8

Reducing emissions

There is good potential for reducing emissions of most pollutants to levels that nature and people can tolerate, without making major economic or material sacrifices. Many of these measures also have socioeconomic benefits.

Emissions of the major air pollutants are closely linked with our use of energy. They can effectively be reduced in two ways: either through technical measures, such as flue-gas treatment at a coal-fired power plant, or through measures that change the system, such as reducing energy use so that the coal-fired power plant is no longer needed.

The technology approach and system change approach are not mutually exclusive – in fact it can be difficult to separate them. But system change will often take a long time, while technical change can give quick results. And even after the energy system has undergone major change, emission control technology will still be important to keep emissions of many pollutants at a low level.

Certain air pollutants, such as carbon dioxide, cannot currently be removed at reasonable cost. Reducing these emissions will require system change that will mean using less fossil fuels. This itself is something of a key issue, since it would reduce emissions of many other air pollutants at the same time. For example, most emissions of sulphur dioxide and nitrogen oxides arise from the burning of fossil fuels, as do a large part of the emissions of volatile organic compounds, heavy metals, etc.

This review therefore looks first at system change, followed by technical measures and their potential. Calculations are then presented which show that it is profitable to clean the air. Finally we discuss what is needed to bring about these changes.

SYSTEM CHANGE

Reducing our consumption of finite energy sources – fossil gas, oil, coal and uranium – requires major changes to the entire energy system. Of the current global energy supply, almost 90 per cent comes from finite resources, see figure 8.1.

One driving force for change in the energy system is the fact that the available reserves of fossil gas and oil are relatively limited, and within a few decades prices are likely to start rising, leading to reduced consumption. There are, however, still large reserves of the dirtiest fossil fuel – coal – which itself does not place any limits on future emissions of carbon dioxide.

Nuclear power is sometimes put forward as a way of reducing emissions of air pollutants, particularly the greenhouse gas carbon dioxide. The potential is limited, however, partly because the fuel, uranium, is a finite resource, and the technology is expensive, complex and unsuitable in geologically and politically unstable regions. It is generally believed that nuclear power ought to be phased our in order to achieve a sustainable energy system.

The third main report of the Intergovernmental Panel on Climate Change, published in 2001, states that the development of technology that helps reduce emissions of climate-changing gases has been rapid over the last five years. Areas that are men-

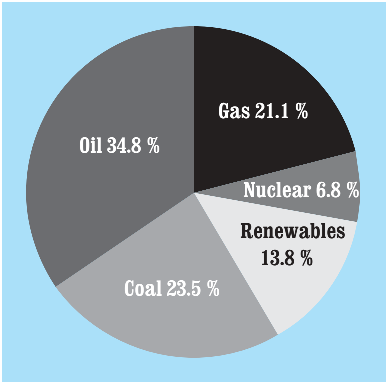

Figure 8.1. Fuel shares of world total primary energy supply. (Renewables in Global Energy Supply. IEA Fact Sheet. International Energy Agency, 2002.)

tioned specifically are wind farms, fuel cells and the harvesting of biofuels. It also reports that the cost of reducing emissions of greenhouse gases is not that high. Emission levels in 2010–2020 can be brought below those of the year 2000 at a low cost – and around half the reduction is actually profitable.

The following section describes the opportunities for using energy more efficiently and increasing our use of renewable energy sources.

Using energy more efficiently

Using energy efficiently is about getting more benefit from the same or a smaller amount of energy. Theoretically there are excellent opportunities for reducing energy consumption in this way. For example, the efficiency of a petrol-driven car – the percentage of the energy supplied that does useful work – is less than 20 per cent. A common coal-fired power plant has an efficiency of 30–35 per cent, while a new power plant with gas turbines can achieve almost 60 per cent. Converting a power station from pure electricity generation to combined heat and power generation can more than double its efficiency at a stroke. The most energy-efficient refrigerator on the market uses just a third as much electricity as the average model. A modern low-energy light bulb rated at 11 watts shines just as brightly as a 60-watt incandescent bulb. Making steel from scrap requires just a third of the energy it takes to it make from raw materials. And so on – the list is long.

According to the EU Commission there is great potential for improving the efficiency of energy use within the Union – it is estimated that around one-fifth could be saved at no additional cost, if the right incentives are used (these are discussed later in this chapter).

