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Energy demand and efficiency in Estonia

Structure, potential and policies

Eric Martinot, Lee Schipper and Marta Khrushch

International Energy Studies Group, Energy and Environment Division, Lawrence Berkeley Laboratory, Berkeley, CA, 94720, USA

Estonia as a case study allows understanding energy efficiency improvements and how they can occur in a former Soviet economy. The structure of energy consumption by end-use sector is analyzed and a picture of energy-efficiency potentials and policies emerges from this analysis, from international comparisons and from extensive in-country experience. The potential for improvements is enormous, and key priorities are district heating systems, buildings and low-cost measures in industry. Economic reform and structural economic changes will drive improvements in industry and transport, while public policies and intervention are needed in heat supply and the residential sector. Key barriers to efficiency improvements include lack of ownership, lack of capital, low electricity prices, inexperience with cost minimization and financial analysis, and lack of meters and controls, especially in the residential sector.

Keywords: Energy demand; Energy efficiency; Baltic states

It is difficult to speak of energy-efficiency investments, even if profitable to both producers and consumers, under the often brutal and uncertain forces of economic reform sweeping Eastern Europe and post-Soviet states. Loss of access to historic markets, unemployment, inflation, declining real incomes, disappearing state subsidies, privatization and changing management structures, rising real energy prices and other economic disruptions are all serious problems. As we witnessed in Poland (Meyers et al, 1994), reform leads to a slashing of industrial output, in spite of authorities' efforts to keep factories open and running, and a consequent initial decrease in both energy demand and the energy efficiency of production.

As a case study, Estonia provides a crucible for understanding how energy efficiency and energy market reforms may occur within the process of economic reform, and how new government policies can influence energy efficiency in a former centrally planned economy. The case of Estonia also helps to illuminate sectors where market forces may reshape energy use without intervention by authorities. Estonia's small size (total population 1.6 million) allows easier and more detailed understanding and analysis, and permits policies and projects to have national impact more easily.

Economic reform represents a unique opportunity for improving energy use in Estonia, since much old and outmoded capital, particularly in industry, will be thrown out. At the same time, the housing and building sectors will be reorganized and consumers and building tenants will for the first time be able to take responsibility for their own comfort. Rather than gradual improvements in energy utilization efficiency through a slow process of attrition of equipment and buildings, we can witness in Estonia the rapid replacement or retirement of substantial productive capacity, the rehabilitation of much of the housing and building stock, and a high turnover in the motor vehicle stock. Thus it is important to think about the future of the Estonian economy and its energy use. Privatization and modernization of old enterprises, growth of new ones, and above all, a greater consumer share in the costs of

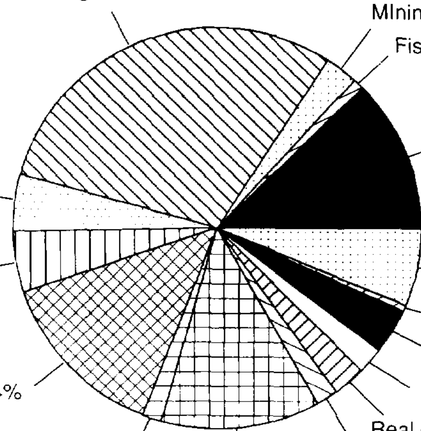

Figure 1 GDP by economy branches (million EEK for 1992)

energy and housing have the potential to transform the economy and energy use.

Previous analyses of the existing energy situation in Estonia have concentrated on the supply side.[1] But little rigorous analysis or comprehensive discussion of the demand side has taken place. Partly this could be attributed to a lack of information and data. Despite intensive scrutiny by central planners, the quantitative structure of energy use in centrally planned economies was poorly understood because user categories were poorly defined, meters were rare, prices meaningless and few authorities actually bothered to see how much (or how efficiently) energy was being used. But beyond statistics, a detailed examination of energy consumption is difficult because it is not simply an energy sector question. Rather, it involves all sectors of the economy – housing, manufacturing, transport, services and agriculture.

Through extensive field work and interviews, data collection, quantitative analysis, analytical models and extensive comparative experience in several Western countries, we are able to paint an in-depth picture of the structure of energy use in the Estonian economy, to compare energy consumption patterns in Estonia with those in other Western countries, to estimate the potential for energy-efficiency improvements, and to consider priorities and policies for accelerating energy demand reductions in Estonia.[2] This work follows upon extensive analysis of energy efficiency potentials and policy problems in the former USSR as a whole (see Cooper and Schipper, 1991; Cooper and Schipper, 1992; Schipper and Cooper 1991; Schipper and Martinot, 1993).

[1]See for example, Ministry of Industry and Enegetics of Estonia (1993); Fenhann 1992a; and International Energy Agency, 1993. Although Estonia is not included, still useful is Fenhann (1992b).
[2]For more details see the full report: Schipper and Martinot *et al* 1994.

Energy and economy in Estonia

During the period of Soviet rule following World War II, Estonia was fully integrated into the economic and political system of the USSR. Characterized by rapid industrialization and urbanization, including the migration of workers from various parts of the USSR (especially Russia) into Estonia, this period forced Estonia to become highly dependent on energy and raw materials from other parts of the USSR. Most Estonian companies were directly subordinated to central planning authorities in Moscow and were prohibited from conducting foreign trade directly with other countries. In the 1980s industry accounted for approximately 40% of Estonia's GDP; food processing and light industry each provided about a quarter of industrial output; and agriculture accounted for some 20%. According to World Bank estimates, at the end of the 1980s Estonia had the highest standard of living of the republics in the USSR, with a per capita income 40% above the Soviet average. World Bank estimates of GDP for 1992 are shown in Figure 1 (World Bank, 1993).

In 1990, a year before Estonia became independent, its newly elected government introduced economic reforms similar to those adopted in most Eastern European countries. Estonia was the first of the Baltic countries (and other former Soviet republics) to adopt market reforms. The Soviet tax system was replaced by a modern Western-type tax structure. Most consumer prices were deregulated and state subsidies to enterprises were gradually canceled. In mid-1992 Estonia introduced its own currency, the kroon (EEK), which has remained stable and freely convertible with Western currencies ever since. Real GDP decreased by 8% in 1990, by 10% in 1991 and by 15–25% in 1992. A major reason for this drop in output was the collapse of trade with the former USSR, while trade slowly expanded with Western Europe and other OECD countries after 1991. A turnaround appeared at the end of 1993 as GDP grew for the first time (Radio Free Europe Report, 29 December 1993), and expectations were for continued growth into 1995. High inflation and real interest rates have also been serious problems. Following price deregulation, inflation soared, but then stabilized in the second half of 1992 and declined to a 30% annual rate by the second half of 1993 and into 1994.

Energy prices have increased dramatically since reform began. The prices of imported oil and gas are now approximately equal to Western European prices. Because of low taxes, retail gasoline prices lie slightly under those in the USA and far below those in Western Europe. Domestically mined oil shale and the electricity produced from it are priced much less (in EEK/GJ) than other forms of energy for two main reasons: the oil shale is cheap to mine (neglecting environmental costs), and electricity rates do not include any capital depreciation or investment elements. Prices for district heat and hot water are subsidized for some consumers and are determined by local municipalities after they account for their cost of fuel purchases.

Increased energy prices have created a significant problem of unpaid debts. Debts to energy suppliers were mounting from energy customers who could not afford (or simply refused) to pay their bills. In 1993 district heating companies reportedly collected only about half of their billings. Industries struggling to survive add to the problem. Huge energy debts accumulated within the energy sector among producers and consumers alike mean that little money has been available in the energy supply sector or in end-use sectors to invest in new capital. In fact, municipalities and energy suppliers can hardly maintain existing equipment, let alone fund new capital investments.

