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INTRODUCTION

One of the important aspects of America's painful adjustment to energy realities since 1973 has been an overwhelming effort to look carefully at how we use energy. Much to our surprise there was tremendous slack in energy use at home even before the Oil Embargo, slack that could have been eliminated profitably. One suggestion that there was waste in our economy came from careful inspection of energy use elsewhere.

But early discussion of energy use in other lands has been marred by many distortions and misunderstandings, not only on the part of those who tend to doubt the potential for energy conservation but even among conservation's strongest supporters. This misunderstanding arises from comparisons of energy use and gross national product, two quantities that have charmed correlators and energy statisticians for decades. Though serious work cannot be based upon relationships between two such aggregated quantities, it is useful to review some of the popular myths surrounding energy comparisons among countries.

I. Myth about Energy and the Economy

1. "Other countries use less energy and enjoy the same standard of living: so can we." This statement has been heard often, most prominently in President Carter's energy speeches, and almost always refers to the well known fact that the use of energy per unit of national income (E/G) is considerably lower in Europe than in the US (and Canada). While much fruitful work has shown that indeed other countries do use energy more efficiently than we in many uses, the reverse is sometimes true, too. Most important, though, the ratio of energy to GNP is inappropriate as a measure of energy efficiency, because effects of climate, economic structure, lifestyle, and the composition of imports and exports can also affect this ratio. We reject the use of gross comparisons either for purposes of justifying increases in energy use or for urging on conservation.

2. "There is a strong correlation between energy use and GNP, both in time and among countries." This correlation is often used for purposes of energy forecasting. There is no question that correlation between energy and GNP, either cross sectional in time for a single country or among countries, can be found with good statistical accuracy. Important for the energy debate, however, is that the price of energy is missing from this simplified measure. While energy prices fell for decades, they are certain to rise now. When even the most simple energy-GNP models are re-run using energy prices as an intermediate variable, and a variety of couplings (or "elasticities") relating price to level of use, the results are usually much different than in the simplified case--the ratio of energy to GNP, for the use of the US, can vary by a factor of more than two for a factor of four variation in energy price. Moreover, among countries at any given level of income there is a fairly wide variation in per capita energy use, again indicating that the correlation, while impressive, leaves considerable scatter. The only firm rule that emerges is that in the long run

THERE ARE NO FIRM RULES RELATING ENERGY USE TO GROSS NATIONAL PRODUCT

Many factors must be considered, none of which are exposed in the simplistic analyses offered by many critics of conservation. We will avoid use of E/G unless no other measures are available.

3. There is so much variation in E/G that intra country comparisons are not interesting. (See Science, April 8, 1977, Letters.) This critique of recent international comparisons overlooks the possibility of comparisons, at a very diaggregated level.

4. "High Productivity in the US is due to high energy use per worker." Though machines (capital) that improve productivity also use energy, the overwhelming share of energy is for space and process heating in any advanced economy, not for operating machines. And most technologies that have advanced productivity have also decreased energy requirements per unit of product. That energy use per worker has increased in most countries is easily explained--machines have increased output/worker faster than output/energy because wages tend to rise while energy

costs fell. But energy use per worker, especially among different countries or different industries, is an especially deceptive measure that should not be used casually in discussions of energy conservation.

5. Industries that use less energy per worker (or per unit of product), like leather or textiles, are "more efficient" than those that use more energy, such as plastics. This popular idea, advanced by some environmentalists, has little validity for energy conservation arguments because different products and processes are being compared whose output is used in different ways. It is not clear to what degree (and at what cost) leather could resubstitute for plastic in, say, seat covers. Nor is the allegation that the energy cost of a shirt made of synthetic fibers is greater than that of a "natural" cotton shirt necessarily any grounds for conclusions about energy use. Energy, as one of many production factors or resources, is not the only factor that deserves attention in the energy debate, and certainly not the only factor in productivity.

6. The U.S. uses more energy/capita (or per dollar of GNP) than most countries because:

a) Our exports are large. Wrong--our exports are relatively much smaller than those of most other industrialized countries, and we tend to import a small amount of energy embodied in foreign trade, while most western European countries export embodied energy.

b) We feed the world. Wrong--agriculture, especially grains and other export staples, is not energy intensive on an energy/ton or energy/$ basis, compared with paper, steel, etc.

c) Our defense is large, especially in other countries. Wrong--because defense includes services as well as airplanes, and our overseas forces draw on energy supplies from other countries. Furthermore, our export of high technology and weapons is not energy intensive (on a per dollar basis) compared to our import of raw materials.

d) Our industry produces more energy intensive products than "theirs." Wrong--while Switzerland, as a single example, produces far less heavy industrial output (paper, steel, chemicals) than we, most other European countries and Japan actually produce more, per capita, than we. Indeed, the structure of U.S. or Swiss industry appears to be more evolved beyond energy intensive raw materials towards higher value-added products than industry in Germany or Sweden. The point is that U.S. energy use cannot be "explained" away by references to structural phenomena such as those above. Nor should we necessarily be ashamed of relatively high energy use in the past, given our access to relatively inexpensive fuels and electricity.

The importance of these myths in the energy debates of the past and present cannot be overemphasized. It was often argued that differences in culture, lifestyle, policies, form of government, or non-energy resource base affected energy use in ways beyond the control of our own energy policy--ergo, we could not imitate other countries. But international comparisons help sort out insulation techniques, industrial processes, automobile propulsion systems that have important consequences for energy use. As techniques for using energy these systems have little to do with the non-technical differences among peoples and countries. Certainly the implementation of specific technologies, in the name of energy conservation, may depend on non-technical aspects of a country and its lifestyle. But such questions can only be answered once energy use and conservation among many countries has been fully examined.

II. International Comparisons: A Few Rules

Our discussion of the myths suggests that energy analysis for the purposes of conservation is necessarily complicated--simplifications have caused too much confusion in the past. In order to make international comparisons meaningful it is necessary therefore to observe certain important practices.

1. What is Conservation?

We need to agree on what we mean by conservation. Elsewhere I have argued that energy conservation means using less expensive resources, most notably capital in place of energy, so as to reduce costs.

To measure conservation, especially among different countries, energy use must be carefully broken down into single homogeneous activities--driving, busses, raw steel, metal products, etc. This breakdown is necessary if we are to measure energy intensity as energy/unit of output, a kind of inverse of efficiency for each activity. By using intensities we avoid the need to compare "standard of living."

Usually reductions in intensity indicate conservation--fewer joules/(degree day - square meter dwelling) almost always indicates greater degree of weatherization in a home, or lesser energy intensity, i.e., a greater effort toward conservation. Turning back thermostats on the other hand means buying less warmth, a change in the mix of consumer purchases.

Structure or variations in the kinds of uses for energy also affect energy use. These variations in the market basket of consumer purchases, or in the composition of industrial output, will to a greater or lesser degree reflect resource costs, of which energy's share is still relatively small for most goods and services. In the short run changes in the cost of energy will only have slight effects on the market basket. In the long run, however, changes in energy costs--and perhaps more important, changes in lifestyle, preferences, government, or institutional policies--can affect total energy use. Labelling these changes as "conservation" is possible, but requires careful examination of many non-energy factors: are the French "energy conserving" because their total land travel is about half our own? My own observations suggest that indeed some of the differences in miles traveled is due to the higher cost of fuel and autos in France relative to incomes, but more of the difference is due to urban planning and lifestyle. Do we call this effect "conservation"? We must be very careful in interpreting structural differences that have great energy implications.*

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*By the same token, are the Swedes less efficient than we are because their most energy-intensive paper and pulp sector is much (four times) larger than ours? According to some measures (such as Commoner's, in The Poverty of Power) the Swedes are "wasteful." In our discussion they are not, at least not solely because of the size of the paper industry.

2. Prices

In addition to understanding and measuring conservation, we must be aware of the mix and cost of fuels and electricity, remembering that some fuels may be relatively cheap to buy but expensive to use, such as coal. Less important for broad comparisons, but vital for detailed econometric or engineering comparisons are the relative costs of other factors of production, especially capital and labor. Does the high cost of labor in the U.S. inhibit installation of double windows as a conservation measure vis à vis Sweden? Do Swedish industries obtain capital at such low interest rates as to make heat recovery equipment "cheaper" there than in the U.S.? A handful of studies have treated factor analysis carefully. As a first approximation, however, energy intensities and energy prices are a good measure of how effectively energy is being used in a country.

3. Physical Comparisons

Certain other determinants of a country's energy are also important, notably climate, composition of imports and exports, age of housing and industrial stock, density of cities and overall density of population. Indeed it is the importance of these factors that makes comparisons of total energy use among countries relatively useless. Only when each factor is sorted out and quantified can meaningful analysis be performed.

