How We Use Energy

IN THIS ISSUE

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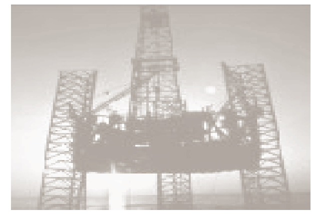
The Notion of End-use Demand



Just as human bodies need food, human societies need energy to function. Our needs for energy fall into types of *end use* – the broad categories of tasks that energy performs for us. Though energy is used in practically every human activity, the basic work it does can be lumped into just four groups:

- **low temperature heating and cooling**: there are just small temperature changes – enough to raise the temperature of a house, say, from -10º outside to a comfortable +20º inside; or heating water to less than boiling, for washing dishes or having a bath.
- **process heat:** the steam production and high temperatures needed by industry.
- **electricity specific:** all those tasks that can be done only – or at least most conveniently – by electricity. This includes everything from running a computer, to lighting our homes, to arc welding.
- **transportation powered by liquid fuels**: we move around our towns, our province, our country, and our world mostly by burning gasoline or jet fuel or diesel, in boats, planes, trucks, trains, and cars. Electrical subway trains, trolley buses, and street cars, and coal-fired steam engines account for just a minuscule part of transportation.

[Note that although these are the basic concepts of how we use energy, the way energy consumption is usually measured does not precisely reflect these categories. End use statistics are presented by **sector** *end use* – residential, industrial, commercial, and transportation.]

Thinking about energy in terms of end use is useful for two reasons. The first is because it makes it clear that energy is not expended just for its own sake, but used to do work.

This focuses our thinking about energy planning and development on **how** we want to get that work done. How can we get the services for which we are using energy? How can we make the technologies using energy more efficient, or how can we substitute other processes?

This approach ultimately demands that we think about how **desirable** our energy-using activities really are. How much do we need – or want – to do all the things we do that use energy?

Second, looking at energy from the end use perspective also points out the restrictions in **substituting** one form of energy for another, and the limits we are dealing with are clearer. For example, transportation, with our current technology, demands easily-carried liquid fuels.

Lots of electricity can't prevent long line-ups at the pumps if there is a liquid fuel shortage, like in southern Quebec during the ice storm of 1998, or the OPEC crisis of 1973 (or, some fear, Y2K disruptions if computer systems fail after January 1, 2000).

Certainly, economics play a large role in deciding if switching from one fuel to another is practical. But it is the **characteristics** of the end use that often determine what energy choice is financially feasible.

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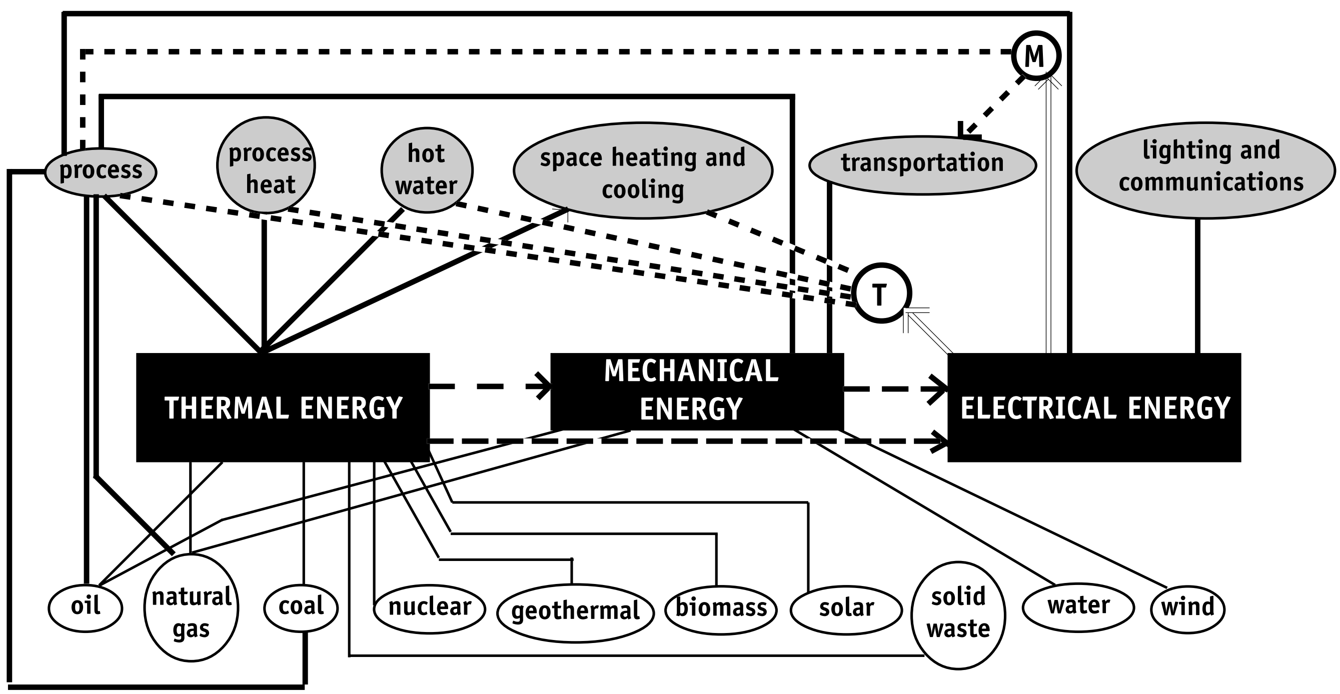
End Use Demand (from page 1)