Like most other East European countries, Estonia's energy supply is almost completely based on fossil fuels. In 1990 oil shale accounted for 53% of primary energy consumption, oil products for 29%, natural gas for 6%, and coal, peat and wood, and other fuels for the rest. Although Estonia satisfied 44% of its energy demand from domestic sources in 1990, it imported all oil products and gas. Until recently, Russia and other parts of the former USSR provided all imported energy to Estonia, but that is slowly changing.[3] Estonia stands out as the only country in the world with an electric power system based almost exclusively on oil shale. But oil shale mining and processing for electric power generation, while making Estonia completely self-sufficient in electricity, are significant sources of environmental disruption.[4] Heat production is also based in part on oil shale, but heavy fuel oil accounted for a large share (40%) of the inputs in the recent past, while natural gas surpassed oil shale as the second most important source in 1985. Heat production is dispersed over more than 7000 small and medium-size boilers. With imported oil and gas expensive, many heating companies desire to switch to wood or peat fuels which are available domestically.

The structure of energy consumption

Appraising the potential for energy-efficiency improvements requires a clear picture of the structure of energy consumption. This picture must include both the quantities of energy consumed, by source, and the activities or output for which the energy is used. In this section we briefly summarize our findings and analysis for each sector of the economy.

Our primary data sources are four sets of energy balances obtained from the Estonian State Statistical Office: a Soviet era balance, the currently published balance (State Statistical Office of Estonia, 1993; unpublished estimates of energy use by branches of manufacturing and unpublished fuel disposition statistics prepared by the Statistical Office for the United Nations). In addition, we received unpublished statistics from the Ministries of Transport and Agriculture, the National Housing Board and Eesti Gas. Published statistical yearbooks and national accounts provided data on economic structure and activity. Much of the non-statistical information we obtained came from interviews, discussions, and seminars over the course of eight months in Tallinn, with researchers, ministry officials (Ministries of Economy, Transport, Agriculture and Environment), staff of the State Energy Department, members of the National Housing Board, and engineers from private consulting companies. The statistical information available from Soviet-style sources breaks down energy consumption by the end-use sector, but this is a sectoral breakdown, not a true functional breakdown (energy use in agriculture, for example, includes energy for transport and housing functions associated with agriculture and its workers). Thus one of the important aspects of the analysis is a transformation of Soviet-style categories into standard Western statistical and accounting categories. More details beyond those presented here on our quantitative findings, data sources, models, and assump-

[3]Natural gas imports from Russia have declined dramatically in recent years, as consumers in Estonia have switched from gas to oil where possible (imported oil is still much cheaper than gas), and reduced absolute consumption because of rising fuel prices. Consumption of gas in 1992 was about half of 1990 levels, and fell even further in 1993.

[4]For a good discussion of the environmental impacts of energy in Estonia, see Salay *et al*, 1993. See also Taehtinen and Nurste, 1992.

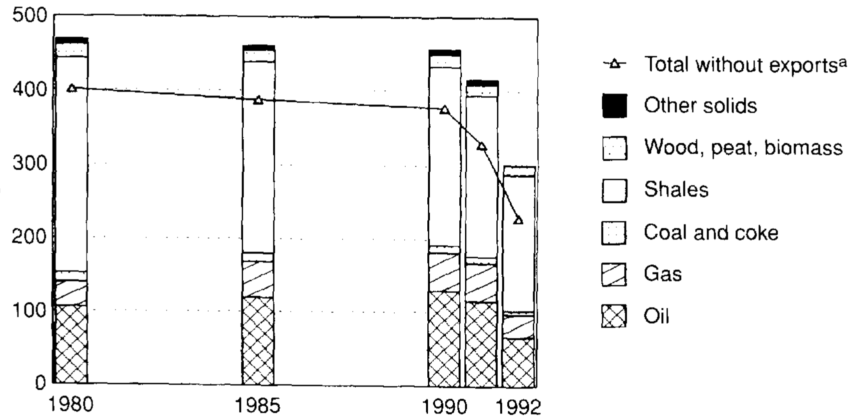

Figure 2 Primary energy use by type of fuel[a]
[a] Calculated at primary production equivalent.

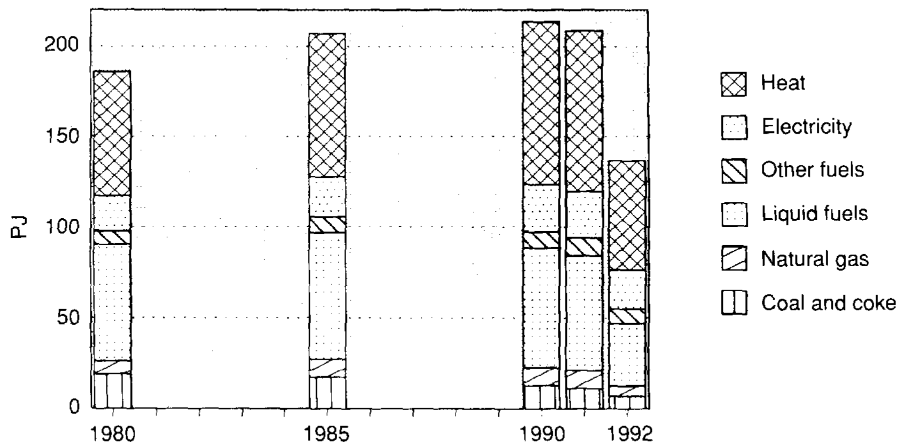

Figure 3 Final energy consumption by fuel

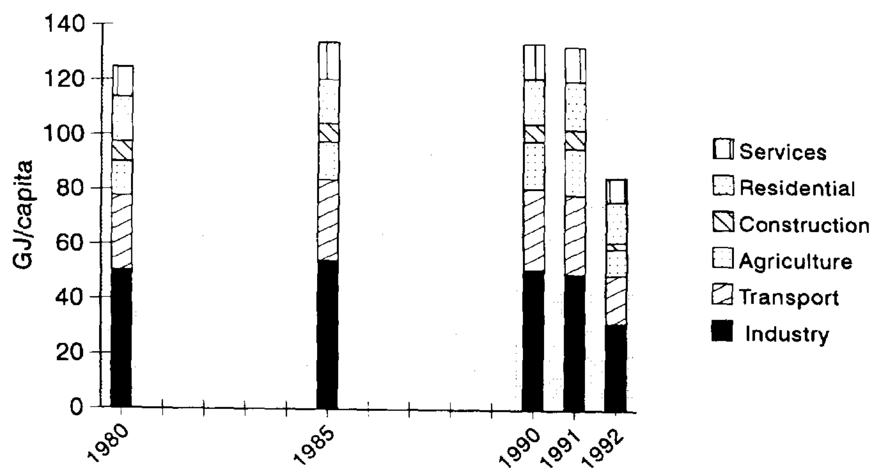

Figure 4 Per capita energy demand by sector[a]
[a] Sectors conform to LBL definitions.

tions may be found in our full report (Schipper *et al*, 1994).

Aggregate energy consumption is portrayed in Figures 2, 3 and 4. Figure 2 shows total primary energy use in Estonia by type, with an indication of the share used to produce exported electricity. Figure 3 shows the energy sources that we actually counted in final energy demand. The important role of heat is striking, as is the

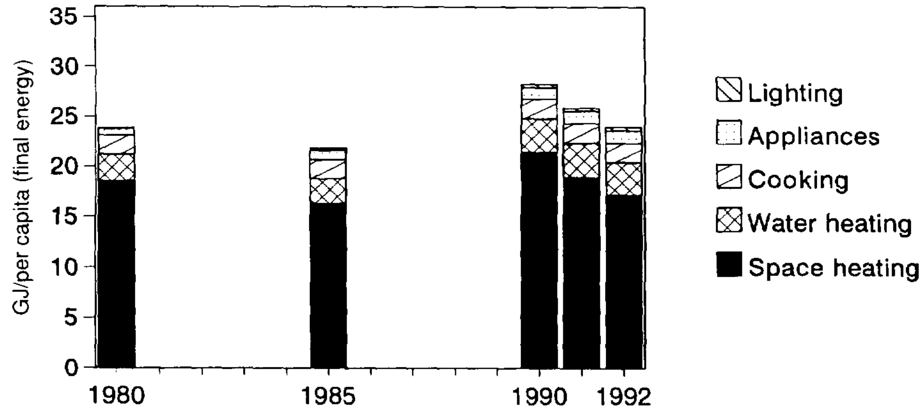

Figure 5 Residential energy use by end use[a]
[a] Climate corrected.