To ensure that the technical potential to use energy more efficiently actually leads to a reduction in energy use, two things are required:

- That the new technology is actually used. A common obstacle is that the consumer lacks sufficient information, or that energy makes up such a small fraction of the cost that it is not considered when deciding to buy a new refrigerator or car, for example.
- That we do not compensate for the lower operating costs by increasing our usage – for example by driving longer distances if a car uses less fuel.

Renewable energy

Even after major improvements in efficiency have been made, society will still require a large supply of energy. On average, the sun provides a very large influx of energy, and eventually solar energy will probably become by far the dominant source of energy. We need to make use of just one ten-thousandth of the incident solar radiation to meet the world's entire energy requirements. For example, the total current global consumption of electricity could be provided by solar panels covering 12 per cent of the area of the Sahara. The amount of solar energy stored by green plants through photosynthesis is ten times greater than the total domestic energy consumption worldwide, and we currently only use 1 per cent of the solar energy that is captured by photosynthesis. One complication, of course, is that the availability of solar radiation and bio-energy are unevenly distributed around the world.

The renewable energy sources that are best for air quality are probably solar energy for heating, and solar panels, wind power, hydroelectric power and wave power for generating electricity. None of these sources produces any waste products

THE VEHICLES OF THE FUTURE

An electric vehicle without batteries – that's a fuel cell vehicle in a nutshell. It works something like this:

The fuel cell itself can be likened to a refillable battery. It has a cathode, an anode and an electrolyte that permits the passage of ions, but not electrons, between the electrodes. Hydrogen gas is supplied to the anode, and oxygen (from the air) is supplied to the cathode. This generates an electric current that is used to drive electric motors, just as in a "normal" electric vehicle. Because there is no combustion it does not produce any air pollutants – the only waste product is water.

So the fuel is hydrogen. This can be supplied as pure hydrogen, or produced onboard from other fuels that contain hydrogen, such as methanol or petrol. It is also possible to run the cell directly on methanol, without first producing hydrogen.

Just how clean and energy efficient a fuel cell will be depends entirely on how the fuel is produced. Ideally the hydrogen gas could be produced in the future by using electricity from solar panels to electrolyse water. But if the hydrogen is instead produced using electricity from power plants fired by fossil fuels there is hardly any environmental benefit at all.

Fuel cell technology has become the vehicle industry's main focus of development towards the zero emission vehicle – a development that is primarily driven by the strict requirements laid down in California and several other US states. But despite several large manufacturers insisting that they will have fuel cell vehicles on sale shortly, it is likely that the big breakthrough will take a few decades yet. Fuel cells are still extremely expensive and there is some uncertainty over which fuel will win out in the future.

In the meantime, conventional internal combustion engines will probably be refined further. Volkswagen, for example, produces a version of its Lupo that uses just 3 litres of diesel per 100 kilometres, and expects to bring this down to 2 litres within a few years. Hybrid vehicles already exist, and more are likely to appear. These have electric motors, but the batteries are backed up by a small internal combustion engine, giving good energy efficiency and low emissions of air pollutants.

The 2003 version of Toyota Prius, a hybrid car that uses 0.43 litres of petrol per 100 km.

directly or makes a significant demand on the Earth's finite resources.

Biofuels are also a renewable source of energy, but they have a greater environmental impact than those mentioned above. Firstly, they produce nitrogen oxides, volatile hydrocarbons and particles when the biofuel is burned, and secondly, extensive exploitation of biofuel can impoverish the soil and have negative effects on biodiversity.

High fossil dependency for transport

Transport is possibly the sector of society where a transition to renewable energy is most difficult of all. This is partly because the energy demand seems to grow all the time (we travel and send goods more often and further afield), and partly because many forms of transport are almost totally dependent on oil. As in other areas it is important both to improve efficiency and gradually switch to renewable fuels. The potential for improving the efficiency of vehicles themselves is very high, especially for cars, see factfile on previous page.

However, because we seem to have an almost insatiable demand for travel, it will probably be necessary not just to improve the efficiency of vehicles, but also to try and influence the overall demand for transport, for example by infrastructure planning to minimize transport and by using economic incentives.

The biggest obstacle to a widespread shift to renewable energy at present is the combination of price and political inertia. Fossil fuels are generally cheap to the consumer and are likely to remain so for some time, even though wind power can now often compete on price with new coal power. One important issue is of course how different sources of energy are taxed. The political inertia is reinforced by the influence of powerful lobby groups that feel their position is threatened (e.g. oil companies) and by our general aversion to change.

