared to the cost of electricity, this represents a rate of return of 25%/year. More recent improvements are more expensive, but will still save the Swedish consumer money. Indeed, the primary motivation for the achievements we have seen has been to reduce the cost of staying comfortable. Thus, many of the achievements in Sweden should be desirable here, and, according to our comparison, economic as well.

POLICY FINDINGS

National polices primarily for housing, secondarily for energy, have played a low-keyed but continuous role in the development of high-tech, low-cost comfort in Swedish homes, but market forces have always been present to guide Swedish homeowners and builders alike. The Swedish government has used the same kinds of instruments as we have -- interest subsidies and other federal home-loan financing systems, and minimum property standards, but has backed up these passive regulations with aggressive research, support of information dissemination, and support for private sector initiatives. This has led to a high standard of housing quality unknown to the average house or apartment occupant in the US.

The Swedish achievements in energy efficiency have not arisen primarily out of a system of forcing regulations, but rather out of a need, recognized by all segments of society, to achieve a high level of indoor comfort and hygiene at a reasonable cost.

- While building codes have played an important information role in showing consumers and builders the approximately economic levels of insulation and in stimulating the building community to reduce the heating needs of new homes, they have not yet forced energy conservation upon builders or occupants. Actual energy-saving practices in Sweden have always exceeded code requirements.

- The system of home loans has actively encouraged increasingly greater thermal performance by effectively removing the first cost barrier for a wide variety of heat-saving investments. Thus the carrot, not the stick, has been the primary policy instrument in Sweden.

It is important to note, however, that energy conservation has always been embedded in a housing policy that has been important for decades, if not centuries, in the Swedish political tradition. When concerns over energy were increased with the 1973 Oil Embargo, few new agencies, actors, or arrangements were needed for the Government, the private sector, and private individuals to respond. This is not to say that the policies put in place after 1973 were unnecessary, rather that they were well matched to existing policies and organizations. The flow of information and research, (i.e., the sermon) was increased measurably after 1973 to accompany the increased use of the carrot.

The energy conservation programs and incentives for new and existing homes were widespread and pervasive, but the primary stimulus for savings in existing homes since 1973 has still been the significant increases in oil prices. Without the pervasive information existing in Sweden before and after 1973 and a stepped up R&D program, however, it is doubtful that the achievements since 1973 in both existing and new dwellings would have occurred. The well-established R&D program, however, contributed over many decades to the ease with which Swedish scientists and companies developed even more energy efficient heating practices after 1973.

The home loan system for new housing (described in part in the Appendix) financed about 90% of all single-family and nearly 100% of all multifamily dwellings during the past two decades. The loans are subsidized initially but the rate of interest rises by 1/2% each year until it reaches the market rate. Down payments are relatively low. Since the early 1960s the system also financed conservation measures beyond those very simple measures demanded by building codes. The primary reason for these measures -- minimal insulation -- were hygienic and structural, the avoidance of moisture and rot. Any feature of a new home required by code was financed by the loan system (see the Appendix), and measures introduced expressly for the saving of energy have generally been cost-effective.

The retrofit program of loans and grants was successful in stimulating substantial investment in conservation in existing homes. In all, the program provided nearly $850 million (at 1983 exchange rates) in low-interest loans and grants, and a smaller but important sum in interest subsidies that affected over one-half of the building stock. However, as many owners of single-family dwellings made conservation investments without state aid as with state aid, suggesting that while the program was sufficient to cause savings, it may not have been entirely necessary. It is likely, though, that the program provided a valuable demonstration effect, causing many retrofits and measured energy savings in the period between 1975 and 1978 when real oil prices, while high, were stable, and inducing some investments in newer, already well-insulated homes. For multi-family dwellings (for which heat is by tradition almost never metered), however, the program had a stronger role in causing savings that otherwise may not have been made.

The loans/grants program and the information campaigns of the 1970s were primarily passive programs. No energy programs were "forcing" in the sense of calling forth non-existant or new, unproven technologies or requiring uneconomic investments. Instead, programs combined with and reinforced the forces of higher oil prices to bring on reductions in oil use constantly during the mid-1970s, while other countries' oil use was creeping back up towards pre-1973 levels. Other programs of information that were instituted during the later 1970s or early 1980s have taken on a more activist nature. It is too early to judge their success. However, there are many regions of the United States where utility or community programs are more aggressive than those in Sweden.

LESSONS FOR THE UNITED STATES

Our study showed that market forces played a key role in Sweden in stimulating further investments for the purposes of reducing energy costs in new and existing homes. Yet market forces were reinforced by various policies that extended individuals' and companies' time horizons to make high-technology energy saving technologies the rule, not the exception.