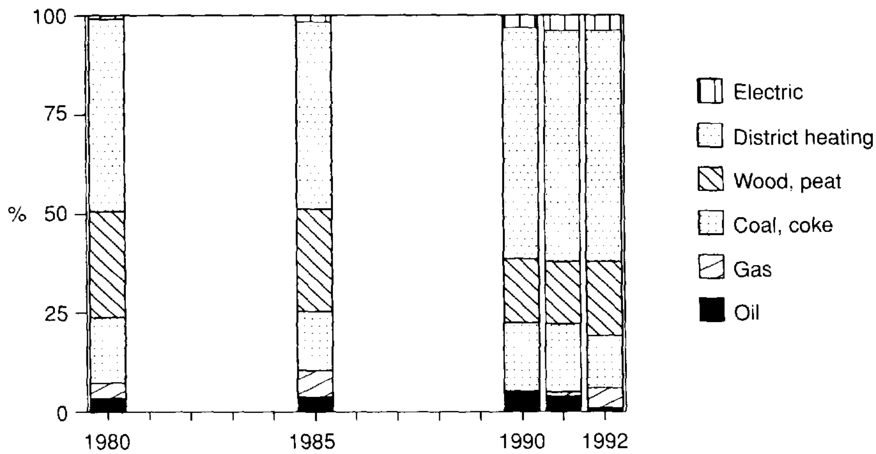

Figure 6 Residential energy home heating fuel choices

rising importance of oil products. And Figure 4 shows the role of each sector in final demand on a per capita basis. The sharp fall in energy consumption from 1990 to 1992 for freight, manufacturing, services and other industries contrasts with the slight decline in energy use in households and the nearly stable consumption of fuels for travel. Each of the sectors has been analyzed individually.

Residential

The housing stock of approximately 190 000 residential buildings provides close to 600 000 dwellings. Multiple-unit apartment buildings provide 440 000 of these dwellings, and the remaining 160 000 dwellings are primarily single-family houses. Living space per capita is about 24 m^2 and the average number of people per dwelling unit is about 2.6. Single-family dwellings are largely privately owned and account for 30% of total living space. Ownership of multi-family dwellings and some single homes as of late 1992 was split among various national, local and other authorities. By Western standards, the stock of apartment buildings is young; most (70%) were built after 1960. Yet their quality and condition is poor by Western standards due to neglect and lack of improvements over the years.

Central heating – heating provided by a hydronic (water borne) central boiler in a building or from a public supply (district heating) outside of the building – provides heat to 77% of dwellings in multi-unit apartment buildings and to 17% of single-family houses. We estimate that about one-fifth of dwellings in apartment buildings rely on boilers in the same building (or those supplying a small group of buildings); the rest depend on the public district heating supply. Individual boilers are fueled by natural gas, heavy fuel oil, some light oil, and a variety of solid fuels. District heating systems run mainly on heavy fuel oil or solids. The remaining dwellings use small room stoves based on solid fuels, LPG, kerosene or even small electric heaters. Figure 5 shows our estimates for the share of dwellings using each heating fuel as the main source. In dwellings supplied by central heating systems, hot water is usually

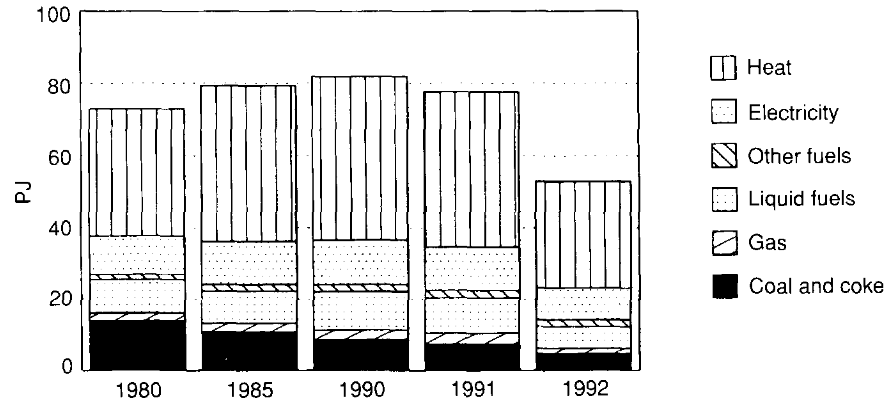

Figure 7 Manufacturing energy use by type of fuel[a]
[a] Excluding transport fuels from liquid fuels.

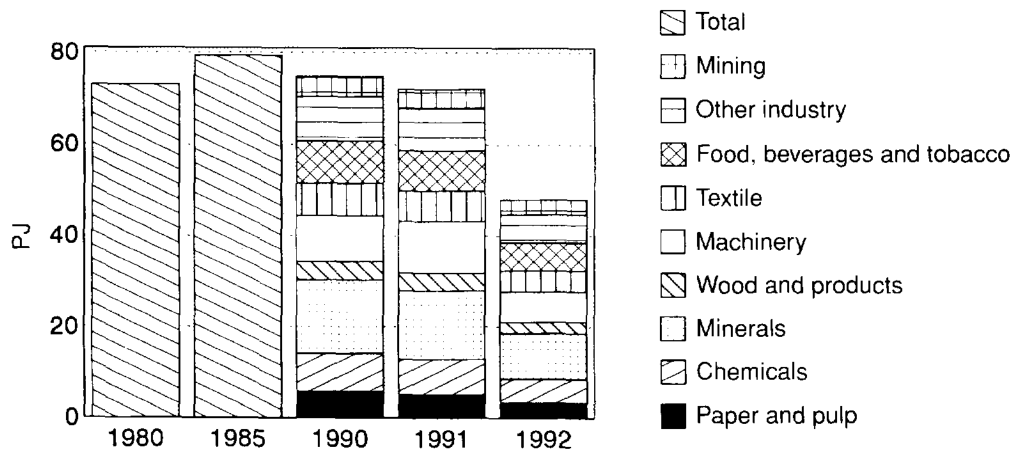

Figure 8 Manufacturing energy use by industry branch[a]
[a] Excluding fuels used for transport.

provided by the same system. This means that district heating systems must run throughout the summertime merely to supply hot water. Other dwellings heat water with electric, gas or LPG heaters. For cooking, most families rely on natural gas or LPG (60%), electric stoves (20%) or wood (20%). Refrigerators and televisions are present in virtually all households, clothes washers in most, and few other appliances are used.

Based on our experience analyzing similar end uses in a dozen other European countries, estimates of the unit consumption of energy by fuel and purpose, and the structure of the residential sector as outlined above, we obtain estimates of energy use for space heating, water heating, cooking, lighting, and major electric appliances. These estimates are presented in Figure 6 on a per-capita basis.

Manufacturing and other industry

The chemicals, minerals (especially building materials like cement and bricks), machinery and food processing sectors are important. Pulp and paper are becoming less important, as two principal paper mills closed in 1993. Notable is the absence of the iron and steel sector in Estonian manufacturing. Manufacturing energy use by fuel is portrayed in Figure 7 and by industry branch in Figure 8. A large share of manufacturing energy use is shown as 'heat', about half of which is self-produced. If we counted energy uses in Estonian manufacturing by Western practices, we would count the fuel actually consumed by enterprises to produce their own heat, not simply the heat itself. This would raise total manufacturing energy use by 10–20%. Other industry includes agriculture, construction and mining, which together made up 15% of total energy consumption in 1992.