Fundamental change is not necessarily all that far off, however. For example, a report produced on behalf of Greenpeace (1999) shows that electricity from solar panels does not need to cost more than conventional electricity, assuming that the panels are manufactured on a large scale. It is estimated that benefits of scale could reduce the price by a factor of four. In the political arena it is noticeable that a growing number of corporate leaders are expressing support for the phasing out of fossil fuels and that several large oil companies and car manufacturers have left the lobby organizations that try to oppose change.

TECHNICAL SOLUTIONS

This sections looks at the emission control technology that is on offer to reduce emissions of air pollutants from energy generation, transport and agriculture, and how far it is possible to go with technical measures alone. Some technical solutions can help to reduce emissions of carbon dioxide, but for this pollutant in particular the measures that are described under system change above are generally more important.

Energy sector

The big combustion plants in Europe, which are mainly used for electricity generation, produce extensive emissions of sulphur dioxide and nitrogen oxides. With the aid of technical solutions these can be reduced by more than 90 per cent. See factfile on next page for details.

The vast majority of large plants are coal-fired and therefore also produce high emissions of carbon dioxide. Technology is being developed to trap and store this carbon dioxide underground, for example in empty gas and oil deposits. However, it must be considered doubtful whether such methods can ever compete with measures that are able to replace fossil fuels – especially as these measures often lead to major secondary benefits such as health improvements, since they also reduce emissions of many other air pollutants.

Transport sector

Diesel-driven vehicles are more energy-efficient than petrol-driven vehicles, but generally emit more nitrogen oxides and harmful small particles. Technology for reducing emissions from diesel vehicles does exist but is not currently widely used because of lax environmental requirements.

SULPHUR AND NITROGEN OXIDES FROM COMBUSTION PLANTS

By far the largest proportion of sulphur emissions in Europe comes from the combustion of coal and oil. These emissions can be reduced by choosing **natural low-sulphur grades of coal and oil**. The sulphur content can also be reduced through technical measures, such as **fuel desulphurization**. Sulphur emissions can be eliminated by **switching fuel** entirely, for example, from coal or oil to fossil gas, since the gas is practically sulphur-free. Another advantage of gas over coal and oil is that it produces more energy per volume of carbon dioxide emitted.

The **combustion process** itself has a big effect on the level of emissions of nitrogen oxides. In simple terms it can be said that emissions increase with rising combustion temperature, and that the combustion of hard coal produces the most nitrogen oxides, oil a little less and gas least of all. New power plants often use **low-NOx burners**, which can halve emissions for a low cost. Another method is to burn coal and other solid fuels in a **fluidized bed**. The fuel is fed by compressed air into a floating bed consisting of sand, where combustion takes place at relatively low temperature, which reduces the formation of nitrogen oxides. **Sulphur-binding substances**, usually lime, can be added during both fluidized bed combustion and conventional combustion. This allows a large proportion, from 40 to over 90 per cent, of the sulphur to be trapped and removed with the ash.

After combustion there are various ways of cleaning the flue gases. Emissions of sulphur dioxide are usually reduced by **flue-gas de-sulphurization**. The most widely used method involves spraying the flue gases with lime in wet or dry form. This makes it possible to remove more than 95 per cent of the sulphur from the flue gases. One drawback is that this reduces the efficiency of the plant as a whole by 1–2 per cent, since the process requires energy.

Nitrogen oxide levels in flue gases can also be reduced. One common method is **selective catalytic reduction**, in which the flue gases are passed through a catalytic converter after adding ammonia. The end product is mainly nitrogen, and nitrogen oxide levels are reduced by between 80 and 90 per cent. Smaller plants often use a simpler **non-catalytic reduction method**, which is cheaper but also less effective. This generally reduces emissions of nitrogen oxides by 50–70 per cent.

Over the last decade a number of **combined reduction methods** have been developed, all of which reduce the level of sulphur dioxide and nitrogen oxides in flue gases in a single stage. Several of these are reported to be able to reduce levels of both pollutants by over 95 per cent, but as yet there are few plants in operation on a commercial scale.

One new technology that has so far only been tested in a small number of plants is **pre-gasification** of the fuel. First the fuel is pre-gasified in a low-oxygen environment, which causes a large proportion of the pollutants to precipitate out. The gas that is formed can then be further cleaned, and then burned at high efficiency. This technology can in principle be used for all types of solid and liquid fuel.