Unfortunately, the marketplace alone -- higher energy prices -- in the United States will probably not support transferring or reproduction of these achievements in the US, because of enormous know-how barriers and perceived financial barriers in the building industry, financial and real-estate institutions and practices, and the perceptions of US consumers/homebuyers themselves, who move more often than do Swedes. While insulation levels have increased roughly with oil prices in Sweden, overall achievements in the US still lag considerably behind heating costs, particularly with respect to walls, windows, air-tightness, heat recovery, and indoor air quality technologies. In 1981, homes in Sweden had on average twice the effective levels of wall insulation as homes in Minnesota! While most of the 20% reduction in energy use per household in the US (since 1973) has been caused by behavior changes and very simple ("low-cost, no-cost") retrofit measures, most of the similar reductions in Sweden were caused by substantial retrofit measures stimulated in part by government funds, but based in the tradition of comfort at low cost. Thus, the US achievements are fragile; they could be reversed by a temporary relaxation of pressures from energy price increases.

Nevertheless, it would be impossible to simply "legislate" these improvements overnight in the US. Housing policy, not energy policy alone, must create the environment in which energy efficient building practices are to be encouraged. However, the carrot, not the stick, is the most important policy instrument. Energy policy goals must be expressed through the actors and institutions already active in the housing area, such as builders, utilities, and local banks.

The most important single policy measure the US could undertake to stimulate energy-efficient construction practices is to remove the bias against investments in energy efficiency inherent in the American housing process. This could be done by including energy-related investments in mortgages without applying them against the loan applicant's affordability criteria, since these investments would lower the applicant's future space-conditioning costs considerably.

Other measures that could be taken by Federal, State, or local authorities include

- Increasing up R&D in the area of housing and energy, including developing labels or other indicators of home performance;

- Supporting a widespread information and testing program to demonstrate the savings that good building practices in the US have achieved in some areas;
- Supporting a massive builder and owner/occupant education effort;
- Supporting a widespread research, demonstration, and education program on retrofit;
- Encourage the pricing of energy at its replacement cost.

At present, the most attractive option for US builders and homebuyers seeking to reduce their comfort costs may be to purchase Swedish technologies or manufactured houses, whose energy-saving properties have been validated from years of experience in Sweden, as this project found. These technologies and houses could convince US builders, financers, and homebuyers, that energy efficiency in homes is affordable, economically attractive. Joint ventures among Swedish and American manufacturers might be an attractive option.

APPENDIX: The Loan System for Financing Conservation in New Homes.

The following table shows the part of the federal home-loan form in Sweden for single family dwellings that pertains to energy. Basically, the loan amount is constructed from the bottom up, based on the size and features of the house. The system finances all basic necessities but puts a cap on the unit cost of most items, such as washers, tile, or windows. After the entire loan is calculated by the builder/prospective owner, it is submitted to the local housing authority, who usually allows the actual cost to exceed a guideline value by 15%, which in turn allows quite a bit of flexibility in design and in choice of features. Any costs above these must be financed privately.

Note that the energy part essentially allows the first cost of the house and thereby the size of the loan, to expand to include costs of extra insulation, a heat pump, or other important energy-saving features, without appearing to penalize the builder or buyer through a higher first cost. Affordability, and the approval of the loan, are not therefore, jeopardized by energy saving investments, nor on the presences of other features that increase the durability, safety, or effective life of the house! Indeed, some of the energy saving features become even more attractive with greater efficiency:

- Insulation outlays (lines 220,221, 222) increase in proportion to the difference between k (1/R) and the amount required by code; since an infinite thickness receives only a finite increase in the loan, the builder/buyer is obviously discouraged from making insulation uneconomically thick. In fact, the formulation in these lines is very close to that which is economically correct, since increased thickness gives diminished savings.

- The heat pump element increases with increasing efficiency, through the COP-factor in line 232.

- If lines 230, 301, and 304 are combined, the purchased of an exhaust-air heat exchanger with hot-water heat pump -- line 304 -- becomes motivated.

This loan system makes home loans available initially at a very low rate (around 6% nominal interest) that increases by 1/2 percentage point per year until it reaches the market rate of interest. Thus there is a subsidy involved, in addition to the deduction of interest payments from tax liability, which was unlimited until 1983. It can be estimated that this system effectively lengthens consumers' and builders' time horizons up to a 20 year payback period for the purposes of investing in conservation measures that are best -- and least expensively -- installed when a house is first built. From a Swede's point of view, a dollar saved each year during the coming life of the mortgage (30 years or more) has a present worth of about $20 not counting any increases in the price of energy. By contrast, the US consumer appears to demand a very high rate of return and a very short payback time, which can be estimated to yield a present worth of $5 on conservation investments. This low regard for the future is hard to reconcile with the long lead times and enormous investments required to make investments in future energy security.