Travel

The most dramatic development in Estonian transport in the last five years has been the rapid rise in the number of private automobiles. Doubling between 1984 and

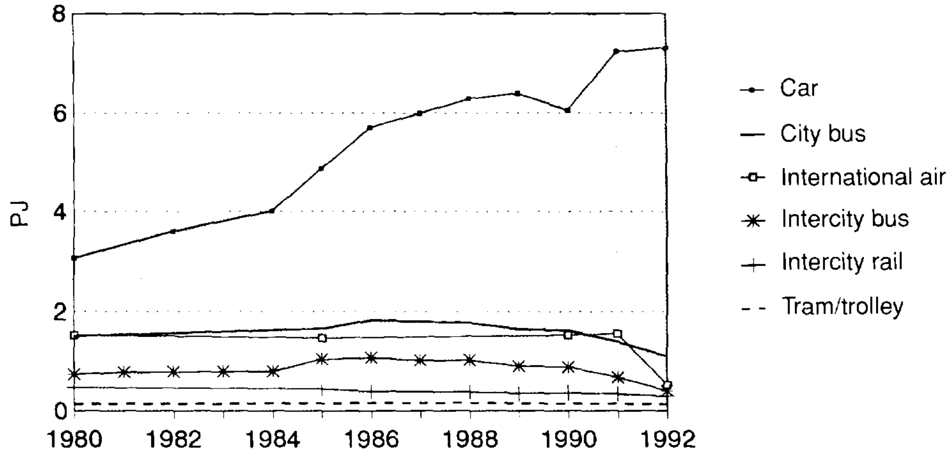

Figure 9 Transport passenger energy by mode

1992 to approximately 270 000, there is now more than one automobile for every six Estonians. In recent years, most of the increase has come from Western manufactured used cars imported from the West or from Russia. The average age of the car stock is 13 years. Data indicate that the average automobile was driven 6000 km pa in 1992, down from 7000 km pa in 1988. An equally surprising and perhaps troubling trend in the opposite direction is the decline in the number of diesel and electric buses and the routes themselves (both number and total length) since 1990. Bus travel is still extremely cheap by Western standards, and intercity buses provide the backbone of intercity passenger transport. Passenger cars use between 10 and 11 liters of fuel per 100 km, a high level but not unreasonable compared to the rest of the former USSR (Schipper and Cooper, 1991). Energy use for passenger travel is shown in Figure 9. Automobile energy use has become increasingly important, climbing as the number of vehicles increases, while that of busses for domestic travel has dropped to second, falling especially after 1990.

Freight

The structure of freight has changed considerably as trucks overtake rails in importance, but both have declined severely. In 1992 rail freight stood at about 4000 tonne-km per capita, down from 7000 in 1990. Truck freight was about 2500 tonne-km per capita, down from 4500 in 1990. Data indicate that truck freight in 1992 was handled primarily by about 10 000 heavy trucks (greater than 8 tonnes capacity) and a fleet of light trucks (under 1.5 tonnes net capacity). Since 1992, the truck fleet size has shrunk, as more than half of the existing fleet, especially those with gasoline engines, are not operating at all. Public freight companies will be privatized (as will some bus lines) but meanwhile, there is increasing use of 3-5 tonne gasoline light trucks.

These sectoral demand analyses lead to several important points. First, the profound role of heat and heating boilers means that heat consuming infrastructure in the industrial and residential sectors, as well as the heat supply sector, is at the center of any efficiency effort. Second, energy use appears high for buildings and industry relative to activity or output. International comparisons confirm this finding, which suggests by itself an important potential for saving energy through upgrading or replacement of equipment and better energy-use practices. And third, Estonia has no real shortage of electricity; under present conditions electricity savings is a lower priority. Plentiful oil shale provides inexpensive electricity, which seems to be causing a boom in the use of electricity for space and water heating. However, a perception that electricity is cheap is misleading, because of the severe environmental impacts of oil shale and the future electric power capacity commitments incurred as electricity demand increases.

International comparisons

An international comparison of energy use in Estonia leads to remarkable conclusions.[5] Energy use per capita in Estonia was comparable to Western European levels in 1990 (Figure 10), despite Estonia's much lower GDP per capita. Total final energy use per capita in Estonia in 1990 was around the same as in West Germany in 1988, which has a somewhat milder climate. The role of the residential sector is comparable to that in West Germany or Denmark. Lower living area per capita compared to the West, meaning less space to be heated and lit, offsets the higher energy intensity of space heating (Figure 11). Overall, the

[5]For more information on international comparisons see Schipper and Martinot *et al*, 1994, and also Schipper *et al* (submitted).

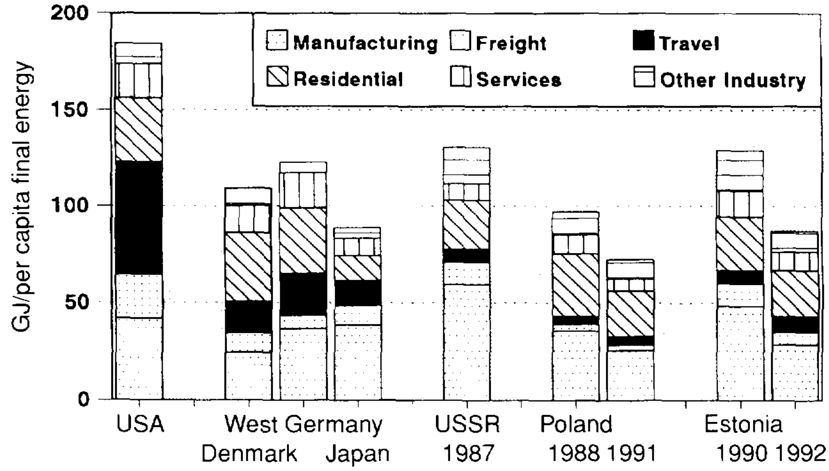

Figure 10 Final energy use per capita by sector

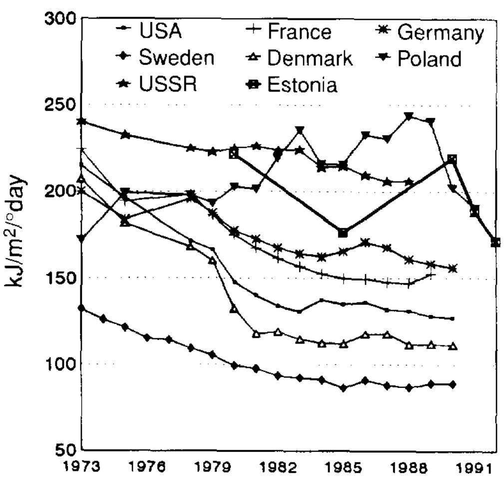

Figure 11 Space heating intensities useful energy[a]

[a] Polish data 1988–91 smoothed for stocks of coal. Other countries from IES database; degree days base 18°C.

small size of Estonian homes, a factor which reduces energy use, is more important than the effect of slightly higher intensities for heating and appliances and a colder climate in reducing residential energy use in Estonia relative to that in Poland or Western Europe. Manufacturing energy use played a similar role in final energy use in Estonia to that in the OECD countries, except Japan, which exports much of its output. The structure of the manufacturing sector is slightly less weighted towards energy intensive industries. The importance of passenger travel is much less than in the West, although energy intensities are about the same (automobiles) or lower than those in the West (rail and bus). In freight transport, per capita activity is comparable to Western Europe, and the importance of trucks in the structure contributes to similar energy use per capita.

Overall potential for energy savings

Estimates of energy efficiency potential and future savings must include not only changes in energy intensities (energy per unit of output or activity), but also fundamental changes in the levels and structure of the activities (tonnes produced, kilometers driven, square meters heated to a certain level of comfort) themselves. These structural changes in the economy will be important factors in future energy consumption and efficiency in Estonia and other former centrally planned economies. In general, both intensity and activity will be influenced by structural economic changes, and both are subject to deliberate policy measures as well. Energy savings from policy measures must be measured relative to how much energy would have been used had no measures been carried out. Energy savings resulting from structural changes can be viewed as 'what would have happened anyway', and must be carefully considered in parallel with other changes.

Existing average and new levels of technology in other countries also provide a guide to the potential for energy savings. If all existing Estonian dwellings, buildings, appliances and vehicles were replaced with equivalent Western versions, Estonian intensities could be reduced by 5–10%. If replaced with entirely new Western-style technologies, intensities could be lowered by perhaps 25–40%. The first figure is a good guide to the savings we might expect from rehabilitation of existing equipment or structures; the second, the figure we expect to obtain as new equipment is installed.