The logical starting point, then, in thinking about what kind of energy mix we want to move toward is not in worrying about whether we have enough primary energy resources, but rather in analysing the services – the end uses – that society needs energy for. For it is there that questions about “how much?” and “from what?” come together.

The diagram below pack an entire energy network into a very small space. The white ovals at the bottom are our fuels and energy sources. The black boxes mark the conversion of these sources to different forms of energy. The heavier straight lines connect sources and energy forms to the end uses in the gray ovals. Dotted lines mark conversions into and out of electrical energy; thermal and mechanical forms are transformed into electrical, which is both used directly, and transformed again into thermal and mechanical forms, at the stage 2 conversions marked by the circles surrounding M and T. (To reduce clutter, arrows been used only where absolutely necessary for clarification. Just remember that sources are at the bottom, and end uses at the top.)

Note that some end uses, like industrial process, have many linkages, both directly from fuels and indirectly through thermal, mechanical, and electrical energy. Others are supplied by few other forms; lighting and communications, for example, are dependent solely on direct inputs of electrical energy. Some fuels, like oil, feed directly into an end use, and into more than one conversion; others, like water, feed only into one form.



THE COST OF ENERGY

End use – driving a child to school, versus making paper, versus cooking bacon with a microwave – helps determine what kind of energy we use, but cost is also a major factor in this choice. However, costs in their turn are affected by end use!

As well, regulation – or its absence– is very important in determining energy costs. Energy use and pricing have been heavily regulated in Canada, though deregulation is becoming more common. Provincially, most electricity pricing is still controlled by utility boards, and provinces or towns own most electrical utilities. A privately owned utility, like Nova Scotia Power Inc., is fairly uncommon.

The National Energy Board controls aspects like the price of sending natural gas by pipeline; the amount companies can charge for the use of national pipeline systems is known as a “toll”. The Canada Nova Scotia Offshore Petroleum Board regulates offshore energy development. International agreements, like the Kyoto Agreement dealing with greenhouse gases, or the Canada-United States accords on acid rain, also affect how energy is controlled, and influence its pricing structure.

Market forces also drive energy prices, of course. Desired profit levels are the bottom line for most energy producers, with the exception of some publicly-owned utilities or cooperatives.

END USE ISN'T THE END OF IT

As important as the idea of end use is, energy use cannot be measured solely by it. This is because it often takes energy to make energy, especially electricity. Our total **primary energy demand** refers to all the energy we consume – in end uses, plus amounts used in processing fossil fuels, plus what is used to generate electricity.

For this reason, energy statistics differentiate between fuels used to make other forms of energy, and fuels used to directly power something, like the gasoline burned in a car. The coal burnt in Nova Scotia Power's Point Aconi thermal plant is accounted for under electrical generation, not under end use.

Primary energy demand and end use are usually broken down into economic sectors, for ease of measuring: **electrical power generation**, **residential**, **commercial and institutional**, **industrial** and **transportation**. These statistical categories all use the work that energy does in different but overlapping ways. Households, commercial services, and industry all need low temperature heating and cooling and electricity; industry requires process heat as well. Transportation is the only category in which the use and the measurement sector are almost identical, and little overlap occurs.