New Home Loan Form ("Laensbostadsnaemden")
Energy Component

Line/Item	Amount/unit	Units	Amount Sought--Approved
Insulation			
220 Attic	(0.2-k) *250	Area	
221 Attic	(0.3-k) *500	Area	
222 Floor	(0.3-k) *250	Area	
Heating Systems			
230 Hot-water heater	2500	1	
231 Oil or woodchip boiler	15000	1	
231 Electric boiler or hot-air system	8500	1	
232 Heat pump	(COP - 1.2)*10 000	1	
233 wood boiler incl electric backup	11000	1	
234 Heat storage -- electric	2500	1	
-- solid fuels	4000	1	
235 Solar collector (max 6250)	800	Coll. Area	
236 Timed thermostat for electric heat	1000	house	
237 Block central heating connection			
238 District heating connection			
239 Heat distribution for air- or hydronic system	2000	dwelling	
240 Hot water meter - flow	500	house	
- energy	1200	house	
Ventilation			
301 Exhaust air fan (Max. 2000/dwelling)	20	m^2 living area	
302 Stove hood with fan	650	1	
303 Air-to-air heat exchanger	1000 + 30	1 + m^2 living area	
304 Exhaust-air HW heat pump	2000 + 30	1 + m^2 living area	

NOTE: For the units, house means "building", i.e, one per structure, while dwelling means just that, and increases with the number of dwellings per structure. Costs for district heating and block centrals are not given. Where the number 1 is given, the unit is simply the number of installations.

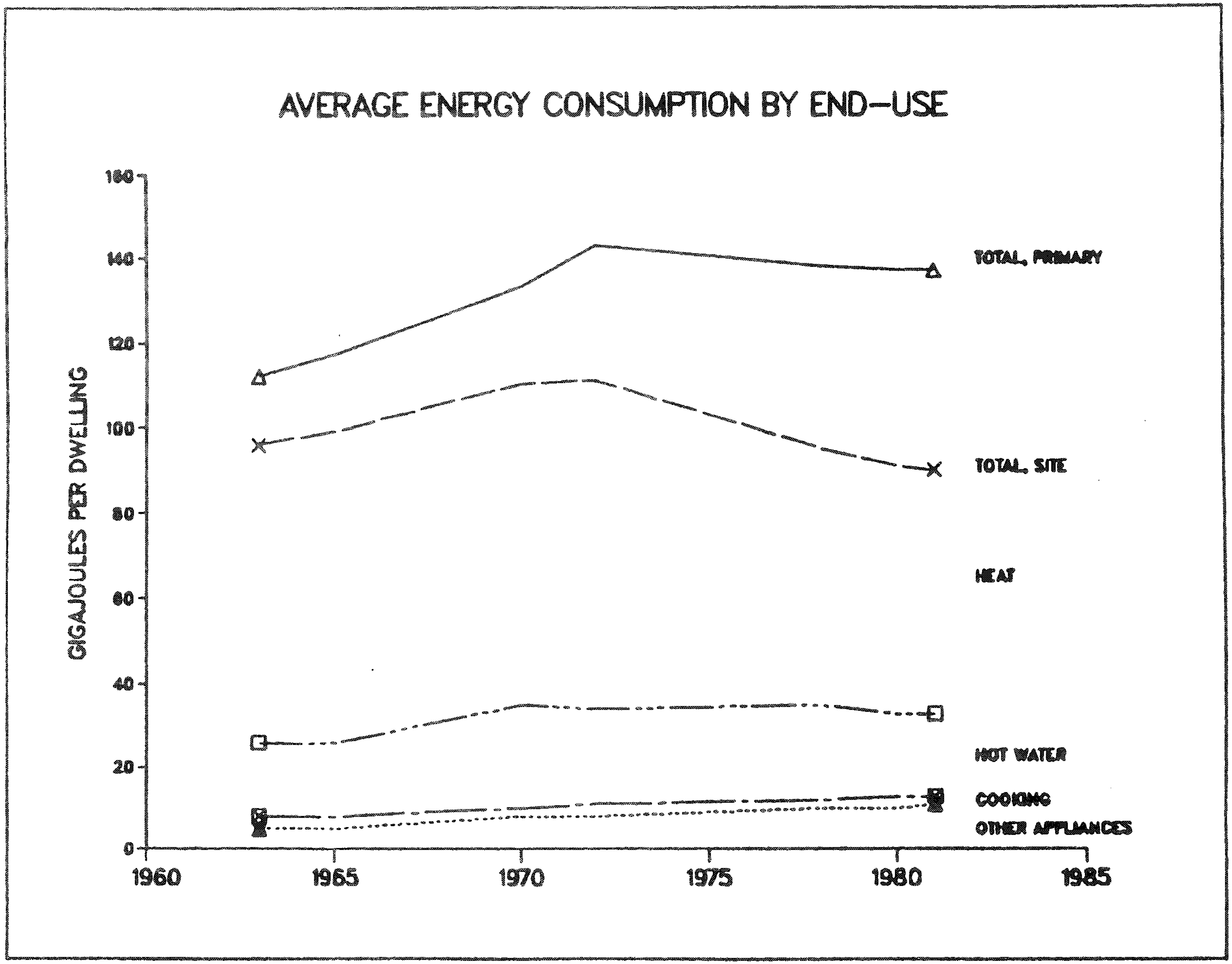
Excerpted from the loan form "Laaneunderlag och pantvaerde", 82.07.