4. Policies

Finally, no study of energy uses among nations is complete without at least a summary of important energy related policies. Are building codes important? Are automobiles taxed? Do standards exist for industrial techniques or are processes chosen on the basis of costs? What about environmental regulations? These policy factors may play an important role in explaining differences in energy use among countries, and must be examined whenever differences in intensity suggest important possibilities for conservation.

To date several detailed comparisons of two or more countries have appeared. The following should be examined by serious conservation students:

*"How Industrial Countries Use Energy" (a comparison of countries

including the U.S. and Sweden, carried out by Resources for the Future)

*"Energy Demand to the Year 1985 - National Studies" - worksheets from the Workshop on Alternative Energy Strategies - contains a mass of raw data on energy use in 15 countries. A follow up volume contains more data as well as projections for 1985 and 2000.

*"Energy Conservation in IEA Member Countries."

*"Comparison of Energy Use Between the U.S. and West Germany" (SRI)

*"Comparison of Energy Use in Japan and the U.S." (Doernberg, BNL)

At somewhat greater levels of detail, examining two countries:

*"Efficient Energy Use and Well-Being, the Swedish Example" (Schipper-Lichtenberg)

While these studies differ in method and findings a reading of all of them suggests that there is flexibility in energy use based upon international examples. To illustrate this flexibility, then illuminate some of the possibilities for conservation, we will concentrate on first some of the lessons from the other comparisons, then the U.S.-Sweden example.

III. Industrialized Countries

The well publicized WAES study attempted an integration of demand and supply forecasts from a large part of the world. As a by-product a rather detailed set of worksheets appeared that provided the data base from which member countries teams made their forecasts. The results are presented in rather raw form (see my review in Technology Review, June 1978) but carefully used they provide the first look at energy use in many countries.

Most of the countries in the WAES data base forecast increases in key consumer amenities--living space (heating), and auto use. Though conservation will be a bit hard in these countries as well--especially where centuries-old buildings are replaced--energy demands in total will still grow somewhat. The important exceptions are Sweden, the U.S. and Canada. There the possibility of negative energy growth in the residential sector and, in the case of the U.S., automobiles, is very real. Thus the overall energy/GNP ratios of France, Germany, Denmark, Japan or the Netherlands will not fall as fast as those of the more energy intensive countries, Sweden, Canada, and the U.S.

The raw WAES data provide some surprising insights into international differences in energy use patterns. Americans travel far more in total then anyone else, but the predominance of the auto in every country (except Japan) is surprising, and auto use seems to increase with income, especially as a competitor to mass transit. The U.S. (and Canada) uses considerably larger fractions of total energy for direct consumer uses (autos, homes) than nearly all other countries, though Europe and Japan are experiencing marked increases today in consumer uses. Another surprise for many observers is the degree to which industrial energy use dominates other countries' balances (first column in Table 2). Intensities of raw materials tend to be lower in Europe than in the U.S. (Table 2), but output of these materials is somewhat greater in Europe, erasing some of the potential differences in <u>total</u> energy use. None of these differences arose out of any "moral war" to save or "waste" energy--autos and gasoline have been taxed elsewhere for fiscal reasons, while industries in Europe, being newer than our own and built to considerably higher energy prices, simply combined resources rationally, using less energy to produce important energy intensive materials.

"How Industrial Societies Use Energy" was able to offer more analysis of data and policies in asking why nine countries with somewhat comparable standards of living used such varying amounts of energy. This study, carried out at Resources for the Future (RFF) shed even more light on the fascinating tale of energy and gross national product. In working with the RFF authors I discovered that Sweden was in many respects an unusual energy user because of energy intensive industries, climate, proliferation of autos beyond most other countries in Europe, and dwelling space. The RFF group is at present updating all their data to follow the U.S., West German and Sweden since their base year of 1972. Nevertheless, the important conclusions of their first book (embellished by WAES and other data) should be summarized here. (See Table 3)

1) Transportation differences account for nearly one half of the variation in the energy/GNP ratio among countries, with the remainder divided up among residential/commercial energy industries, and energy transportation. Differences in total energy use in manufacturing were small because greater efficiencies in Europe are offset somewhat by greater output of raw materials compared to the U.S. (see Table 1 and 3).

2) U.S. households spend a larger fraction of their incomes on direct energy purchases than do European, at least before the embargo. Not surprisingly, U.S. prices were the lowest. (Some prices are shown in Table 6.)

3) After adjusting for climate the U.S. uses 40% more energy for space comfort than the average in Europe. Part of the reason is the larger, detached homes in the U.S. vis à vis the continent. Moreover, full house heating is only saturated in North America and Scandinavia. Efficiencies were significantly better in Sweden, with Canada lying between Sweden and the U.S.

4) In the transportation area (Table 5), total travel, efficiency of each mode, and (to a lesser extent) the actual mix of modes varies widely. The auto dominates everywhere (except in Japan) but higher urban densities, higher auto costs, higher fuel costs and other measures have kept the absolute level and relative share of heavily subsidized public transit at two to six times the U.S. level per capita. In the freight sector, higher U.S. consumption is explained mostly by larger volumes of freight moved farther, because the U.S. system appears to be more reliant on rail overall. This reliance on rail is due to structural or historical or geographical or political reasons and it appears to me to have little to do with energy costs.

5) In industry, it takes more energy in the U.S. to heat a given material than in most countries in Europe. (This confirms the WAES implications.) Obviously other factors, such as the cost of capital and labor influence the choice of technologies used in industries. Table 2 includes the RFF data for the steel industry.

My own view of the RFF evidence and many other studies suggests that higher fuel prices in Europe have made more energy efficient technologies profitable. Elsewhere the evidence points to these technologies, especially in steelmaking and cement, being more productive in all resources, not just energy. Thus the energy conservation characteristics of European heavy industry do not appear to arise simply because more labor is used. Instead, capital may substitute for energy, as suggested by Long and his co-workers. Clearly, the RFF study, combined with other evidence, offers proof of the existence of many energy using technologies, and processes in industries that would save energy when employed in the U.S. Further investigations will reveal which technologies are attractive.

In short, the RFF study finds much variation in energy intensities among important tasks. Not all of this variance embodies conservation, but the flexibility of energy use is clear.

II. The U.S. Sweden Comparison

Neither the WAES study nor the RFF survey fully breaks down energy use in any of the countries surveyed. At the time these two surveys were underway, however, I began (with my colleague Allen J. Lichtenberg) comparison of energy use in Sweden and the U.S. This work has been continued by others, leading recently to a comparison of energy use in individual towns in Minnesota and Central Sweden. These energy profiles reveal many details not available to the wide area surveys. Though many are weary of the "Swedish example" Sweden provides an interesting comparison with the U.S. precisely because so many features there are close to those in the U.S. Sweden also exhibits certain extremes, like climate, but lies median to other European countries in other areas. Because data on energy use in Sweden is excellent, many ideas could be reviewed that only arose more recently in studies of other countries. It is therefore worth reviewing the highlights of the comparison. (Readers wishing greater detail should turn to Science, 194, 1001, 3 December 1976.)

To compare any two countries, many small effects have to be accounted for before energy use could be directly compared, including differences in natural distances, fuel extraction (almost non-existent in Sweden) and climate.* An additional consideration, often overlooked, turns out to be important. If one counts the energy embodied in the goods and services making up foreign trade, it is found that the U.S. is a slight importer of energy, in an amount equivalent to 1% of the total energy use in 1973. This includes the energy used to refine fuels that are imported and exported, but not the thermal energy of combustion contained in those fuels. Sweden, in contrast, is clearly a net exporter of embodied energy, with the net embodied energy amounting to 8-9% of total internal consumption. This is also true for West Germany or Japan. On the fuel side, Sweden, like most European countries, imports a larger share of her energy, both crude and refined, while the U.S. imports considerably less in relative and absolute terms per capita. The U.S. exports coal and Sweden exports refined oil because of excess refining capacity. Moreover, geography and trade put certain uses of energy out of reach of the normal accounting practices, since a much larger share of Swedish production, consumption and travel passes through foreign countries than is the case for the U.S. Fortunately, the most troublesome discrepancies or difficulties turn out to be relatively small or readily quantifiable.

After allowing for these adjustments, it is found that the greatest differences in energy use appear in the intensities (or efficiencies) of use for process heating, space heating, and transportation. To display the overall effects of both intensity and mix of output, these relative quantities (for Sweden and the U.S.) are displayed in Table 6. As can be seen, space heating in Sweden is remarkably less intensive than in the U.S., when measured in Btu/square meter/degree-day. Other studies suggest that Sweden and Denmark are unique in this area. The living space per capita is nearly as large in Sweden as in the U.S., while most of Europe falls behind these countries in this important measure of living standards. The energy intensity of apartment heating in Sweden is nearly as great as that in single-family dwellings (see below). This means that the relative efficiency of space heating in Sweden vis

*Air conditioning is non-existent in Sweden, but there is little need to heat factories in the U.S. and these two uses, by coincidence, nearly compensate.