Planning for Energy Use

Since the mid 70s much effort has been devoted to the development of energy modelling & forecasting techniques. So much was expected from models that some came to believe that all that was needed for accurate forecasts was a large computer & a set of mathematical equations.

A typical model starts with one or more *scenarios*. Scenarios are possible pathways into the future, possible in that they are internally consistent & anchored in the present.

To be effective scenarios should reflect different ways of seeing the world, & creative glimpses into the future, not just high & low forecasts. For example, energy scenarios exist which project the potential use of currently impractical fuels like methane hydrate from the deep seabed, or hydrogen.

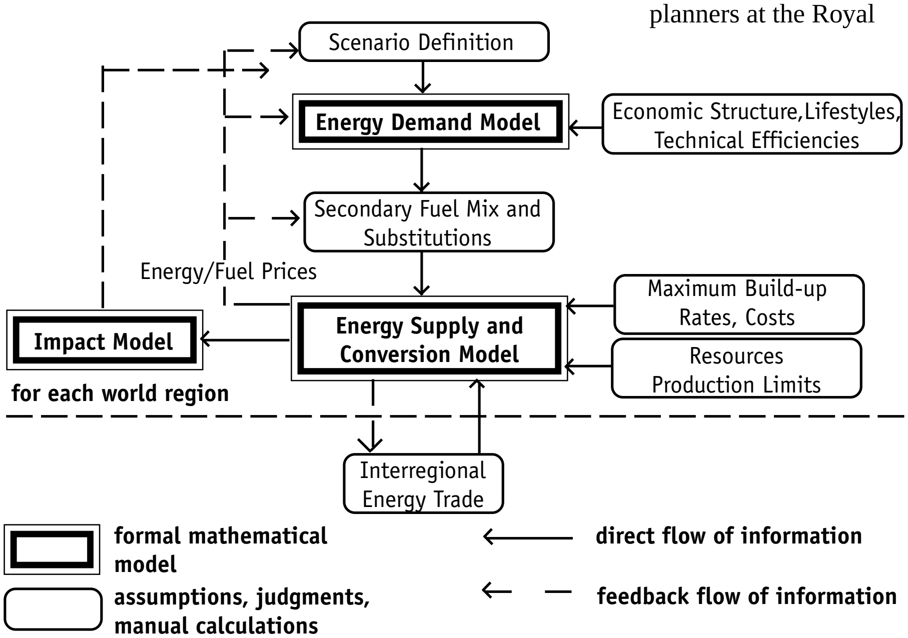
The diagram below illustrates a model system used by the International Institute of Applied System Analysis to create its highly respected energy projections. Note that there are three interactive models which feed into, & feed back into, each other.

Model outputs are used by planners & decision makers in energy companies & by policy makers in government. In fact, the scenario technique was developed by planners at the Royal Dutch/Shell Group of Companies. With a demand prediction, supply needs can be anticipated as well as expected price. Policy makers can use the information to shape public energy policies.

Energy users, especially small to medium, respond to energy commodity prices by substitution and /or conservation. A properly designed model can anticipate this reaction.

In using models one must bear in mind that they all require some judgmental inputs – one avoids the word 'guess', of course! – which means their output is not a certainty.

One should remember the advice of the analyst Dr. A. N. Whitehead: "There is no more common error than to assume that, because prolonged & accurate mathematical calculations have been made, the application of the result to some fact of nature is absolutely certain."



HOW DOES THE WORLD USE ENERGY?

As might be expected, primary energy demand & end use vary widely from country to country, depending on economic conditions. Directly comparing energy use between the Third World & the more industrialized nations is difficult, as many less developed countries use relatively little commercial energy – oil, natural gas, electricity, etc. – & still rely heavily on local traditional sources: animal dung, firewood, charcoal. The amounts of these are almost impossible to estimate, & thus energy consumption in developing countries tends to be underestimated.

A review of the country by country statistics gathered by the United Nations & the World Resources Institute for the biennial publication *World Resources* shows that sectoral use patterns have changed little in the past twenty years in the developed world. Roughly the same proportions of end use are maintained; however, overall consumption in each sector has grown. There has also been little change in the very poorest nations. In many of the more rapidly industrializing and urbanizing countries, however, more commercially sold energy is used, with proportionately greater end use in industry & transportation.