FIGURES AND TABLES

Figures on the following pages illustrate some important facets of residential energy use in Sweden, particularly the low value of heating. Figure 1 shows the evolution of energy use per dwelling in Sweden through 1981. Figure 2 shows the percentages of single-family and multi-family homes using different fuels for space heating (and in almost every case, for hot water as well) from 1963. Figure 3 shows space heating energy use (considering useful energy, that is, energy delivered to rooms minus conversion losses in boilers) for a variety of countries studied. Figure 4 shows space heating energy use in oil heated single-family dwellings. The two space heating figures are corrected for heated house area and climate, that is, the number of degree days.

The next figure shows the evolution of k (or U)* values in newly built swedish homes during the 1970s. Values for walls and ceilings are shown. The figure also gives thealues demanded by codes in effect during each year. The following chart shows approximate values in R-units for Sweden and for Minnesota, one of the coldest states in the US, and colder, on the average, than most of Sweden.

* A U value is the inverse of an R value: the thicker the insulation the lower the U value. In Sweden U (or R) values are always calculated to take into account effects that essentially reduce the effectiveness of insulation, such as thermal bridges caused by wooden studs. Therefore, they are "net" values. By contrast, the often quoted R-values for insulation in the US are usually just the nominal value of the insulation, given its thickness, with no regard for the impact of studs or other thermal bridges.


AVERAGE ENERGY CONSUMPTION BY END-USE
GIGAJOULES PER DWELLING
0
20
40
60
80
100
120
140
160
1960
1965
1970
1975
1980
1985
TOTAL, PRIMARY
TOTAL, SITE
HEAT
HOT WATER
COOKING
OTHER APPLIANCES