à vis the U.S. <u>cannot</u> be ascribed to the greater proportion of apartments there compared with the U.S.

On the other hand, households in Sweden generally have fewer appliances than in the U.S., reflecting a different lifestyle and lower after-tax incomes, and this results in a lower household use of electricity. Other European countries fall even farther away, though the gap is narrowing. In the commercial sector, the same high degree of thermal integrity appears in Sweden.

Indoor temperatures in Sweden are higher than in the U.S. One relative inefficiency in the use of heating and hot water occurs in Sweden because of common metering and unregulated hot water and heating systems. This leads to a surprisingly large consumption of fuels for heating in apartments, although the overall use of heating is more efficient in Sweden than in the U.S. because building shells are well constructed.

In the industrial sector, the differences in intensity are consistent with the results of other studies. Sweden is neither the most nor the least efficient. While oil refineries in Sweden produce relatively less gasoline than in the U.S., other product mixes are comparable. The overall Swedish mix in manufacturing is weighted more heavily towards energy-intensive products than is the case in the U.S. The lower energy intensities found in Sweden, however, are generally tied to higher energy prices there, suggesting that prices do affect industrial energy "needs" considerably. Carlsson showed that higher prices have been important in eliminating the building of any new wet cement ovens, given the energy conserving dry oven today.

The greatest contrast is found in transportation, dominated in both countries by the auto. Swedes travel only 60% as much as Americans and use 60% as much fuel per passenger mile. This held Swedish gasoline use in the early 70's to 1/3 of our own. Mass transit and intercity rail are less energy intensive and more widely used in Sweden, while air travel is overwhelmingly larger in the U.S. Intra-city trucking in Sweden is considerably less energy intensive than in the U.S., but long haul trucks in Sweden use slightly <u>more</u> energy/ton-mile than in the U.S.

The greater distances in the U.S. mean that ton-mileages (at distances greater than 30 miles) are far greater there. The overall U.S. long haul mix is less energy intensive but total use is greater because of distance. Here is a clear example of how greater use, on the part of the U.S., has little to do with inefficiency. In fact, the American freight machine is more weighted to less energy intensive railroads than in most other countries.

Historically, higher energy prices in Sweden than in the U.S. are an important factor that has led to the more efficient energy use in that country. While pre-embargo oil prices in both the U.S. and Sweden were roughly equal (Table 7), Americans enjoyed natural gas and coal resources that provide heat at 20-50% lower cost compared to oil. In the case of electricity, the two countries were radically different (up to 1972). Since 75% of all electricity generated in Sweden was produced by hydropower, the ratio of the cost of electricity to the cost of heat from fuel was only half as great in Sweden as in the U.S. Industry in Sweden naturally developed a more electric-intensive technology base. However, 30% of thermal electricity generation in Sweden was accomplished through combined production of useful heat and electricity in industries or in communities, the latter systems providing district heat. Consequently, in Sweden only about 7,000 Btu of fuel were required (in 1971-72) for the thermal generation of a kilowatt hour of electricity. Increases in the cost of nuclear electricity and oil favor the continued expansion of combined generation, but institutional problems have slowed that expansion in the late 70's.

An example of the effect of different prices helps explain Swedish energy use. In Sweden, autos are taxed in proportion to weight, both as new cars and through yearly registration. Swedes found a loophole, the registration of autos through companies, but the government discovered this trick and raised the tax on company owned cars. Gasoline is taxed, the amount recently being raised to 90 cents per U.S. gallon, vs. less than 15 cents in most of the United States. Even still Sweden has a relatively low priced gasoline market compared with France or Italy (Table 5). But overall high prices, compared to the U.S., restrain total auto use, especially in short trips and in cities.

Although the impression that Sweden is somehow "energy wise" and the U.S. less so is unavoidable, the real lesson from this two-country comparison is that energy use for important tasks is flexible, given time, technology, economic stimulus and, in some cases, favorable government or institutional policies. Indeed Sweden could be using more energy than the U.S. per capita (or per unit of GNP) and still be more efficient, (as is the case in manufacturing) or the converse. And Sweden is not a special case. Other countries show similar variations in energy use. The Swedish example has reinforced the findings of the broad survey.

V. Other Countries Since the Embargo

What has happened since 1973? While in many respects it is too soon to tell, the evidence suggests that countries are conserving energy. The International Energy Agency, which keeps watch on oil consumption, points out that since the Oil Embargo the elasticity of energy consumption with respect to GNP has fallen remarkably in nearly every country. It takes far less energy now to produce a unit of GNP growth than before the Oil Crisis.

While this result holds for nearly every wealthy country, it is still subject to all of the vagaries of E/G statistics. For example, one IEA study showed that during recessions the U.S. E/G tended to rise, while E/G in most other countries fell. One explanation is that the E/G in the U.S. is dominated by consumer uses of energy that only fall in extreme recessions, while in Europe E/G, dominated by commercial and industrial uses, contracts more quickly with economic slowdowns. In Sweden, for example, 1974 was a boom year for the economy but real conservation efforts resulted in a 9% increase in industrial production with only a 1% increase in energy use. In 1976, however, industrial use fell due to recession. In the U.K. energy use has fallen absolutely while GNP has increased. Clearly these contrasting events must be separated in any discussions of conservation.

Nevertheless the IEA data do suggest that conservation is working.

People, firms and institutions are discovering that it pays to use energy more efficiently. Table 8, while relying on the energy/GNP ratio as an indicator, does give the impression that energy use and economic activity have a different relationship now than previously. The marginal increase in energy consumption needed to raise GDP by $1000 is shown for two periods, and the most recent five years show a clear decline in all but one country, Spain. Most important, these changes, signifying at least some significant conservation, have taken place without an overwhelming change in capital stock, though the marginal nature of the statistic applies to new activity. As existing stock is replaced or retrofitted the overall E/G should fall even more than it has so far. While a sector by sector analysis has yet to be done for most countries, data from Sweden and Denmark indicates that economies in the housing sector have been significant. In the latter country 19% of all roofs were insulated in 1974 and 1975! All countries have shown improvements in industries, and the U.S. has shown a dramatic improvement in the energy consumption of passenger autos. Thus the phenomena of conservation, even before large scale campaigns involving investment have been mounted, appears to have been anchored in the economies of the largest or richest industrial countries.

At the same time structural changes are still reshaping the patterns of energy use towards somewhat more energy intensive activities. Thus autos are still growing in importance in a country like Germany, where auto ownership was relatively high and freeways extremely well built out even before the Oil Embargo. There may be a subtle reason why the auto competes so well with one of the best and fastest rail systems in the world--speed limits are unknown on the German Autobahnen. Limiting speeds in Germany having proven politically impossible, the net result is that automobiles can travel point-to-point faster than even the fastest trains in many cases, since much transit time (home to station, stopovers) is eliminated. In Sweden by contrast several 200-400 km stretches that are well developed from the motorist's point of view are nevertheless faster by train, because Sweden has a speed limit of 110 km/hr on freeways and 90 on other main roads. Thus the rail corridors

Malmö-Gothenberg, Malmö-Stockholm, Stockholm-Gothenberg and Stockholm-Luleå still compete with autos for long distance travel.

Of course a 200+ km/hr trains system could be built in Germany (as has been working in Japan) but then the energy saving qualities might be reduced or eliminated. Germans are not necessarily "wasting" energy by abandoning the Bundesbahn for the Autobahn, because they are gaining in time and convenience. This subtle example then illustrates well the problems facing the so-called "efficient" nations.

VI. What Can We Learn from Other Countries

While much of the value of studying the energy habits of other countries lies in the understanding we get about how energy economies work in theory, it is useful to review practices in foreign countries that may be of practical help for American energy users. It should be emphasized, however, that we must work to find our own solutions to energy uses that are climate dependent (buildings), lifestyle dependent (land use planning and transportation) or policy dependent. Even in industry it is important not to simply shop in other capitals for energy-saving equipment, but to build instead on existing ideas with new ideas, leapfrogging existing efficient technology to find even more productive ways of using energy with other resources.

a. Buildings

Only the Scandinavians widely display truly enviable practices in the buildings sector. There energy use per unit of area per unit of climate, the best measure of efficiency, is truly less than in Central Europe or the United States. Moreover, evidence accumulated in conversations with European energy officials suggests that most European countries are a long way from establishing truly energy efficient building stocks.