Time frame is an important determinant of energy savings potential. In the very short term (the next few years), savings of heat in buildings and industry from low-cost/no-cost measures can be substantial. Potential savings in transport (from better maintenance and use) are small, typically 5–10%, while improvements to electrical equipment will produce even smaller savings. In the medium term, during the period through 2010, most motor vehicles and electrical equipment will be replaced, affording a significant savings potential. Policies might accelerate these processes so that greater savings are realized sooner. In the longer term, after 15 years have passed, new factories and industrial processes could come to dominate industrial activity, while the transport and housing infrastructure could also be modified significantly.

In time, entire processes and factories will change as the socialist approach to both technology and management is replaced by one with a greater market orientation. In this respect, we believe that engineering estimates of energy saving potential in industry underestimate what can be achieved. By the same token, changes in the work environment, product quality, and above all, the uses of electricity will by themselves probably increase energy and electricity requirements somewhat more than what we might expect. The same phenomena will occur in the consumer and building sectors; better economic times will bring about more home floor area, more comfort, and more and larger electric appliances and office equipment. On balance, we think that the reborn Estonian economy will use far less energy in the year 2010 than it does today in almost every production process, and that Estonians will use less energy per unit of comfort or convenience. Total energy use, of course, will also depend on the size of the economy and its structure.

There have been five recent studies which offer overall estimates of energy efficiency potential. Our own sectoral analyses and international comparisons for Estonia confirm the validity of these aggregate estimates and findings:

- The World Bank, in its Estonia country study (1993), suggests that 'Estonia used two to four times more energy in 1990 than might be expected on the basis of its per capita GDP level compared to other European countries'. Although we do not believe that aggregate energy/GDP ratios tell us much, the enormous value for Estonia certainly suggests some efficiency potential.
- The *Energy Master Plan for Estonia* (Ministry of Industry and Energetics of Estonia, 1993), although focused primarily on energy supply rather than demand or efficiency, concluded that up to 50% of heat and up to 30% of electricity could be saved. In the short term (five years or less payback), the plan estimated that perhaps 4–15% of energy consumption could be saved with low-cost and elementary actions and an additional 10–15% with more expensive actions.
- The State Energy Department (1992), in cooperation with the former Ministry of Buildings, issued a Program for Energy Conservation in Estonia in July 1992. Part of this document related to heating and emphasized simple boiler tunings on a large scale coupled with fuel substitutions to local fuels as means of reducing imported fuels. It concluded that savings of 4–10% could be obtained from simple and inexpensive methods and 10–15% more from extensive tunings using imported measurement equipment.
- A report sponsored by the EC Thermie Program claimed that, with Danish materials, a 20% energy savings could be achieved in the three buildings investigated, with simple payback of less than four to five years (Ministry of Buildings of Estonia, 1993). Savings in excess of 20–25% were deemed too expensive. In an old block building, savings of up to 40% might be economically achieved, principally because roof insulation is relatively cheap.
- Using average Western practices in regulation, management, and control, Schipper and Cooper (1991) compared Soviet and Western energy intensities. They found that energy intensities in the former USSR could be reduced by 25% for space heating from district heat supplies, 35% for space heating from on-site boilers, 20% for water heating, 25% for new refrigerators and other electric appliances, and 20% for new cars and aircraft. So much of the energy consuming technology in Estonia is based on Soviet equipment that these findings can also be applied to Estonia. The only difference is that buildings in Estonia appear to have been constructed to somewhat better thermal standards than those in Russia.

Below we analyze the energy efficiency potential in various end-use sectors. These sectors appear in order of priority: first residential, then industry, followed by services, travel and freight. These priorities are in order of potential gains, but are also in order of the impact that explicit government policies might have on future energy consumption. With a few exceptions, improvements in manufacturing, services and travel will depend on the individual decisions of managers and consumers in response to free-market prices, investment and purchase options and capital availability. These decisions will be made for reasons other than energy savings. Energy consumption in these sectors will primarily be influenced by energy prices, taxes and free-market factors beyond the control of authorities. Heat supply systems and residential buildings, however, provide both large technical potential and some of the greatest opportunities for policy interventions by Estonian authorities to accelerate efficiency improvements and for assistance by international agencies.

Efficiency potential in the residential sector

Improvements in the building stock must be distinguished along three dimensions: new versus existing homes, public versus private homes and single-family houses versus larger multi-family apartment buildings. The technologies, economics and time scales of energy efficiency vary greatly depending upon these dimensions. Most residential buildings will have a long lifetime, thus rehabilitation is generally necessary for many. In apartment buildings, insulation, air tightness, ventilation, windows, heating equipment and practically the entire building are worth improving. Large apartment buildings have complex heating systems. Changes in heat losses through outside surfaces affect the basic heat load of the heating system and also air infiltration. Thus changes to the outside surfaces should not be made without making adjustments to the heat supply and providing heat controls to individual apartments. Otherwise a mismatch between supply and demand will occur and the overdimensioned system will simply provide too much heat. Similarly, applying insulation without weatherstripping and careful caulking of cracks, as well as improving the windows, ignores the obvious problems of air leakage.

We estimate that applying these measures to apartment buildings and adding heating controls would reduce heating needs by about 40%. Developing a package of improvements for existing windows alone could probably offer 20–30% reductions in heat losses through windows. Modern Swedish or Finnish windows probably have only 30% of the heat transmission of existing windows in Estonia. Applying only the simplest measures to individual apartments affords a smaller reduction, probably on the order of 15–20%. The initial experience with a Swedish building retrofit demonstration project in the Mustamaee district of Tallinn seems to confirm that basic retrofit measures can produce at least 15% or more in savings (Stockholm Konsult/Energy & Environment, 1993). Danish studies (Energiministeriet, 1990) clearly indicate that measures applied to the outer shell (insulation, improved windows and so on) or within the walls (new hot water pipes, ventilation) should be undertaken when the building is slated for rehabilitation. Opening walls is very expensive and should only be done when many related goals can be accomplished simultaneously.

Single-family dwellings (ie detached houses) afford somewhat more flexibility, since the buildings are less complex than multi-family structures. Adding insulation to the loft is relatively easy and adding second (or third) layers to existing windows during the heating season is common in many countries. Improving the boiler and heating system is also important, but the potential gains are not as great. Since the occupant is also usually the boiler operator in a single-family dwelling, good feedback already exists whereby the occupant adjusts the boiler according to need. Most occupants also pay for their heat by how much they actually consume, in stark contrast to occupants of apartments. This creates a direct incentive for occupants to control indoor temperatures, upgrade equipment and monitor equipment performance.

In 90% of residences, domestic hot water is provided by the same district or boiler systems that supply central heat. Measures to improve these boilers will reduce losses in producing hot water. Increased insulation of holding tanks will also improve energy savings. Small boilers using solid fuels have notoriously high losses in combustion, heat transfer and storage. Hot water systems that heat water only as required have few losses other than combustion losses where gas or LPG is used.

Replacement of household appliances has begun, including more efficient cooking stoves and electric appliances, although only by the minority of wealthier Estonians who can afford them. While inefficient but small Soviet-made appliances, primarily refrigerators and clothes washers, dominated the market in the past, Western models are already entering through Electrolux and other importers. Energy requirements for modern refrigerators, freezers, clothes washers, dryers, dishwashers and televisions are 40–60% below what they were (for comparable size and features) in the early 1970s. Many households will begin to acquire larger Western refrigerators and automatic clothes washers, and wealthier households will also purchase much rarer appliances like freezers, dishwashers and clothes dryers. Efficiency improvements will reduce electricity needs for new major appliances as much as size and features increase demand.