A review of some available data for Norway, Mali, & the United States highlights some of the country to country differences even among the developed economies. One of the things that stands out about the United States, beyond the sheer magnitude of the energy it consumes, is that it is one of the least energy-efficient countries in the OECD. Cars, appliances & commercial buildings in the US use 20-33% more energy per unit of activity, & US industries 10-25% more, than in most other countries. Average prices, especially of gasoline & diesel fuel, have encouraged this, coupled with a lack of good public transit in many cities, & planning practices – or lack thereof – that have encouraged urban sprawl for the past 40 years. Although energy intensity, a common measure of efficiency, did fall by about 36% betweeen 1949 & 1997, the growth of the American population & economy drove total energy use up 209%.

A look at how energy consumption in American end use sectors has shifted since 1949 points out the linkages between technological changes, end use demand, & fuel choices. Coal made up almost a quarter of residential & commercial consumption in 1949. In 1997 its proportion is vanishingly small. Natural gas use in industry has trebled, while coal has been halved, & electricity has increased nine-fold.

Mali, in sub-Saharan Africa, is among the poorest countries in the world, with 65% of its land area desert or semi-desert, & a population growing at about 3.2% a year on 1.24 million sq. km of land. Its per capita GDP is only US$600, & traditional fuels supply almost all the energy in rural areas. Its overall per capita consumption has changed little in the past 30 years, remaining a miniscule fraction of that of more developed countries. Detailed energy use statistics are not readily available, but an indication of how little Mali uses in comparison to the industrialized world is shown by its production of only 235 million kWh of electricity in 1995; its per capita consumption of electricity stood at only **28 kWh**. Its 10 million people have only 11,000 telephones & televisions, two radio & two TV stations, & 1,773 km of paved highways.

Norwegians, on the other hand, have the highest per capita consumption of electricity in the world, mostly because of their household use. Norway's electrical rates are very cheap, due to large hydroelectric developments.

General per capita energy consumption by Norwegian households is unusually high, about 40% above the OECD average. Electricity supplies a very large share of residential sector needs, at about 75%. Ironically, because of Norway's large offshore oil & gas industry, its greenhouse gas emissions are also relatively high despite its dependence on hydroelectricity.

Norwegians have relatively large homes; not only do they use electricity for space heating, they consume more lighting and hot water, & have more appliances, than other northern countries. Total electricity consumption in the residential sector is almost exactly the same as that of India, at 28 terawatt-hour per year – with the slight difference that the latter has 210 times the population!

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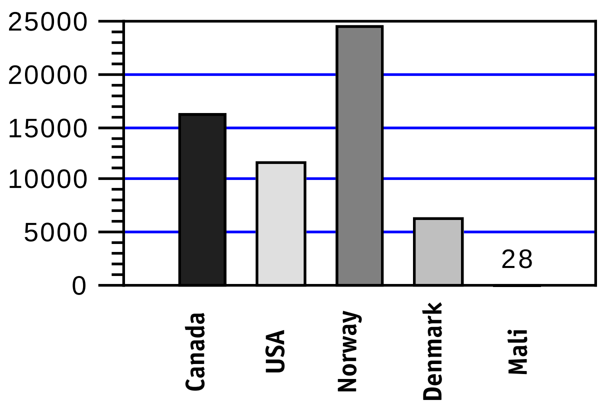
1995 Per Capita Electrical Consumption (kWh)



ENERGY USE IN CANADA

Energy demand in Canada is projected to rise steadily over the next decade, almost as quickly as in the 1970s. The National Energy Board middle-of-the-road ‘Current Technology’ scenario forecasts growth rates at 1.5% a year, with electricity capturing additional market share regardless of the scenario.

There have been slight shifts in the relative sizes of energy demand sectors over the past twenty five years. Residential has fallen about 3%, largely reflecting rapid energy efficiency improvements and energy conservation measures undertaken by households. Commercial demand is at about the same proportion now as in 1971.

The industrial sector has consistently accounted for approximately one-third of total end use demand, the largest share of any sector.

Despite this, the industrial sector’s share of total economic output has declined steadily, from more than 40% in the late 1960s, to less than 30% in 1995.