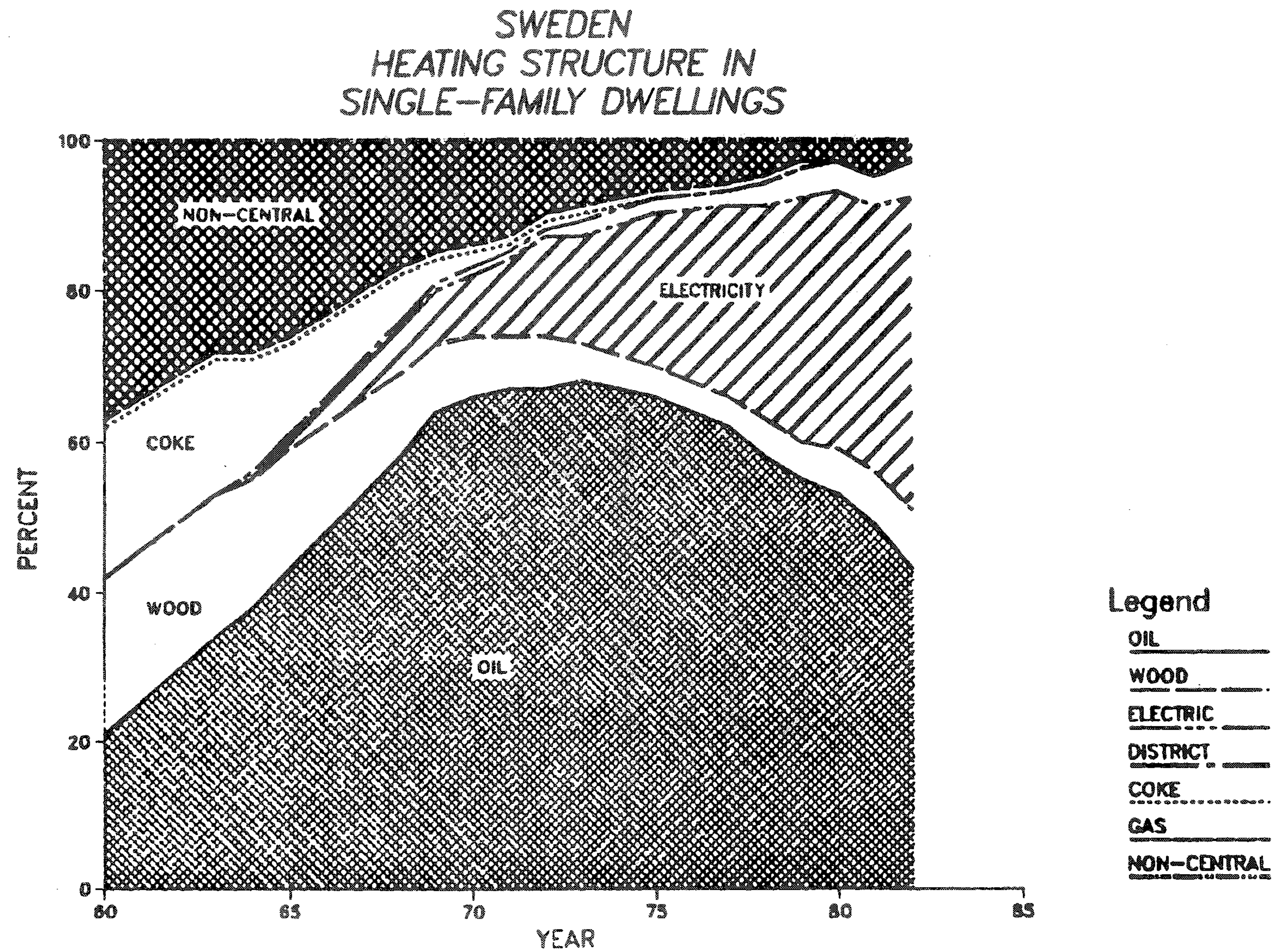

SWEDEN
HEATING STRUCTURE IN
SINGLE-FAMILY DWELLINGS
NON-CENTRAL
ELECTRICITY
COKE
WOOD
OIL
PERCENT
100
80
60
40
20
0
60
65
70
75
80
85
YEAR
Legend
OIL
WOOD
ELECTRIC
DISTRICT
COKE
GAS
NON-CENTRAL

Fig. 2 (Part 1)