While many retrofit strategies are straightforward (ie windows, insulation, and heating equipment renovation), heat metering and controls in buildings are of special importance, pose special problems and deserve greater attention. Metering means installing heat, gas and/or electricity meters and then charging each dwelling unit for the actual energy consumed. Control means proving electronic or manual controls so the same dwelling unit can control its share of consumption when provision is collective, ie from district heat or a building-wide boiler. There should be no doubt that collectively metered buildings (ie when the consumption for the building, but not for individual dwellings is metered and regulated) require more heat per square meter than buildings with individually metered dwellings. This is borne out by a comparison of Swedish multi-family dwellings with no individual heat meters with single-family dwellings using the same fuels. Modern meters that measure consumption as the difference between the incoming and outgoing radiator-water temperature are preferable to small evaporation meters commonly used in Western Europe, but either way occupants tend to be responsive when they see their own consumption. Controls are equally as important. If the occupants of each unit are to be responsible for their own consumption, they must have control over what they actually use. In the Nordic countries, a variety of systems, including thermostatic valves on each radiator, outdoor temperature sensors controlling the flow of heat to the building (or combustion in the boiler), or shunts that permit closing of any room or radiator, all permit occupants to throttle back heat.

Meters and controls on individual dwellings are not simple for Estonia. Installing this equipment is expensive unless the building or heating system is being revamped. Heating systems are often designed so that apartments are connected in series along the same set of pipes, making regulation of individual dwellings difficult. Metering becomes difficult when pipes feed vertically through a building and each room of an apartment is connected to a different set of pipes. Even the buildings themselves may be connected in series along one set of outdoor district heating distribution pipes, making building-level regulation difficult. However, the initial experience with two retrofit projects in the Viru region of Estonia in 1993 (Vrudan Ingenjioerselskab I/S, 1993) indicates that installation of radiator thermostatic valves and heat meters on an individual apartment level may prove practical and bring about significant savings.

Efficiency potential in industry

Industry poses a dilemma: every investigation reveals many opportunities to reduce energy needs with little or no capital investment, but which industries will survive to make the effort worthwhile? Given that capital, both monetary and human, is scarce in Estonia, the challenge is to prioritize investments. Two particular dangers are that time and money could be expended on factories that will be forced to close, or that interventions oriented explicitly to energy efficiency might duplicate efforts that would be carried out anyway as old factories and equipment are modernized or replaced.

Estimating the potential in industry is aided by a significant number of audits already conducted in factories across Estonia by foreign consultants in the past few years. In the period 1991–93, 36 significant audits were conducted in industrial enterprises by the European Union Thermie program (6), AS ESTIVO of Estonia (20), US Agency for International Development (4) and the Swedish National Board for Industrial and Technical Development (6).[6] Other industrial audits were also proceeding by 1994. In general, these audits have shown that savings of 5–20% can be obtained at no or minimal cost, and that savings of up to 30% or more are possible.

These audits have tended to group potential savings into three categories according to time frame and economic payback: (1) no-cost/low-cost or short-term measures with typical paybacks of less than one year: proper boiler tuning and monitoring (2-4% savings); energy management through better monitoring, accounting, and control (10% savings); changes in manufacturing processes and operating practices (5–15% savings); preventive maintenance of equipment; plugs on steam and pressurized air leakages; reduction of hot water wastage and losses; and substitution of electric heating for central heat in certain types of workspaces. (2) Medium-cost or medium-term measures, which might pay back in two to four years: secondary heat recovery from flue gases and process furnaces; improved insulation of pipes, furnaces, and ovens; and increased return of heating steam condensate. (3) High-cost or long-term measures with paybacks of longer than five years: lighting replacements (were considered high-cost because of low electricity prices); conversion of heating systems from steam to water; process steam-on-demand systems; new technological processes; and burner-automation systems for boilers.

Efficiency potential in other sectors

Most of the problems that plague the residential sector also haunt the service sector. Heat losses and boiler problems abound. In Sweden and Denmark, improved heating equipment, added controls, and added insulation to walls (or replacement windows) helped reduce heating energy use in the service sector by approximately 20–30% between 1973 and 1993, even though floor space increased. Floor space in the Estonian service sector is increasing, but equivalent or greater heating savings are still possible because of the poor condition of the buildings. Service sector buildings need ventilation and even cooling, and rely more on electricity for motors, electronics, and lighting than do homes. The experience with electricity in the USA suggests a significant potential for savings in Estonia by improving the efficiency of equipment.[7] But that savings will be offset

[6] NUTEK (1992); USAID (1992).

[7] A study in the USA found that in spite of the rapid increase in the number of electricity uses, electricity use per square meter of floor area in the service sector in the USA held steady between 1979 and 1986; see Schipper *et al*, 1990.

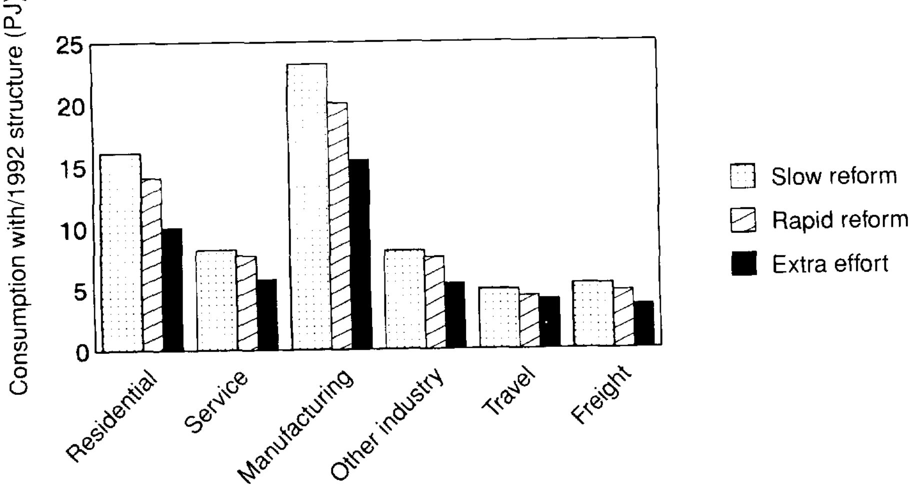

Figure 12 Energy saving potential in Estonia changes by 2010

considerably by increasing electrification of most service space.

The rapid evolution of travel toward more individual (ie automobile) modes in Estonia should come as no surprise. Prior to 1992 the automobile stock was almost exclusively Soviet made, with fuel efficiencies of comparably sized cars significantly lower than those made in Japan, Europe or the USA. Present trends suggest Estonians are buying primarily Western cars (both new and used) whose average power is greater than typical Russian-made small cars. Higher numbers of cars coupled with (presently) low gasoline taxes means greater energy consumption in this sector. The potential for reducing fuel intensity depends very much on what kinds of cars Estonians buy. Therefore, the potential for fuel savings in automobiles is directly tied to how Estonian authorities chose to tax both cars and fuel. These choices will affect the new (and used) car stock profoundly, as we have shown for Western countries (Schipper *et al*, 1992), as well as the kilometers driven.

Because most Estonians do not yet own cars (one car for every six Estonians in 1993), it is fair to say that policies that keep urban and intercity busses clean, efficient, filled and running could contribute to massive fuel savings by restraining growth in automobile use. This is not simple: the Krakow, Poland municipal system reports losing riders to cars as car ownership increases (Meyers *et al*, 1993). Improvements contribute to saving energy in the bus system. Newer, Western buses are more powerful and more efficient than the old Hungarian-made Ikarus that were so common in Eastern Europe. The bus fleet is clearly in need of rehabilitation, and as this occurs, the efficiency of busses should increase through replacement. But there is the risk that economically necessitated service cuts or fare increases in the short term will force more people to switch to cars for regular travel.

An increase in truck hauling with smaller, lighter trucks on more efficient routes will partially offset an increase in the quantities of goods hauled. Estonia is becoming a transit hub for neighboring countries, and the volume of transit freight is increasing as well. Freight is likely to shift away from bulk materials toward more finished consumer products. In Western countries this shift has advanced the share of trucks in freight haulage because the average shipment is smaller than that of bulk raw materials sent by rail. Furthermore, the expansion of private consumption of manufactured goods, if it follows the trend in Poland, will mean an expansion of the decentralized retail sector, which depends on small trucks. Both these changes have increased energy use for freight in Western countries (Schipper and Meyers *et al*, 1992). The existing fleet of heavier Soviet-made trucks will probably be replaced by a wider variety of lighter, more efficient Western pickups, vans and light trucks. Similarly, private operators face a greater incentive to fully utilize both vehicles and trips, which should reduce empty hauls. As with cars, price signals will play an important role in the future of trucks; fees based on laden weight and actual use would have a significant impact on energy consumption.