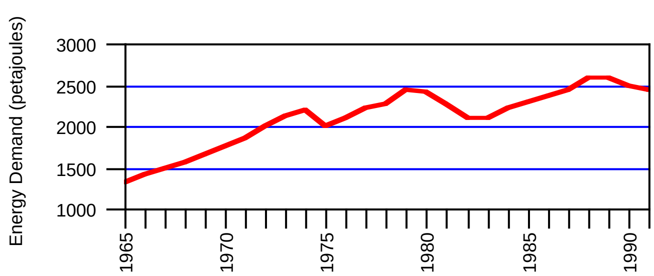
Transportation consumption has risen a few percentage points, and now makes up about a quarter of total secondary energy demand.

The accompanying graphs illustrate some of the more interesting features of Canadian energy end use.

ENERGY ISN’T THE ONLY WAY WE USE FUELS

It is important to remember, too, that although this paper focuses on energy, it is not the only use for hydrocarbons. Petroleum products permeate our lives — lubricating oils and powders, building supplies, asphalt, many plastics, fertilizers, herbicides, medications, nylon and polyester cloth, pesticides, PVC piping, Styrofoam insulation ....

So, although energy and its uses are the main focus when we discuss hydrocarbon developments, we must not overlook the strong demand for petroleum as a feedstock to make other goods. In 1991 in Canada, for example, 10% of “energy” sources were processed into non-energy products.



Closer to Home: Nova Scotian Energy Use

Nova Scotia' total primary and end use energy demands have declined somewhat in the 1990s, by about 5.3% and 3.5%, respectively over the decade. Residential, commercial, and industrial demands have all gone down in the past ten years; transportation was the only sector to increase, by about 2%.

These changes probably reflect a number of factors: increased energy conservation and efficiency in the residential and commercial sectors, a shrinking industrial base (including the impact of the groundfish

HOW DOES THE WAY WE LIVE AFFECT HOW WE USE ENERGY?

Canada, with one-half of one per cent of the world's population, accounts for about two per cent of human carbon dioxide emissions, and one per cent of methane. Although we are minor contributors to overall global emissions, we are among the highest per capita emitters.

Our per capita energy consumption is about five times greater than the global average, and more than any other G7 country. Canada's harsh climate, rapid population growth, vast geography and natural resource-based economy have made us more dependent on energy than most nations.

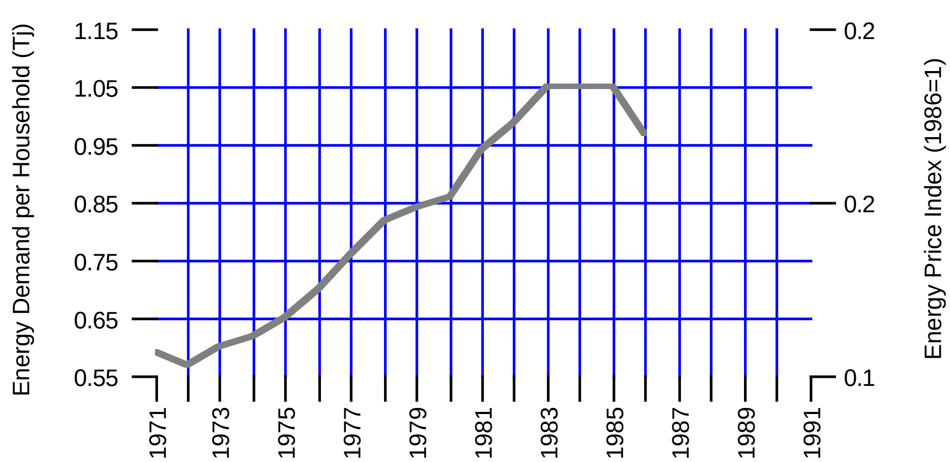
Canadians are altogether too familiar with our climate and the need to use energy to keep warm. Many homes, particularly in Nova Scotia, are older and less energy efficient than new ones – but we also place a high value on the heritage of older buildings.

The energy efficiency of new buildings is steadily increasing as regulations are updated and building technology changes, but it is frequently not cost effective or technically possible to bring older homes up to these high standards. New houses have gradually increased in size following market demand, but improvements in energy efficiency have more than offset the energy needed to heat larger living space.