Scandinavian home building practices make it clear that we can reduce building energy needs considerably--by as much as 80% compared with pre-1973 homes in the United States. While insulation of existing homes in the U.S. is the most popularly cited need, control of infiltration and ventilation may make an even larger contribution to saving energy profitably, when existing or new Swedish buildings are compared with untight U.S. structures. Experience in the building research programs at the Center for Environmental Studies, Princeton, and the Lawrence Berkeley Lab suggests that we can achieve the low air infiltration rates now called for in Swedish or Danish building codes (considerably less than 1 air change per hour in homes).

One effect of careful insulation and tightening of structures is the increase in comfort that goes beyond the relief of a lower heating bill. When structures are carefully controlled the heat comes on less, causing less air exchange and heating up of the indoors near vents. Drafts are reduced. The temperature difference between floor and ceiling, between areas near windows and inner parts of rooms is reduced, reducing both air motion and discomfort. Indeed there is the suggestion that Swedish homes are built so well in order to satisfy desires for comfort ahead of simply saving energy.

One of the most important technologies being applied in Scandinavia is the heat exchanger. It has become clear that infiltration losses in homes can be reduced so far that odors, indoor pollution including evaporated plastics, radon gas from building materials, cigarette smoke, can become a nuisance or even a true health hazard. Forcing ventilation by fans and ducts has been a common practice in Swedish homes. The exhaust air contains valuable heat, however, and an inexpensive heat exchanger could recover much of the heat while allowing the unpleasant pollutants to be exhausted before they could build up in the home. In new Swedish apartment buildings, where the heat content of exhaust air is enormous, heat exchangers can be required, an attractive possibility for centrally heated and ventilated U.S. buildings. It should be noted that heat recovery is extremely important in the U.S. in warm months, when coolth from exhaust air can be recovered in the system. At present several European and Japanese firms are planning to market inexpensive heat exchangers in the U.S. Undoubtedly U.S. manufacturers will be close behind, and soon ahead.

b. Industry

Why do European process industries use less energy/output than our own? For one thing, European capital is newer, since the economic growth of the postwar period was greater than in the U.S. But newer equipment in both Europe and the U.S. uses less energy per unit of output than older. Thus from a structural point of view, Europe has an "advantage." The price of energy has been a big factor. Since energy is an important cost factor in the paper, cement, steel and chemical industries these areas show (not surprisingly) the greatest energy differences, particularly the paper industry. However, it is important to add that both the U.S. and Europe are improving since the embargo, since industrial energy and power prices in both countries have risen considerably. Thus, a new large dry oven installed in Slite, Gotland, Sweden, undercuts all existing Swedish cement ovens in terms of energy performance. But the same is true of new American facilities, according to a report in the New York Times (1 Jan. 1978). Thus we are learning.

One topic of controversy that has attracted considerable attention because of multi-country comparisons is the role of factor substitution in industrial energy use. Several studies have produced apparently conflicting results as to the possible substitutability of capital for energy. When specific energy using industrial branches are studied, however, the energy saving role of advanced technologies that substitute capital for energy appears clear. This is particularly true of process industries where heat, not electricity, dominates energy use. Thus Carlsson notes that the dry cement oven, which actually costs less (in investment/output) replaces the wet oven in most countries now, allowing increases in productivity and in energy efficiency. In Sweden at present an intensive program of investment in energy saving devices in existing industrial plants is underway. Most countries show a marked decline in energy/output for important materials over time (see Fig. 1).

A recent comparison of steel making in the U.S. and Japan showed clearly through both process anlaysis and economic factor analysis why Japanese steel mills use less energy per ton of output. This investigation noted differences in the steel making process, the U.S. still using considerable numbers of energy (and pollution) intensive open hearth furnaces while the Japanese rely on a considerably higher fraction of basic oxygen furnaces. The latter produces more steel per manhour and per unit of energy. Less Japanese steel was "wasted" in each process or lost so that overall output was also greater in a Japanese mill. In the final stages of forming, the continuous casting process, by which hot steel is formed immediately into intermediate or final products rather than being cooled down (and later reheated with natural gas), was also important in accounting for the 25% energy saving in Japan. Long et al found that overall Japanese steel making employed less labor and slightly more capital per unit of output than American steel making. The Swedish example, examined by Carlsson, lies intermediate to these two.

Long and his colleagues looked at steel and paper making for a number of countries and found again that capital can substitute for energy in most industrial countries. The same workers also measured the relationship between energy and capital across time and most European countries for all manufacturing and found again that capital was a clear substitute for energy. They noted that this held both in the high priced energy countries like Japan and West Germany and in the U.S. Thus international comparisons point clearly to opportunities for the U.S. to look at a variety of industrial technologies that are profitable when energy prices climb.

The clear lesson from foreign experience is that technology, prices, and the actual composition of natural resources available to a country share in determining the energy use and conservation characteristics of industry. Other countries pay dearly for fuels, so these resources were "conserved" relative to the United States. Historically conservation also accompanied gains in productivity.

One important topic being discussed in Europe is structural change. Should governments encourage or discourage the growth or decline in the most energy intensive industries, ones that would be more vulnerable to energy supply interruptions in the future? The question is particularly important in the European steel community and in the Nordic paper industries. The U.S. faces similar questions in the steel and aluminum industries, especially as sources of cheap electricity literally dry up for the latter. While such questions are beyond the scope of the present discussion they must be kept in mind because they can have great influence on total energy demand in the long run.

Cogeneration of electricity and heat in industrial plants is receiving increasing attention in the U.S. In this area Sweden ranks high in the world, particularly because of the size of the paper industry. However, even in Sweden "cheap" electricity has hindered the expansion of cogeneration, especially just now when long term electricity contracts hide the marginal cost of new power from existing plants. About 5% of Sweden's 1972 electric power production came from industrial cogeneration, 4% in 1976 (a recession), and estimates of 8 to 10% arise from studies of the 1985 period and beyond for the United States. For Germany, France, and Italy total cogeneration in industry amounts to around 15% of total electricity production according to recent OECD figures.

However, cogeneration in Sweden has always been regarded as a method of using waste heat from electric power production. A much larger potential that is untapped in both Sweden and the U.S. arises when one makes electricity whenever high temperature (or low temperature) heat goes unused, the electricity being sold to the utility net whenever it is not needed on site. American estimates find a potential of 5 to 15% of all electricity in 1985 can be generated this way with good profitability for the generator. Institutional factors may inhibit this growth in an energy conserving technology, but the foremost barrier is still the unrealistically low price of electricity to industrial users. Additionally, the uncertainties over environmental regulations, lower prices for natural gas and oil than in Sweden, and fear of utility/industry cooperation, figure in the muzzling of the cogeneration potential in the U.S. International comparison of experience in cogeneration deserves more study now to determine which existing arrangements are most attractive for the future. This applies both to technical and to institutional problems.

c. District Heating

One technology often suggested by the European experience is district heating, by which blocks (or square kilometers) are provided with water-borne heat (and hot water) from central plants. In Denmark, Sweden, Berlin, and many eastern European countries a significant fraction of all apartments and most buildings in city centers are heated by district heating. Elsewhere district heating makes important local contributions, though in no case does the energy savings attributable to DH make more than a small impact on total energy consumption.

How does district heating save energy? Heat-only systems produce hot water in well maintained high temperature boilers whose heat transfer from fuel to water is significantly higher than in individual boilers, more than offsetting the relatively small ($\leqslant$ 10%) losses in transmission of water. In the ideal case the largest possible fraction of hot water is made in conjunction with electric power. Heat that would have been rejected to the environment is now used to heat buildings, the extra amount of energy added to this water (or alternatively the electric power sacrificed) typically 5-8 times less than the useful heat produced. Alternatively DH can be described as a system that produces electricity for far smaller losses than in condensing-only power plants. Energy savings equal the extra fuel required were electricity and heat made separately. Exactly how large a fraction of all district heat is produced with electricity varies depending on the characteristics of the heating season (or need for cooling) as well as the electric power demand characteristics and existing power plant mix. DH economics depend both on this accounting and critically on capital cost of distribution, which in turn is very dependent upon the amount of heat sold per square km. In dense areas with long heating seasons, such as cities in Sandinavia, DH provides low cost heat.

Other important advantages accrue to cities with DH. Pollution from burning oil is clearly reduced because controls are better than in separate boilers. This advantage was important in starting up such systems in Sweden in the days when oil was cheaper. Moreover oil-fired DH systems run on cheap heavy oil. Additionally DH centrals can run on a variety of fuels, including wood or coal, and can be built to switch rapidly. Since the combustion operation is centralized congestion associated with delivery of fuel is minimized. Finally DH relieves individual building owners or occupants from worrying about heating, and reliability is good.