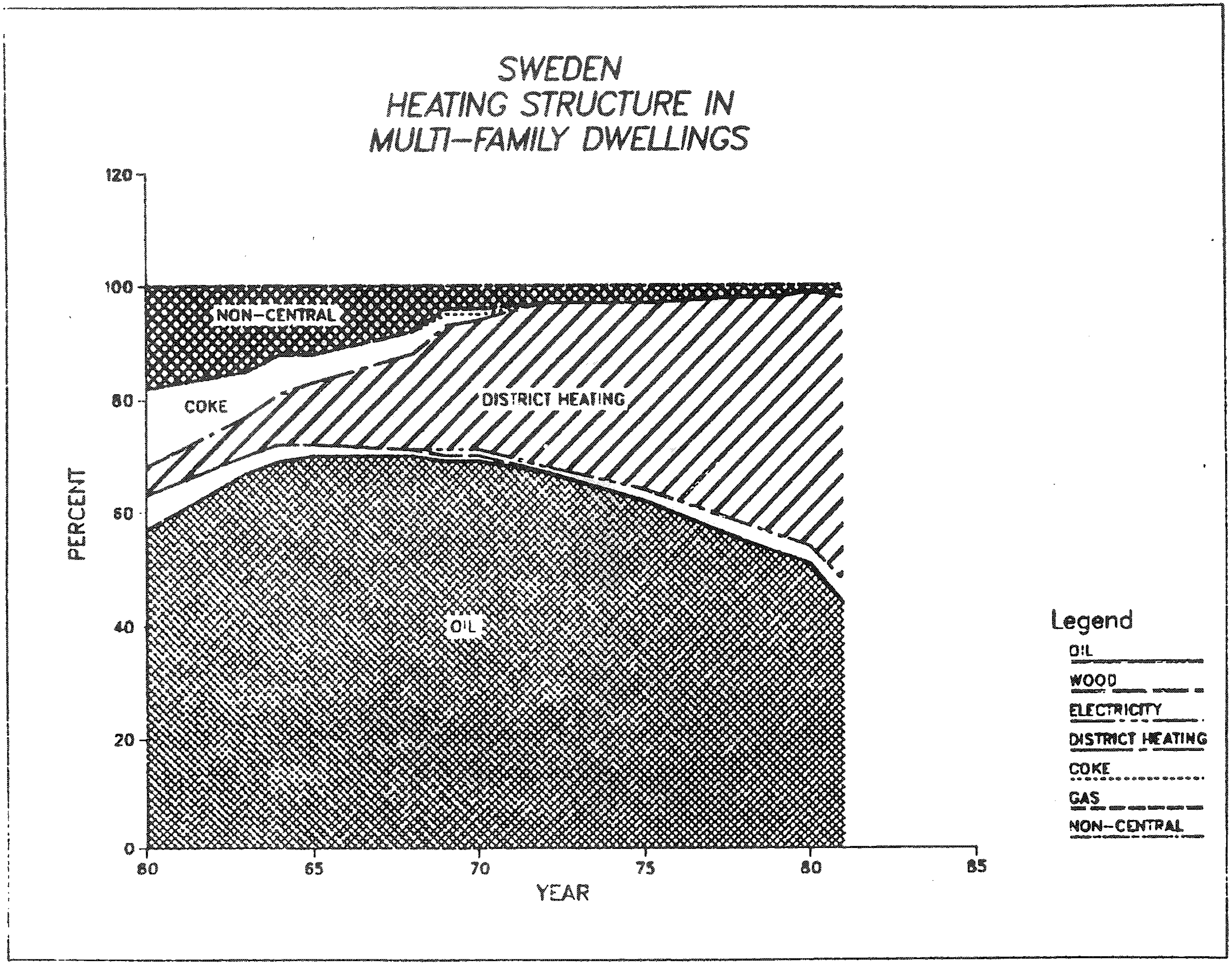

SWEDEN
HEATING STRUCTURE IN
MULTI-FAMILY DWELLINGS
120
100
80
60
40
20
0
PERCENT
NON-CENTRAL
COKE
DISTRICT HEATING
OIL
60
65
70
75
80
85
YEAR
Legend
OIL
WOOD
ELECTRICITY
DISTRICT HEATING
COKE
GAS
NON-CENTRAL

Fig. 2 (Part 2)

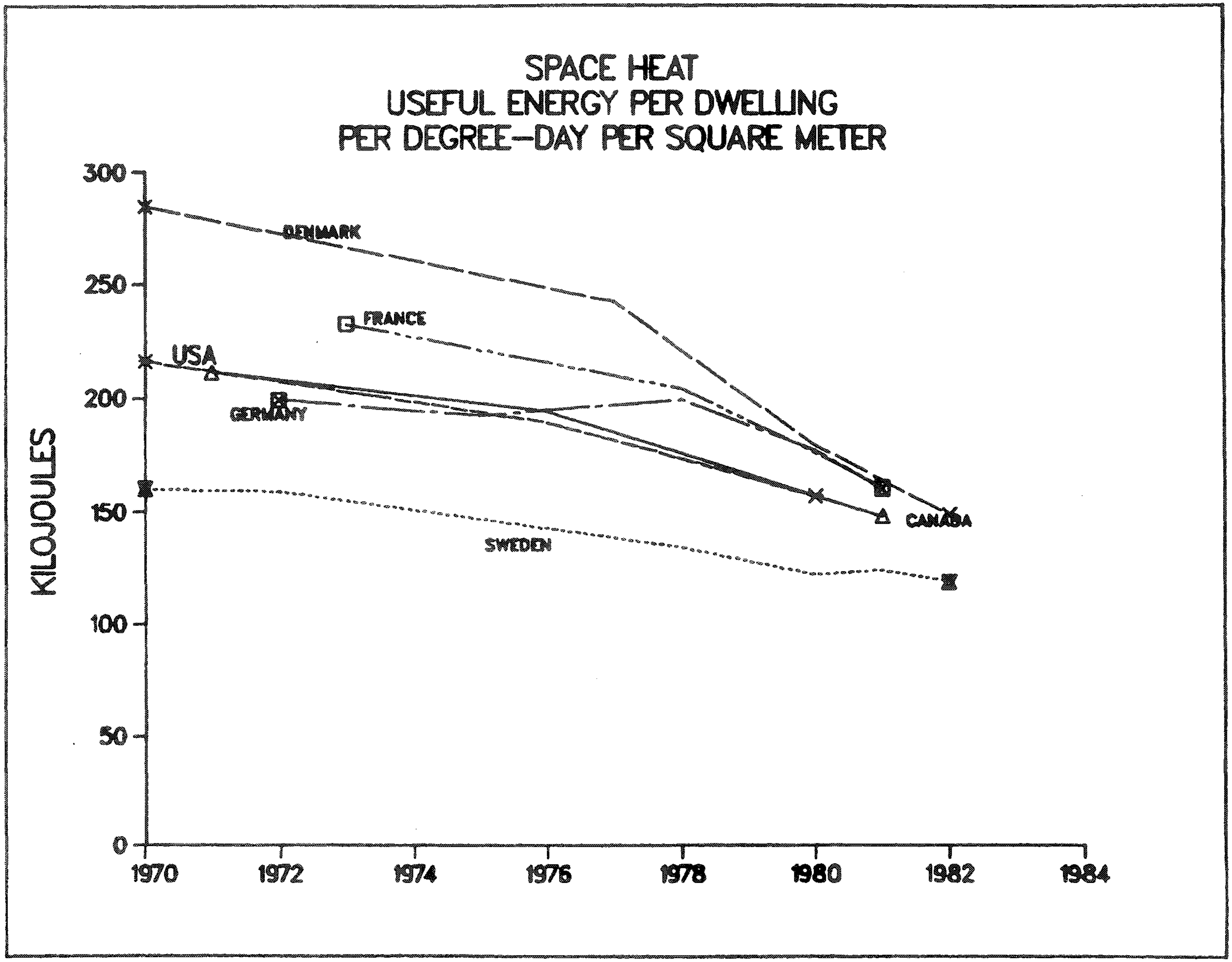

SPACE HEAT
USEFUL ENERGY PER DWELLING
PER DEGREE-DAY PER SQUARE METER
KILOJOULES
300
250
200
150
100
50
0
1970
1972
1974
1976
1978
1980
1982
1984
DENMARK
FRANCE
USA
GERMANY
CANADA
SWEDEN