Future scenarios and energy efficiency potential

In a fashion similar to what we did for the former USSR as a whole (Schipper and Martinot, 1992)[8], we postulate three economic scenarios to distinguish three possible paths of energy efficiency improvement: slow reform,

[8]Schipper and Martinot, 1992. For a more detailed description of these scenarios and the general analytical approach, see Schipper and Meyers *et al*, 1992.

rapid reform and extra effort. Slow reform is just that, a series of a few, indecisive steps toward freeing prices, privatization and marketization of the economy and the energy sector, somewhat akin to the course followed in Russia and Ukraine. Rapid reform takes these steps at a more deliberate pace, akin to the course followed in Poland. Extra effort presumes that economic reform moves swiftly, and public and private authorities include many initiatives for improving both the technology of energy use and internalizing environmental problems into energy prices.

The results of these scenarios for Estonia are shown in Figure 12, which gives the theoretical impact of energy intensity changes on total energy consumption by 2010 based upon 1992 structure. The process of slow reform itself might reduce intensities by 15–25% by the year 2010, all else being equal. Rapid reform could increase the reduction to 35% and extra effort could push those reductions closer to 50%. The gains would be principally in the housing and building sectors. As dramatic as these improvements seem, they would only bring typical energy intensities in Estonia by 2010 to the level of Western Europe in 1990! Note that these calculations do not account for structural changes, which are likely to further reduce energy use in manufacturing but to increase it in the other sectors. Can these savings be achieved? The savings suggested by slow reform are almost inevitable. Those proposed in the two other scenarios are far less certain. In the following sections we discuss some of the barriers to and ingredients of the rapid reform and extra effort scenarios.

Barriers to improving energy efficiency

At the heart of the inefficient energy uses we observed in Estonia lie three fundamental causes: (1) The formerly planned economy had no competition or market forces and few enterprises or private citizens had control of or responsibility for cost minimization. (2) Energy prices were unrealistically low and the returns from using energy more efficiently were minimal even if cost reduction was desired. (3) Both the economy and political system were closed, and access to information, equipment and capital for energy-use efficiency was very limited. In theory, these root causes of inefficiency are fading. But changing the rules on paper is one thing, and it will take time for Estonians as private or public officials or individuals to learn to make economically efficient decisions about resource consumption and capital investments. This point arose in almost all our conversations with Estonian experts.

Energy (and energy efficiency) are but two problems plaguing Estonia and other economies in transition. It is tempting to try to ignore these other problems and focus only on energy and energy efficiency, particularly because of the environmental and national security implications of energy use. In the rationing of scarce labor or capital, proposals that the energy problem jump ahead in the queue of other problems should be viewed with skepticism. Energy-efficiency policies must not substitute for sound resource pricing, clear demarcation of public and private responsibility, enforceable environmental regulations or a careful evaluation of the real rates of return for investing scarce capital.

The Estonian Plan for Energy Conservation in 1992 quite plainly pointed out generic barriers to energy efficiency in Estonia: lack of ownership, unrealistic energy pricing, lack of financing, lack of incentives or motivation (especially price related), lack of domestically produced equipment and materials, lack of information, insufficient research, inadequate training, insufficient legislation and obsolete standards. The first four items are particularly important. Lack of private ownership of energy consuming infrastructure and the consequent lack of responsibility for its maintenance and improvement are clearly barriers to efficiency improvements. This can be seen in buildings, which are still state property and managed by municipal administrations which have very little money for improvements. Yet even where private ownership exists, low energy prices make normal energy efficiency improvements uneconomic or extend payback times beyond attractive horizons. Capital from financial institutions is expensive and generally available only for short-term (a few months to one year) investments. Lack of affordable, long-term financing stems from several factors: high real interest rates; high inflation and future uncertainties about the economy make investment paybacks and viability very uncertain for longer-term projects; and lack of private ownership makes securing collateral difficult for loans other than retail trade. Although prices have risen dramatically, privatization is under way and financial institutions are becoming stronger, ownership, pricing and capital problems did not disappear with Estonia's break from the USSR but will linger for quite some time.

The lack of incentives and motivation for innovation and cost minimization in state owned enterprises of the former USSR was well known and applies equally to inefficient use of energy and material inputs alike. Yet even when enterprises become privatized and accountable for making a profit, rather than just for producing a certain quantity of goods according to a central plan using pre-ordained inputs, these attitudes may persist. Or managers faced with a full array of other problems requiring attention may view energy as too small a part of total costs or too low a priority to worry about. Finally, lack of interest in making simple low-cost, low-tech changes may stem from an attraction to the latest high-tech equipment from the West.

Even where a desire to improve energy use exists, a lack of training and experience in management, basic cost accounting, life cycle investment analysis, and other Western financial concepts and practices inhibit proper investments and changes. On a consumer and enterprise level, people need to understand how investments in more efficient equipment can pay for themselves through reduced future energy costs. On a national level, some of the money spent on expensive, imported fuels can be better spent reducing the need for these fuels in the first place, and authorities need to be able to understand the paybacks involved.

Lack of research and meager information are problems with their roots in the former regime. On the one hand, the USSR had some of the most highly trained scientists and engineers and a wealth of scientific information. On the other hand, the training and research were closely molded by the state, information was literally locked up and horizontal interaction between different branches was rare. Public authorities in Estonia will have to assess existing data and synthesize new data in order to calibrate a fresh base line of energy use in Estonia and to assess the state of the energy consuming infrastructure.

Finally, there is the problem of legislation and standards. Independent Estonia was left without a post-Communist legal framework for most activities and has had little experience organizing ownership of utilities, energy enterprises, apartment buildings and commercial buildings. Laws governing property and rent, laws governing transfer of property, laws governing finance and banking, including home mortgages, regulations on vehicle registration and inspection and so forth all need to be put into place. Each of these problems has an impact on energy use and affects the process of changing energy use. The most critical are those governing ownership and rental of buildings, safety, fire and thermal standards on buildings and safety and emissions standards on motor vehicles.

Key issues in housing and heat supply

Complementing the generic barriers described above are several key issues related to the housing sector and public heat supply, posed below as questions:

(1) How much longer must electricity and heat remain subsidized? Electricity subsidies are only indirect (rates do not account for debt, capital depreciation, environmental costs, and mining subsidies), while the national government and local municipalities directly subsidize heat to poorer consumers. The simple fact is that Estonia's average per capita income (roughly US$80 on an exchange rate basis in 1993) does not allow consumers by themselves to pay for and maintain an energy system that must draw fuels and capital from world markets. Energy subsidies are tied to future income growth and to a reduction in heating costs through use of cheaper domestic wood and peat fuels.

(2) Who really controls the central heat supply? District heat supply companies, as natural monopolies, must remain regulated in some way. Poorer people prefer a later start of the heating season in the autumn and lower temperatures to reduce bills, while more affluent citizens advocate earlier starts and higher temperatures. As more enterprises become privatized, the self-generated heat that they supply to the public system may no longer be subject to central control.

(3) Can individuals or building tenant associations monitor and control their own heat consumption? Metering and monitoring are possible, yet control of heat supply to individual flats is often difficult or impossible. Without a way to monitor and control heat consumption through meters and valves, consumers are left with no motivation or means to reduce consumption. More consumers are attempting to become independent from the central heating system by installing electric heaters and even removing radiators. An unresolved legal issue is whether consumers can avoid paying for central heat if they do not want it. A further complication is that those in the middle of a building receive free heat from those around them.