Whether DH is a good buy for the U.S., however, is questionable. Winters here are shorter, though often colder during peak times, than in Scandinavia. When comparisons are made of DH economics in Europe and the U.S., the heating load that enters in the U.S. calculation is often assumed, at today's levels, rather than calculated based upon conservation that would be appropriate at the price charged for DM. But European figures for heat demand are bloated by the lack of individual meters, a problem particularly acute in Sweden. That real cost of DM may be unknown since the unit price is so sensitive to the number of units over which the enormous fixed costs are spread. If DH can provide cooling, of course, the economics change considerably since such cooling reduces electric peak loads and reduces waste heat loading in the summer in cities. Certainly technical studies and actual implementation, as has been discussed for cities in Minnesota and other colder states, are important. At present, it appears that it is far cheaper to save fuel by end use reduction than by DH.

However, the real problems for DH in the U.S. may be institutional. Sweden and Germany have contemplated mandatory hook-up laws as a means of insuring high density and thereby lowest costs. Land use planning with long time horizons, far more prevalent and accepted in Europe, is essential to the orderly build-up of a system over a decade. Moreover, DH has penetrated principally apartment areas. In Västerås, Sweden, where virtually all single and multiple family dwellings receive district heat, unit costs for detached houses were two to four times greater than apartments, because of both higher distribution costs and considerably greater losses per dwelling. In the U.S. detached houses dominate, and little high density new construction is on the horizon. DH may not fit into our living patterns except in existing downtown areas, possible with urban renewal.

Will European DH systems be important in the U.S.? Unfortunately many of the advantages appear only indirectly and not as direct cost reductions, especially when conservation reduces heat needs so much in most of the U.S. And DH can only appear as a result of coordinated action, with government present at nearly every stage. Indeed it has been argued that DH has been attractive in many places precisely as an extension of municipal power into the service of comfort. But haggling over nearly every government effort recently does not speak well for DH.

Thus DH faces institutional tangles that may only be worth overcoming in areas like Minnesota where the potential benefits are inarguably great. Smaller ventures, such as time of day pricing and individual metering of apartments or large scale retrofit insulation programs ought to be tried first before any large scale DH is promoted on a national scale, as is often advocated here and in Europe. For ultimately the energy saved/unit investment should be far higher with simpler schemes than district heating.

d. Transportation

In transportation the lessons for the U.S. are ones of a sensitive policy nature. The difficulty in dealing with transportation, as incomes rise and autos become more important, is clear: autos are popular. Obviously one cannot "hold back" the auto in the U.S. without offering attractive alternatives.

Because of low gasoline prices, tax subsidies for owning single family dwellings, little or no land-use planning, and easy access to freeways, mass transit in America seems hardput to capture all but a small fraction of land passenger miles. The decline of mass transit's share of passenger miles in Europe, very much similar to what was seen in the U.S. 20-40 years ago, emphasizes this even more clearly. As usual, this decline in the mass transit share of traffic happens because the auto increases its absolute role in traffic. New owners, new patterns of commuting, new uses of the auto for vacations have become as abundant in Europe as in America in the last war era. Thus auto miles have increased tenfold in Sweden since 1950, and similar increases have occurred everywhere in Europe. (See Table 5.)

Clearly strategies to save energy in this area should concentrate first on efficient, light autos. The MPG standards in effect in the U.S. and Canada further this end, though in my view taxes on weight ("gas guzzler taxes") and gasoline would be helpful in accelerating progress beyond the nominal goal. The latter is particularly important during the present stagnation of gasoline prices--efficient vehicles lower the out-of-pocket cost of driving, making mass transit or walking less attractive, especially in short trips. In Europe where auto size has increased somewhat, the spread of manufacturing of autos among several countries and strong resistance within countries makes standards on MPG unlikely, but higher gasoline prices have already brought on new light vehicles like the Rabbit (VW), "Le Car" (Renault) or Volvo 343. Nevertheless there is still much room for improvement in the European vehicle fleet.

Technologically, however, European and Japanese manufacturers offer autos with high MPG (VW Rabbit, Honda) that have stimulated American manufacturers, airplanes (the Airbus), and light diesel trucks. A recent ad in Business Week appealed to the American shipping market by pointing out that there were far more energy-thrifty light diesel trucks in Germany than in the U.S.A. The U.S.-Sweden comparison suggested the consequences--short range intra city trucking consumes far less energy/mile in Europe than in the U.S. Here is an area ripe for technological development.

Clearing cities of as much auto traffic as possible, leaving busses, taxis and light trucks, would also improve freight handling and energy use, reduce pollution and congestion, and allow more efficient use of autos that venture about. Such a practice is very attractive in the old capitals in Europe, especially Stockholm, but meets with jeers in the U.S. Stockholm has considered city-gate tolls, but Berkeley, California challenged a system of traffic rating barriers twice in municipal elections, though the barriers won each time. The lesson is clear--transportation policies that affect patterns of transportation must be introduced carefully and slowly, again with an eye to the very long run, lest local opposition from consumers and businesses crush even the best of intentions. These could have enormous energy payoffs by decreasing the need to travel.

e. Conservation Policies and Programs

What about conservation policies in IEA member countries? All countries profess an interest in conservation, but only some have actively supported conservation through the marketplace, through financial arrangements, or through effective standards. Thus the IEA survey, "IEA Reviews of National Energy Programs" (June 1978) shows that while the U.S. still "enjoys" the lowest energy prices, most countries still struggle with less than marginal costs for one form of energy or another. Some countries like Germany, Switzerland, or the U.S., must await cooperation from regional jurisdictions before certain kinds of legislation, such as building codes, can pass. Sweden, Denmark, and Holland have begun campaigns of loans to industries wishing to modernize energy use, while Sweden, Denmark, Holland, France and West Germany make loans and subsidies available to homeowners or apartment owners who wish to install energy saving devices. Energy labels on major energy-using appliances have only become mandatory in a few countries. The Common Market, which, unlike the IEA, possesses some supranational legislative capability, has discussed standards on all heat producing devices for building and has begun a prototype support campaign to encourage innovations in buildings that save energy. A list of actions in the buildings sector covering IEA countries is shown in Table 9.

One effective technique employed in Sweden, Denmark, and the U.K. is the energy audit. An engineering or consulting firm prepares a study of an industry, such as bricks (the U.K.), or auto painting (Denmark). The results tell policy makers what progress can be expected in that branch. More specific audits of firms are used today by other firms. The Danish auto-painting study analyses why some firms use as little as 2/3 the heat of other firms; the U.S. Cement study does the same for cement. These studies are especially helpful to smaller firms whose own expertise and budgets are limited. In Sweden the audit extends to the single firm, and the consultant leaves the firm with concrete suggestions on ways to improve energy productivity. Even estimates of costs and savings are given.

The lesson here is that in the industrial area information is a vital ingredient in energy conservation. Larger, energy intensive firms, whose collective consumption accounts for as much as 3/4 of a nation's industrial energy use, are usually well-informed about conservation possibilities. Smaller firms, however, have far less access to information and expertise. Hence the government, often through the branch organization, acts to provide that information. In the United States some electric utilities have become consultants for small power and light customers, often under pressure from local utility commissions.

On the whole, however, energy conservation programs in Europe are still in their infancy, as in the case of the U.S. My own studies suggest that Sweden has progressed the farthest, followed by Denmark, Holland, the U.K. and the U.S. The IEA notes that most of the efforts are underfunded in relation to stated goals. Of course it is hard to assign "saved" Btu's to specific programs when higher energy prices are themselves in large part responsible for changes in consumption patterns. On the other hand, aggressive energy standard programs, as have been implemented in California or Sweden in the residential or commercial sectors, do lead to identifiable savings insofar as structures (or appliances) are built to lower life cycle costs because of the standard. What all countries lack, however, is follow up measurement--are the low energy houses in Sweden, Denmark, or California performing in fact as well as they were designed? Answering that question will not be inexpensive or easy but is very important for planning future conservation programs and even supply development. Unfortunately few European countries have integrated detailed data on housing stock, industrial plant, and automobile stock into energy models or into the energy data books of national agencies. The result has been a great degree of difficulty in developing conservation programs or allocating resources, since so little appears to be "officially" known about consumption patterns. This view was constantly expressed in my discussions with officials in transnational organizations in Europe and in individual countries. In this respect the tremendous energy consumption data effort underway in the U.S. is admirable and will make an important contribution to our conservation planning while Europeans still argue over whether retrofit insulation is profitable in existing homes and apartments.

VII. Lifestyle

While we have not treated lifestyle explicitly it is clear that this factor does enter into explaining differences in energy use patterns among countries. For the energy conservation planner wary of establishing normative conservation goals or standards, the issue of lifestyle may be unwelcome. Nevertheless it is important to use our observations of other countries in an attempt to understand the possible couplings between energy, conservation and lifestyle.