Fig. 3

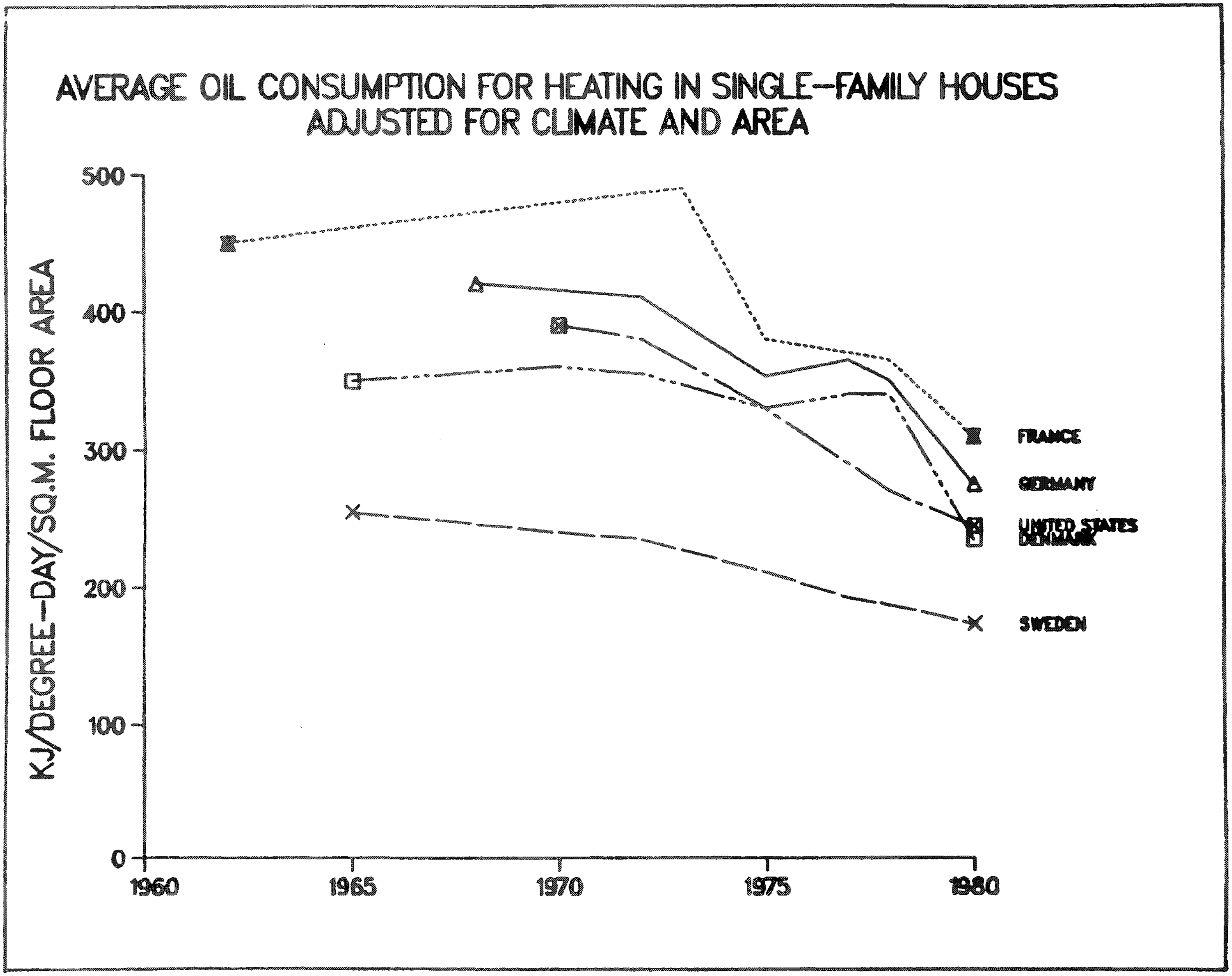

AVERAGE OIL CONSUMPTION FOR HEATING IN SINGLE-FAMILY HOUSES
ADJUSTED FOR CLIMATE AND AREA
KJ/DEGREE-DAY/SQ.M. FLOOR AREA
500
400
300
200
100
0
1960
1965
1970
1975
1980
FRANCE
GERMANY
UNITED STATES
DENMARK
SWEDEN