(4) Who will own the buildings and when? Apartment privatization will clearly be an important step toward more efficient household energy use, although it is proceeding slowly.[9] As owners, individuals and tenant associations will have a direct stake and interest in cost-reducing building maintenance and efficiency improvements. Once property becomes private, it can be used as collateral for capital investment loans.

(5) Who pays for distribution system losses? Most consumers are billed for heat according to heat produced at the plant plus some correction for distribution system losses, not as it enters their buildings. Thus district heat supply companies have little incentive to reduce distribution losses. In one Estonian town, for example, the standard distribution system loss used

[9]In part, unresolved property restitution is preventing privatization where claims from pre-World-War II property owners have been made (about 200 000 such claims existed by mid-1993). By the end of 1994, apartment tenants are supposed to declare their intent to privatize, but the privatization process itself will take longer (private communication with Allsaar, 1994).

for billing is 18%, while in reality losses are more like 30%. Heat meters and billings for heat as it enters the building are now allowed, in which case the supply company pays for the losses. While this is a zero-sum game (if the supply company pays for losses, it simply raises heating prices to compensate), the responsibility for distribution system losses is key to motivation and incentives to invest in reducing them.

(6) Will electric heating take over? While electricity prices remain low, electric heating is cheaper than purchasing heat from central heating networks for new and renovated buildings. And electric heating affords greater control over heating comfort. Conversion of heating from central heat to electricity in existing buildings, if allowed, will make the problem worse. Electric heating on a large scale will strain electric distribution networks and commit Estonia to costly future electric power capacity investments sooner than would otherwise be needed. And the environmental consequences of electric heating are also serious as the electricity is produced from oil-shale with severe regional and transnational pollution problems.

Priorities and policies for the future

In this section, we discuss priorities for Estonian policy makers and international assistance or business communities, and specific policies we believe are important for accelerating energy efficiency improvements. We seek to identify imperfections and barriers in energy-use markets that require public policy initiatives to improve resource allocations. The goal is to accelerate the transition to a better, not a perfect, market for energy uses in Estonia. And where energy efficiency improvements can be identified as those which would happen anyway, those processes can be accelerated.

In our discussions with experts and authorities, several clear priorities became apparent.[10] The first priority, almost universally acknowledged, is the need to focus on district heating supply systems.[11] The second is to improve heating equipment within buildings: substations, boilers, pipes, shunts, pumps, valves etc. The economic returns and cost effectiveness of investment in these systems seems to outdistance those in end-use housing improvements such as insulation and windows. As one expert put it, 'It simply makes no sense to save energy in apartments when all that heat is being lost in the distribution network and at the boiler.' We suspect, however, that end-use improvements in buildings should go together with heat supply improvements at least initially, until actual experience gives clearer conclusions. Heat metering and individual radiator thermostat valves within apartments, where possible, are also a high priority; they are inexpensive and could reduce heat consumption significantly if heat billing is tied to actual measured consumption.

A second clear priority is low-cost/no-cost measures in industry. These typically involve little if any capital investment, but rather such things as regular boiler tuning, smarter energy management, conducting deferred maintenance and operational process changes. Of course, the cost of such no-cost measures can be measured in management time and attention, which may be in as short supply as investment capital itself. Authorities can sponsor audits and other demonstrations, and measure results carefully.

Other important priorities for energy efficiency that address some of the barriers discussed earlier are the following:

(1) Definition and regulation of the boundary between public and private responsibility. Certainly privatization of industry and housing is a key part of this priority. Responsibility and control of heat production and distribution, especially where multiple enterprises, both private and public, provide heat to a common system, is another. Building maintenance and renovation is another.

(2) Economic analysis of what kinds of investments will be profitable at what future times under different economic conditions. For example, what level of heat prices will make certain investments profitable? At what interest rates? These economic analyses are not being performed by many, and not many Estonians have yet developed the ability to do them.

(3) Training and education of Estonian policy makers, enterprise managers, and engineers in the skills of financial management, cost accounting, energy and resource economics, life cycle investment analysis and other fundamental Western economic concepts. In the words of Salay *et al* (1993) 'local government officials, building managers, and engineers also need training in economic management . . . It is crucial that such training focus on the energy-using sectors and on those persons who are in an economic and institutional position to implement energy-efficiency measures, not only on experts in energy production and distribution.'

[10]For published evaluations of energy efficiency priorities, see Moetus, 1993; and Ots, 1993.

[11]The World Bank approved loans in 1994 for investments in Estonian municipal district heating systems and for conversion of district heating boilers from oil to domestic biomass fuels (peat and wood). The district heating loan included renovation of district heating systems in Tallinn, Tartu, and Parnu, including boiler improvements, new substations for buildings, pipeline replacements, variable speed pumps, and other energy efficiency and reliability improvements.

(4) Revision of thermal performance requirements for new homes and buildings, development of analytical tools to model these requirements, enforcement mechanisms to see that the requirements are followed, and training of architects and engineers in methods to satisfy the requirements. The old Soviet building codes (SNIP) were still being used as of the end of 1993, although designers are allowed to design buildings according to any standards they wished as long as they are better than the SNIP codes.

(5) Accumulation of retrofit experience through demonstrations and experiments. The lack of heat meters and retrofit experience has impeded so far the gathering of information on actual costs and potential savings from retrofits. Experiments and demonstrations can measure the real changes in energy use that arise when well-defined efficiency strategies are carried out.

(6) Careful, publicly funded and published research to measure energy uses in all sectors. Many of our recommendations involve research, both of a scientific and survey or market type. Certainly some information is vital to private firms wishing to market their goods and services in Estonia. It is important that information remains in the public domain. In this sense, the confidentiality of the 1993 *Energy Master Plan for Estonia* sets a poor example for a nation emerging from more than 50 years of suppression of information vital to public policy debates (Ministry of Industry and Energetics, 1993).

Foreign entities, whether bilateral or multilateral assistance organizations, multinational corporations and vendors, or non-governmental organizations, can play an important role in improving energy-use efficiency in Estonia and implementing the policies listed here. They should be careful to (1) involve Estonians themselves in conception, implementation and evaluation phases of projects and policy proposals; (2) ensure that energy-using products and processes brought into Estonia are efficient; (3) avoid only paper studies; and (4) translate documents into the Estonian language. In recent years many completed foreign energy projects in Estonia have been criticized for their lack of concrete results (only many pages of paper), their lack of follow up and dissemination of results, and reports written only in English.

Conclusion

The onset of rapid economic reform in Estonia led to the collapse of industrial activity, with energy use for industry and for freight dropping as well, although less rapidly. Energy use for households fell slightly, and that for services also dropped, but neither sector collapsed as did industry. Energy use for travel fell only slightly, as private automobile ownership soared. We observed the same pattern in Poland, which suggests that this is characteristic of the process of rapid economic reform and should be expected in other former Soviet republics. In all sectors, efficiency worsened because capacity was underutilized.

There is no question that energy use in Estonia is inefficient. The very process of reform will improve efficiency markedly. Sound public policies could raise both the scope and the speed of those improvements. Beyond this, how hard should authorities push? The wider issue, which we cannot easily resolve here, is whether energy saving investments deserve special consideration above other possible investments by Estonian or foreign investors. If emphasizing energy-saving investments is a strategy proposed to confront the underpricing of energy, then we cannot recommend it, unless it is clear that energy prices will soon rise. If favoring energy-efficiency investments is a strategy to reduce the emissions from energy production and use, we propose instead a series of emissions fees or taxes on the pollution of concern, something of great interest to a government looking for sources of revenue.

If, on the other hand, favoring energy-efficiency investments is proposed as a way of paying more attention, and more quickly, to an important part of economic development that was overlooked during the communist period, then we support it. But it is critical not to waste government money or attention on subsidies or other special considerations to energy-efficiency investments that are going to be made anyway. Even without intervention, economic reform will provide higher energy prices, competition among firms to cut costs and modernized production. But market forces will be very slow in coming to the household and service sectors. Western authorities have struggled for decades to improve energy use in apartment buildings, commercial buildings, and even private homes, working against many kinds of market failures. Here there is a clear role for intervention.

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