Quantitatively there are two aspects of lifestyle that bear directly on energy use: the mix of non-energy goods and services, aside from energy itself, demanded by consumers, and the mix of key energy intensive activities that interact directly with energy. To the latter group belong indoor temperatures, patterns of auto ownership and use, land use patterns, appliance ownership, vacation and travel habits, and ownership of second homes or boats. The U.S., Canada, and Sweden tend to have the greatest energy demands arising from these patterns, while the remainder of Europe, while considerably "behind," is narrowing the difference somewhat.

It is hard to label activities such as living far from work as "wasteful," yet it is important to investigate why people live and work where they do, why they may evacuate cities on weekends for summer homes, why they prefer detached single family dwellings to apartments. For example, most countries allow homeowners to deduct mortgage interest payments from taxes, an important subsidy for homeowning, especially in high tax countries like Sweden. Moreover commuters in Sweden can deduct the cost of the monthly bus pass from income, and those who can prove that driving saves one half hour (each way) compared to mass transit can also deduct the full cost of driving. These "lifestyle" subsidies may be justified on social grounds, but they have a measurable impact on spreading people out, which in turn tends to increase energy use.

Should any country "embrace" another country's lifestyle for the sake of saving energy? Probably not. However important the connection between lifestyle and energy, there are so many conservation opportunities that involve technology or minimal behavioral adaptation to higher energy costs that we may not need to consciously live like other peoples just to save energy. However, understanding the energy implications of alternative patterns of consumption, location and occupation certainly would illuminate options for society. Thus the energy comparison of Mora, Sweden and New Ulm, Minnesota created great interest in trying to quantify the energy implications of perceived differences in lifestyles in the two countries. In this case the market-basket differences probably have less to do with observed differences in energy use than the lifestyle (or technical) differences in direct consumption habits.

While little data yet exists that allows general conclusions to be made about energy and lifestyle, details from the Swedish-American comparison and other work support some important tentative findings:

* The greatest differences in driving habits arise in the use of the auto for short trips, far more prominent in the U.S. Commuting via auto is gaining, however, in all countries, and load factors are low, partly because people living in clustered areas are still riding mass transit. Greater distances in the U.S. affect distance to work, but do not account for the significantly greater distances travelled. Indeed, distance per car per year (Table 5) varies far less across countries, suggesting that it is the ownership of a car that sets off lifestyle changes leading to increased driving nationally.
* Land use planning influences lifestyles and energy use considerably. As people spread out into suburbs, often aided by government home-building subsidies, cars become a vital link to shopping and services. Still, zoning in Sweden allows some services to be "built in" to residential areas, while in the U.S. the great suburbs seem to isolate residences from services.
* The low relative cost of scheduled and charter air flights in

the U.S., compared to Europe, offers an energy-intensive but time-saving alternative to auto vacation travel. In Europe low cost charters have gained immensely in popularity, at least in the Scandinavian countries, but in most places the auto seems to dominate vacation travel, causing immense traffic problems never seen in this country. Additional studies should be made to compare patterns and costs of auto use in Europe and the U.S. Rail travel is still important for vacationing and even much intercity business travel in Europe, because of high density. Density clearly helps mass transit.

* Whole house heating is only saturated in the U.S., Canada, and Scandinavia. One OECD study suggests that affluence in Central Europe will support significantly greater demand for heat. Similarly appliance use will grow. Auto ownership is still far from saturation in Central Europe and is growing dramatically. Whether autos and appliances will ever approach those in America in size is unclear. If European countries begin now with appliance standards new large devices not yet in place could be significantly more efficient than their American counterparts of the 50's and 60's at similar levels of use and saturation.
* Other lifestyle aspects of living patterns remain to be understood vis à vis energy use. For example, what is the overall impact of commuting to second homes in countries like Sweden, Denmark or France? Does Americans' moving every six years (on the average) inhibit our ability to design communities and residences for long range resource costs? Will increases in affluence in Europe lead to "Americanization" such as is observable in Sweden and Denmark?

Quantitatively it is possible to separate effects of life-style from energy comparisons by concentrating on the use of heating, autos, and appliances. Whether lifestyles directly affect the intensities of <u>devices</u>, which can be affected by policies and prices, is unknown. In any case we know that lifestyles do affect energy use, and we know that these structural effects are apparent in a few important areas. This accounts for a significant amount of the differences in energy use between North America and Central Europe (Scandinavia being intermediate). Since conservation affects mainly intensities we can safely say that a great deal of conservation can be decoupled from lifestyle issues, while further reductions in overall energy use might come about through key lifestyle changes in the U.S. Whether these changes themselves would occur is another matter worth discussion elsewhere.

VIII. Summary and Conclusions

What have we learned from surveying energy use and conservation in industrialized countries? First, there is no question that other nations use energy in a variety of ways that are often more efficient than our own techniques, though the reverse may be true as well. These technical differences account for a major part of the differences in energy use among countries. Energy prices (or taxes), higher in most European countries (and in Japan) than in the U.S. or Canada, have played an extremely important role in bringing on these energy saving technologies. This factor is too often ignored by those who cite other countries as examples of energy conserving societies relative to our own. But we can say without doubt:

> International comparisons of energy use show that there is much technical flexibility and conservation potential within present U.S. energy use patterns, and in other countries, provided that economic incentives and time are allowed to play a role.

Energy use policies per se are of a secondary nature in the establishment of today's practices, but policies will be more important in the future. Energy saving building codes are the most important of these, but are themselves only truly significant in Scandinavia and perhaps now part of the U.S. Most European countries plan to introduce or stiffen building codes, but the Scandinavians are by far the leading practitioners of energy efficient buildings.

Lifestyle, coupled to energy through the standard and size of homes and the nature and extent of personal transportation, plays an important role in the differences in energy use, to some degree among the higher energy users (Scandinavia, North America) and to a greater degree among other wealthy countries. While the coupling between life-style and energy must be considered in any energy policy, it must be stressed that energy has rarely if ever been a consideration in the formulation of transportation or housing policies insofar as style and other non-technical factors are concerned. The fact that social policies may even encourage energy consumption from a structural point of view while encouraging conservation from a technical point of view--a situation already brought about on the structural side in the U.S. 20 years ago--suggests that energy will remain the tail of the dog but never the whole animal. Certainly energy and non-energy policies need close coordination, but Swedish experience suggests that such is not always simple. Ultimately, however, energy policy should be able to fit in with other important goals, as we gain more knowledge of the link between energy and everything else.

It remains to pass judgment, however, on an important issue raised by international comparisons of anything. Sweden is not the U.S. (and vice versa). Are our comparisons meaningful in any sense? Does the small size of Sweden's homogeneous population, cultured in a tradition of political trust not common in the United States, allow institutions and people to function differently in reacting to a national problem? Does the lack of a class of poor people allow the Swedish government to carry out stern (but necessary) measures related to energy while we worry for years legitimately over the impact of any policy or economic move on our large class of poor?

These are the kinds of issues that most often surface when any mention of energy policies or experiences in other countries occurs. It is often assumed that such issues make really detailed international comparisons worthless.

My own counter to the negative implications of such questions is that the goal of our work is to find ways in which we can economize on the use of energy and other resources. The evidence is clear that in certain important areas great economies have already been achieved, both in the U.S. and abroad. To argue that experience abroad cannot be studied and tailored to U.S. conditions is in a sense to assume that there is something in the U.S. system that makes economical use of resources difficult or impossible. But historically America has become more economical with resources over the long term. To insist that new economies that are technically possible, economical, and already in place in other parts of the world are somehow unachievable because "we are not they" seems to me incorrect. Rather it behooves us to observe what we--and they--are doing as a means of improving on what we would otherwise do in the future--and thereby conserve energy. After all, energy conservation, according to economist Kenneth Boulding, is just "thinking before using energy."

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Table 1. Some basic data on 9 industrialized countries. Note that these figures account for consumption but do not measure efficiency or structure

Consumption by sector	U.S.	Canada	France	W. Germany	Italy	Netherlands	U.K.	Sweden	Japan
A. (tons oil equivalent per million dollars GDP)									
Total energy consumption	1,480	1,772	795	1,031	915	1,272	1,121	1,062	849
Transformation losses	250	401	140	170	133	164	254	267	147
Energy sector	135	128	57	74	48	100	81	33	48
Transport sector	327	305	117	132	136	134	145	121	105
Industry sector	309	388	219	299	282	254	318	275	330
Household-commercial	374	480	223	300	220	407	271	348	164
Nonenergy use*	86	70	38	55	96	213	53	18	54
All sectors minus transport	1,153	1,467	678	899	779	1,138	976	941	744
B. (index, United States = 100)									
Total energy consumption	100	119.7	53.7	69.7	61.8	85.9	75.7	71.8	57.4
Transformation losses	100	160.4	56.0	68.0	53.2	65.6	101.6	106.8	58.8
Energy sector	100	95.6	42.2	54.8	35.6	74.1	60.0	24.4	35.6
Transport sector	100	93.3	35.8	40.4	41.6	41.0	44.3	37.0	32.1
Industry sector	100	125.6	70.9	96.8	91.3	82.2	102.9	89.0	106.8
Household-commercial	100	128.3	59.6	80.2	58.8	108.8	72.5	93.3	43.9
Nonenergy use*	100	81.4	44.2	64.0	111.6	247.7	61.6	20.9	62.8
All sectors minus transport	100	127.2	58.8	78.0	67.6	98.7	84.7	81.6	64.5

* Energy raw materials used as feedstock for the petrochemical industry.