Between 1984 and 1994, residential energy use increased by about 16%. At the same time, the proportion of energy used for space heating decreased by almost 5% – the increase in energy use is largely a result of how many more people own and use appliances such as dishwashers.

Partly because of more dishwasher use, the energy used to heat water also increased during this time, by about 3%. The use of air conditioning has also increased, but still accounts for less than 1% of total Canadian residential energy use.

The design of the urban environment has a profound effect on energy use and, once built, it is extremely expensive to change. The continued expansion of



NEW TECHNOLOGIES & ENERGY EFFICIENCY

Improvements in end use efficiency might have decreased energy consumption over the last decade – if only our level of activity had not increased. Technology improvements have reduced energy requirements, but patterns and intensity of use often overshadow these gains.

For example, between 1970 and 1984, the fuel efficiency of new small cars improved an average of 2.2% per year; large cars & light trucks improved by 3.7% per year. Even with these improvements in efficiency, shifts in the amount of travel & the type of vehicle used resulted in a small increase in passenger transport energy use between 1984 and 1994.

Improvements in space heating efficiency & reductions in heat loss helped limit energy use in the residential sector. In the early 1980s, normal efficiency (60 to 65%) furnaces were common, but by 1994, they had been eliminated from the Canadian market, leaving only mid- (78 to 83% efficiency) and high-efficiency (90% or more) units for sale. Housing units built today are also better insulated and more airtight than older units, requiring less energy. However, using passive solar to meet space heating needs is still uncommon.

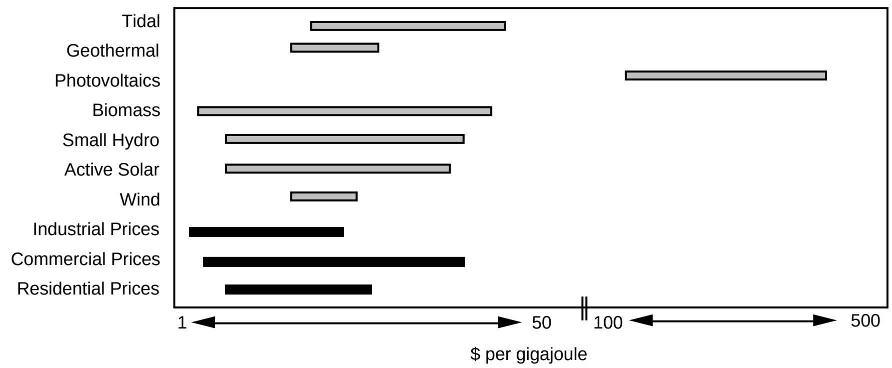
The pulp & paper industry is a major energy user in Nova Scotia. Between 1984 and 1994, the industry shifted from fossil fuels to wood wastes & pulping liquors as its primary energy source. The energy content of these alternative fuels is less than of fossil fuels and, as a result, more energy is consumed to do the same amount of work. At the same time, efficiency improvements, such as shifting from chemical pulping to mechanical pulping & recycling, reduced energy consumption in some plants by 20%.

Technological improvements do not occur at an even pace. For example, fuel efficiency of vehicles improved substantially from 1970 to 1984; but the average fuel efficiency of new vehicles has hardly changed since. Vehicle stock turnover, however, has continued to result in efficiency gains in the passenger transport sector as older, less efficient vehicles are replaced.

With the coming of offshore natural gas from the area around Sable Island, we in Nova Scotia have a chance to think about our energy infrastructure, and how we can make it better for future generations. How do we want to heat our homes and run our factories?

If we are going to spend the money to pipe natural gas into communities in the province, are there other steps we can take at the same time to improve efficiency and cut harmful emissions? For example, our wasted heat in electrical power generation could be used for district heating or industrial processes, if we planned our infrastructure properly.

The cost of such fuel substitutions also affects the adoption of new technologies, and the choice of an end use energy source. The accompanying graph reviews the current costs of alternatives versus traditional commercial fuels.



Comparison Between End Use Alternative Energy Supply Costs and Conventional Energy Prices

***Want more information? Check "Finding Out About Energy" in* The Energy Context, *and "Sources and Resources" in* Global Questions.**

International use (from page 4)

Norway's neighbour Denmark's per capita electricity use is included for comparison in the accompanying graph. Because of their structural differences in fuel mixes, these neighbouring countries, although culturally similar, have very different end use sectors & consumption requirements.

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