Fig. 4

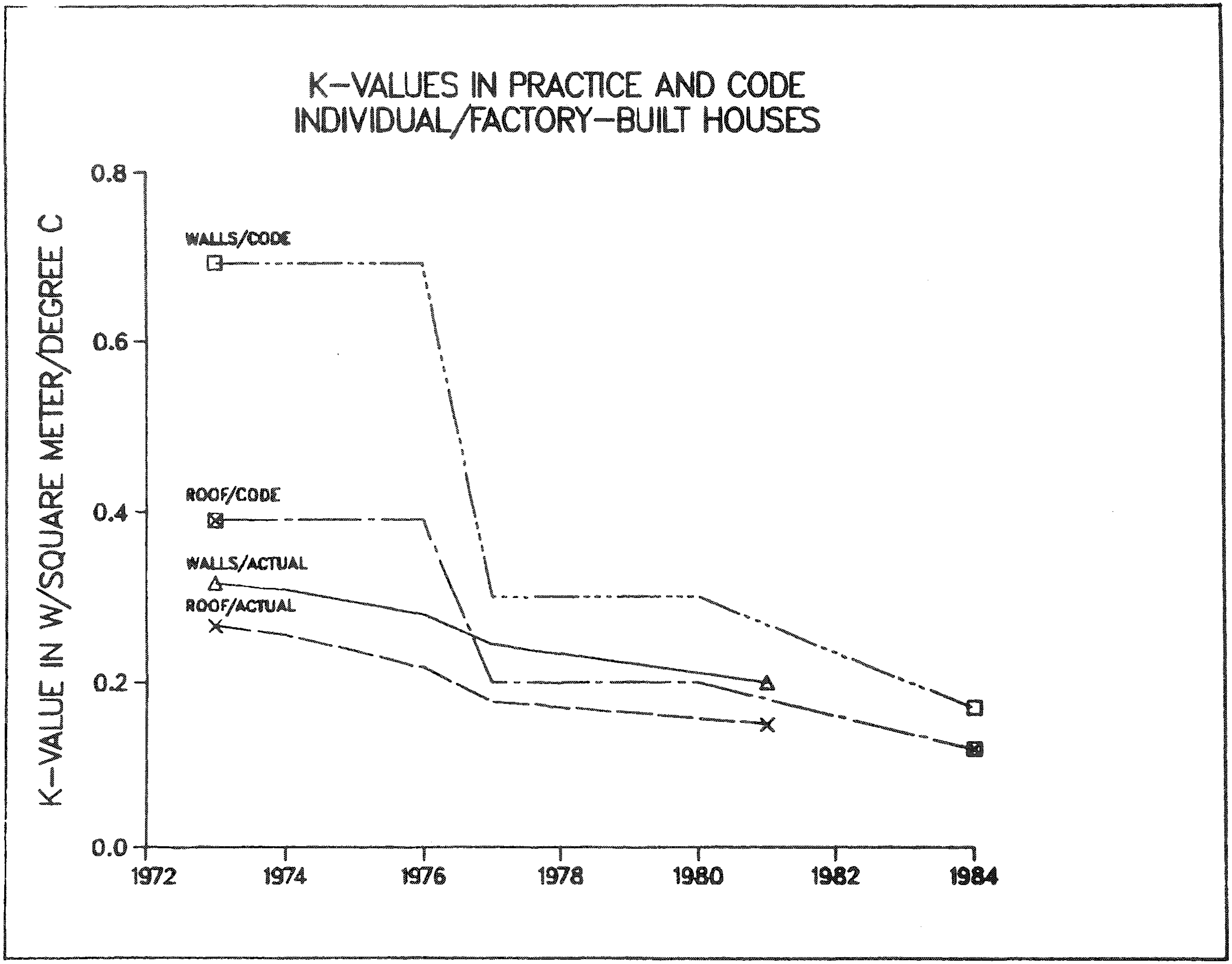

K–VALUES IN PRACTICE AND CODE
INDIVIDUAL/FACTORY–BUILT HOUSES
K–VALUE IN W/SQUARE METER/DEGREE C
0.8
0.6
0.4
0.2
0.0
1972
1974
1976
1978
1980
1982
1984
WALLS/CODE
ROOF/CODE
WALLS/ACTUAL
ROOF/ACTUAL

Fig. 5

EXAMPLE: WALL B-VALUES, SWEDEN AND U.S.

		Sweden	U.S. (State)
1967	Code	R-8	
1965–70	Practice	R10-13	
1973	Practice	R17.8	
1975	Practice	R20	
1977	Code	R18.5	
1977	Practice	R22	
1980/1	Practice	R25	R11-13 (Minnesota)
1983	Practice	R25-30	R15-18 (Minnesota)
1984	ELAK Code	R32	

FIG. 6