Source: RFF Note one ton oil equiv. = 11.63 mWh = 40.8 GJ.

Table 2. Energy in industry, comparative intensities.

	Industrial sector: % of total energy use	crude efficiencies for			Steel, 1972				
		cement	pulp and paper	oil refinery	% of total energy	furnaces, percent: open hearths	basic oxygen	electric	tons/oil equiv/ton steel
Austria	30.7	21.5	14.4 *	—	—	—	—	—	18.8
Canada	26.0	22.7/35.4	28.2	—	2.5	39.5	43.9	16.6	16.3
Denmark	16.8	39.2	14.8 *	12.7	—	—	—	—	—
France					7.5	43.5	45.9	10.6	22.2
Germany	36.1	21.7	18.3	19.1	9.6	25.2	64.6	10.2	23.4
Italy	34.4	23.0	14.2 *	10.7	6.1	20.1	39.1	40.8	16.7
Japan	47.3	28.6	21.4	11.0	14.9	2.0	79.4	18.6	19.7
Netherlands	32.5	31.4	—	—	4.4	4.2	88.9	6.9	20.5
Norway	33.9	27.5	27.6	—	—	—	—	—	—
Sweden	31.6	33.4/20.1	20.5	11.7	5.6	21.3	36.5	42.2	19.3
Switzerland	18.3	—	23.3	—	—	—	—	—	—
United States	27.7	38.6	24.2	21.4	3.9	26.2	56.0	17.8	23.9
United Kingdom	28.5	33.1	26.2	17.5	7.3	37.9	42.7	19.4	25.5

All quantities in GJ/ metric ton. Steel data from RFF, other data (incl. Austria) from IEA. No corrections for product mix or inputs, so figures should be taken as illustrative only. Where two figures are given for cement, the former is for wet, the latter for dry processes. Paper marked with * probably excludes some energy embodied in purchased pulp, and Canadian/Norwegian figures are affected by electricity accounting.

Table 3. A schematic ranking of factors affecting comparative energy consumption/GDP ratios, by country, 1972
(for a given category, the lower the number, the greater the effect on raising the energy/GDP ratio)

Factors	United States	Can-ada	France	West Ger-many	Italy	Nether-lands	United Kingdom	Sweden	Japan
Energy prices (lowest prices = 1)	1	2	4	5	9	6	8	3	7
Passenger miles per unit GDP	1	5	9	3	2	6	4	6	8
Percentage of passenger miles accounted for by cars	1	2	8	4	7	5	6	3	9
Energy consumption per car-passenger mile	2	1	4	8	5	7	9	6	3
Cold climate*	7	2	5	4	9	3	5	1	8
Size of house & percentage single family	1	1	6	6	8	5	4	3	8
Extractive industry GDP as percent of total GDP	2	1		4	6		3	5	7
Industrial GDP as percent of total GDP	7	8	2	1	6	4	5	9	3
Ratio of industrial energy consumption to industrial GDP	2	1	9	8	6	5	4	3	7
Degree of energy self-sufficiency	2	1	7	5	8	3	4	6	9
For reference:									
Energy/GDP ratio	2	1	9	6	7	3	4	5	8
Energy per capita	2	1	7	5	9	4	6	3	8
GDP per capita	1	3	4	5	9	6	8	2	7

* Climate measured by degree days. Source of ranking, RFF.

Table 4. Some important energy prices

	Gasoline, without/with taxes, ¢/liter, 1977		Low sulphur heating oil $/GJ 1972	1977	dom. electricity ¢/kWH, 10,000 kwh/yr 1976	dom gas $/GJ 1972	1976
Austria	19	38		4.67	6.0		4.44
Belgium	16	37		3.52	5.1		5.00
Canada			.96	2.22	1.8	0.91	1.39
Denmark	17	41		3.64	4.5	___	5.83
England	12	25	1.41	2.69	2.7	2.39	2.75
France	16	40	1.22	3.58	3.5	3.30	6.11
Holland	17	39	1.03	3.47	4.4	1.70	3.05
W. Germany	15	35	0.89	3.19	3.8	3.09	5.28
Italy	14	51	1.03	3.06	5.3	1.91	2.22
Japan			1.15	3.33	5.6	___	6.90
Norway	16	39		3.72	2.5	___	___
Sweden	17	35	1.24	3.44	2.3	___	___
Switzerland	15	36		3.08	2.7		6.94
United States	13	16	.74	2.78	4.1	1.12	2.50

(For 1972, see Table 5)

Approximate prices in US¢/liter: Source of Data, Industriverk, Stockholm,

RFF, OECD 4.7 Swedish crown = 1$, 1977

Table 5. Passenger transportation: 1972

	Pass-MI/cap	MI/auto	% Auto	Energy/Cap MwH Cap	Intensity	Gas price (US=100)	% of income	Auto ownership, cars per 1000 people 1961	1972
United States	11,300	9,360	92	9.4	.90	100	3.4	344	462
Sweden	6,280	8,900	84	(3.8)	(.60)	(180)	(0.8)	173	303
Canada	6,550	10,000	88	6.3	1.1	(110)	___	237	377
France	3,980	___	77	2.2	.71	256	0.7	133	269
W. Germany	5,870	8,900	82	2.4	.51	243	1.1	92	253
Italy	4,160	7,610	80	2.2	.65	348	0.6	48	229
Netherlands	4,620	10,000	81	2.2	.59	___	___	53	229
United Kingdom	4,990	8,950	80	2.0	.49	192	1.1	113	230
Japan	3,760	___	34	0.9	.74	250	0.2	7	119
Europe avg.	4,840		80	2.3	.60	___	___		

Source: RFF; IEA; Swedish data modified by Schipper and Lichtenberg; Prices for gasoline, income shares from RFF; distance/auto/yr from WAES.

Passenger transportation: Shown are the total miles, the share taken by autos, the resulting per capita energy consumption, the intensity in kwh/passenger mile, the gasoline price relative to the US, and the percentage of income spent on driving. Finally, auto ownership figures for 1961 and 1972 are shown, displaying the rapid growth in Europe and Japan that still lies far from saturation.

Table 6. Sweden/U.S. contrasts in energy use; ratios are listed

		Per capita demand	Intensity	Total energy use	Notes
Autos		0.6	0.6	0.36	Swedish 24 M.P.G. driving cycle uses less energy
Mass transit trains, bus		2.9	0.80	2.35	Mass transit takes 40% of passenger miles in trips under 20 km in Sweden
Urban truck		0.95	0.3	0.28	Swedish trucks smaller, more diesels
Residential space heat (energy/deg day × area)		1.7 ×0.95)	0.5	0.81	Sweden 9200 deg days vs 5500 U.S. deg. days)
Appliances		?	?	0.55	U.S. more, larger appliances
Commercial total/sq ft		1.3	0.6	0.78	Air conditioning important in U.S. only
Heavy industry (physical basis)	Paper Steel Oil Cement Aluminum Chemicals	4.2 1.1 0.5 1.35 0.5 0.6	0.6-0.9	0.92	Sweden more electric intensive due to cheap hydroelectric power. Also Swedish cogeneration
Light industry ($V.A.)		0.67	0.6	0.4	Space heating significant in Sweden
Thermal generation of electricity		0.3	0.75	0.23	Swedish large hydroelectric, cogeneration

Listed are the ratios of Swedish/US demand, intensity, and energy use totals. Differences in demand account for structural differences (market basket) Differences in intensity tend to indicate conservation. For transportation the demands are measured in passenger or ton miles.

TABLE 7 Typical energy prices in the U.S. and Sweden. Exchange rate used is $1 = 5.18 skr (1960-1970) and 4.30 skr (1974). Data sources listed in Schipper and Lichtenberg.

	U.S.[a]				Sweden[b]			
	1960	1970	1974	*¢/kWh 1970*	1960	1970	1974	*¢/kWh (1970)*
Oil Products (¢/gal):								
Gasoline[c]	30	35	45	*1.04*	53	61	116	*1.82*
Diesel	23	28	35	*0.83*	42	48.8	90	*1.45*
Heating oil-								
Small customers	15	18	35	*0.50*	13.3	13.2	40.6	*0.37*
Large customers	10.5	12	25	*0.33*				
Heavy oil	7	8	23	*0.23*	7	8.5	22.5	*0.24*
Gas (¢/MM Btu):								
Residential	82	87	113	*0.29*	—	550	680 (1973)	*1.9*
Industrial								
Firm service	51	50	—	*0.17*	—	—		
Interruptable service	33	34	—	*0.11*	—	—		
Coal, Industrial[d]								
($/ton):	10	13	25	*0.14*	—	18		*0.2*
Electricity (¢/kWh):								
Base	2.75	2.75	—	*2.75*	3.14	2.12	2.3 (1975)	—
Base and space heating	1.75	2.0	—	*1.5*	—	~1.5	2.0 (1975)	
Industrial	1	1	1.5	*(0.4-2.1)*	—	0.93	1.8 (1975)	*(0.6-2.2)*

Table 8. Gross energy performance

energy and growth

	1960 -1972	1972-1977
IEA	1.05	0.48
W. Germany	0.99	0.30
Japan	1.02	0.67
Italy	1.59	0.31
Holland	1.65	0.43
Spain	1.10	1.63
Sweden	1.08	0.81
United Kingdom	0.73	negative
United States	1.11	0.34
France	0.86	0.54

Conservation Performance: Tons of oil equivalent required to increase GDP by $1000 during pre and post embargo periods. Data from the IEA. Note that the coefficient for the United Kingdom in the second period is undefined because energy use contracted while GDP increased.

TABLE 9:
Implementation of Energy Conservation Measures in the Residential and Com:::ercial Sectors

-: no measure
P: planned measure
X: existing measure

	FINANCIAL/FISCAL INCENTIVES								BUILDING CODES								APPLIANCE EFFICIENCY						INFORMATION/ADVICE/ASSISTANCE							FUEL UTILIZATION	
	TAXES	Removal of Sales Tax	Discount on Taxable Income	SUBSIDY GRANT	LOAN	Others		Job Creation and Conservation	NEW HOMES Federal	Local	EXIST. HOMES Federal	Local	Federal/Public Buildings	MAX. TEMP. Air	Water	Prohibition of Bulk Meters	ENERGY LABEL Mandatory	Voluntary	STANDARD Federal	Local	MAINTENANCE	Others	INFO. SERVICE/ CAMPAIGN	PUBLICATIONS	SCHOOLS	VISIT/CONSULT	HOME ENERGY AUDITS	TV/MASS MEDIA	Others		
Canada	–	X	–	X	X			X	X		X		X	–	–	X	X	–	P	–	P		X	X	X	X	X	X			
U.S.	–	–	P	X	P	X		X	X	P	–		X	–	–	P	X	–	P	–	–		X	X	–	P	P	X			
Japan	–	–	–	–	–			–	–		–		P	–	–	–	–	X	–	–	–		X	X	P	–	P	X			
N.Z.	X	–	X	–	X			–	X		–		X	–	–	–	–	–	–	–	–	X	X	–	–	–	X	–			
Austria	–	–	–	X	–			–	X		–		X	–	–	–	–	X	–	–	–		X	X	X	–	–	X			
Belgium	–	–	–	X	–			–	X		–		X	X	–	–	–	–	–	–	X		X	X	–	–	–	–			
Denmark	–	–	P	X	–			–	X		X		–	X	X	–	–	X	P	–	–		X	–	–	–	–	–	P		
Germany	–	–	X	X	X			X	X	X	X	X	X	X	X	P	–	X	X	X	X		X	X	X	P	–	P			
Greece	–	–	X	–	–			–	–		–		–	–	–	–	–	–	–	–	–		X	–	–	–	–	X			
Ireland	–	–	–	X	–			–	P		–		–	–	–	–	–	–	–	–	–		X	–	–	–	–	X			
Italy	–	–	–	–	–			–	X		X		X	X	–	X	–	P	–	–	–		X	X	X	X	X	X			
Luxembourg	–	–	–	–	–			–	–		–		–	–	–	–	–	–	–	–	P		X	X	–	–	–	–			
Netherlands	–	–	–	X	–			–	X	X	–		X	–	–	–	–	P	P	–	–		X	X	X	X	–	X			
Norway	–	–	–	–	X			–	X		X		P	–	–	–	–	–	–	–	P		X	–	–	–	–	–			
Spain	–	–	X	–	–			–	X		–				–	P	P	–	–	–	–		X	–	–	–	–	–			
Sweden	–	–	–	X	X			–	X		X		X	X	–	–	–	–	–	–	X		X	X	X	X	X	X			
Switzerland	–	–	–	–	–			X		X		X	X	X	–	–	X	–	X	–	–		X	X	–	–	–	–			
Turkey	–	–	–	–	–			–	P		P		–	–	–	–	–	–	–	–	–		X	X	–	–	–	X			
U.K.	–	–	–	X	X			X	X		–		–	–	–	–	–	–	P	–	–		X	–	–	X	–	–			

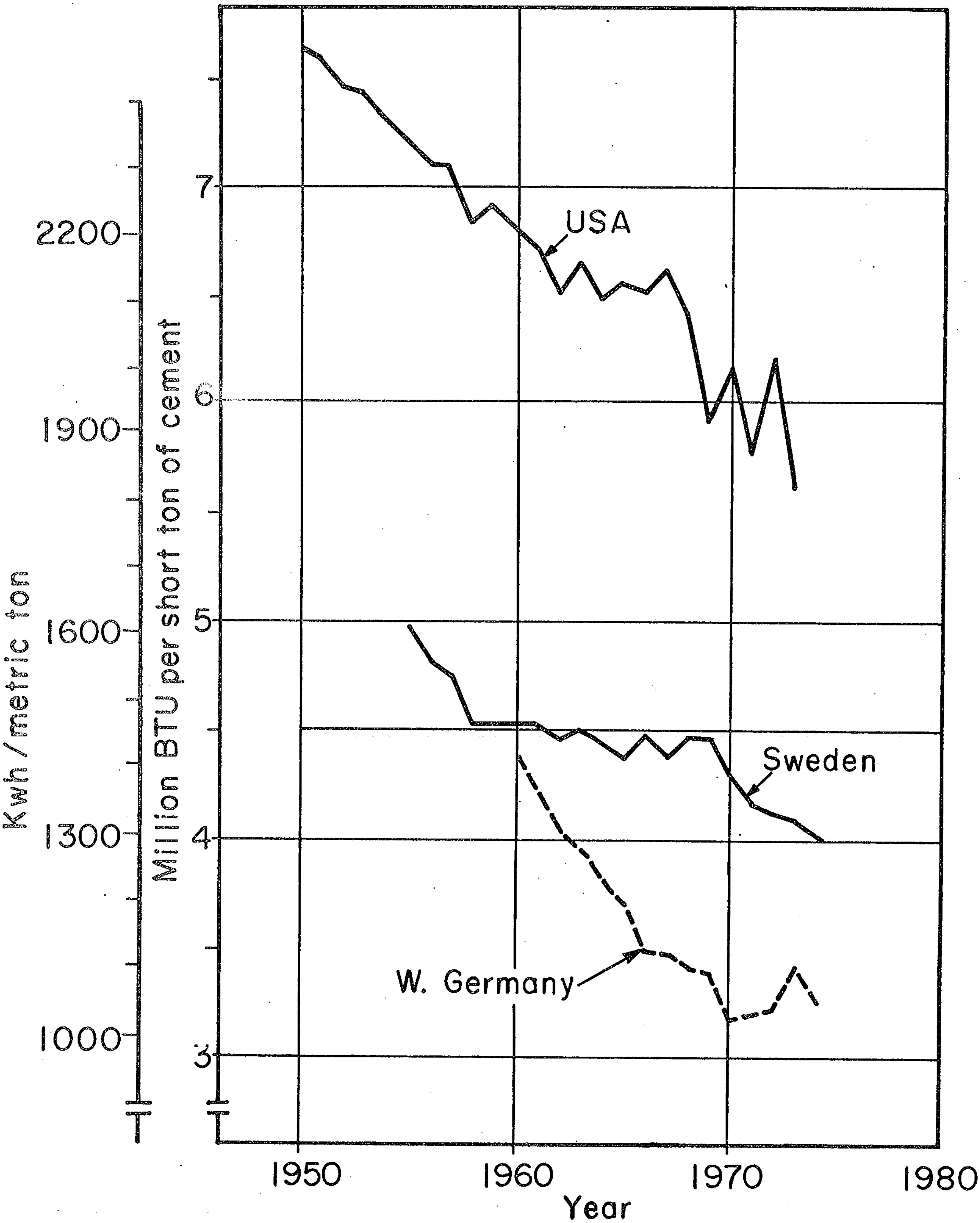

FIGURE 1. Energy Consumption for Cement. From Bo Carlsson

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