Heavy vehicles are in most cases diesel-driven and produce high emissions of nitrogen oxides and particles. Emissions of volatile hydrocarbons and particles can be reduced with the aid of oxidative catalytic converters, particle filters and/or cleaner fuels. Increasingly strict emission requirements will compel the use of technology to remove nitrogen oxides, for example by selective catalytic reduction (SCR). The potential to reduce emissions is especially good for working vehicles, since emissions from these engines have been unregulated until recently.

The **quality of fuel** has a major influence on the level of emissions from both petrol-driven and diesel-driven vehicles. Fuel with a low sulphur content is especially important in this respect, since sulphur impairs the efficiency of catalytic converters and itself leads to the formation of very small particles. A low sulphur content also makes it easier for vehicle manufacturers to combine low fuel consumption with low emissions of nitrogen oxides and hydrocarbons.

In addition to petrol and diesel oil there are also a number of **alternative fuels**. In light of the increasingly strict emission requirements for conventional vehicles a transition to other fuels would not greatly benefit air quality. However, these fuels can help to reduce emissions of carbon dioxide, assuming that they are produced from renewable energy sources.

Current emissions from **shipping** can be reduced considerably. The easiest way to reduce sulphur emissions is by switching to low-sulphur oils. New technology that is currently undergoing development and testing is seawater scrubbing, which removes sulphur from the exhaust gases with the aid of seawater, and is reported to give a reduction in SO_2 emissions of up to 90–95 per cent. To reduce emissions of nitrogen oxides there are several different technologies, including selective catalytic reduction (SCR) of a similar type to that used in combustion plants, which are able to reduce emissions of nitrogen oxides by more than 90 per cent. Low-sulphur oils are now used widely by vessels on Swedish shipping routes, thanks to differentiated shipping dues and port fees. Reducing speeds at sea could reduce fuel consumption and emissions of air pollutants significantly.

In the case of **air traffic**, improvements in engine technology can be expected to reduce fuel consumption and emissions of air pollutants somewhat, but it is unlikely that there will be any dramatic changes. Emissions from air travel are relatively small, but are increasing rapidly. They also have more significant effects than corresponding emissions at ground level, as a result of the rather different conditions that exist at the altitudes at which planes fly.

In summary it can be said that there are no technical obstacles to making vehicles considerably cleaner and more energy-efficient than today (with the possible exception of air travel). The critical factors in the development of emissions are the application of existing and new technology, the extent of future travel and transport, and the form of transport we choose.

Agriculture

Agriculture accounts for most of the emissions of ammonia into the air. If farmyard manure is handled in the wrong way more than half the ammonia content can evaporate before the manure reaches the soil. It is important that the manure is spread at the right time and in the right weather conditions, and that it is quickly ploughed down in the soil. The losses are especially high in warm and windy weather, and are considerably lower in cool, damp weather. If the temperature is so low that the soil is frozen, however, the losses can increase, since nitrogen in the form of ammonium cannot make sufficiently good contact with the soil particles. The losses during storage, which can also be considerable, are greatly reduced if manure pits are covered.

Although this is actually more an issue of system change, it should be pointed out that modern industrialized agriculture is hardly sustainable in the long term. By shifting towards more "organic" farming methods the supply of nitrogen in the form of artificial fertilizer would be reduced. This would itself act as a strong incentive to conserve the nitrogen available to crops, for example by minimizing the evaporation of ammonia. Another change that would favour sustainable production and reduce emissions of ammonia would be to reduce livestock farming (and hence meat consumption), which could be done by removing existing subsidies.

More efficient conservation of the nitrogen available to plants also reduces the formation of the greenhouse gas nitrous oxide in soil. Agriculture also makes a marked contribution to emissions of the greenhouse gas methane. Various adaptations would make it possible to reduce these emissions, including technical changes to the cultivation cycle.

How far can technology take us?

As part of the negotiations on reducing emissions of air pollutants in Europe, computer models were used to create various scenarios to illustrate the costs and benefits of reducing emissions of substances that contribute to acidification, eutrophication and the formation of ground-level ozone. One of these scenarios involves using the best available emission control technology to reduce all emissions. Structural measures, such as changing fuels, improving energy efficiency and changes in lifestyle are therefore not included.

If this MFR scenario (MFR stands for maximum technically feasible reductions) was implemented it would reduce emissions in Europe as follows compared with 1990 levels, (based on the assumption that energy consumption increases by 15–20 per cent during the period):

- Sulphur dioxide -90 per cent
- Nitrogen oxides -80 per cent
- Ammonia -42 per cent
- Volatile organic compounds -75 per cent

The models show that the environmental situation would be dramatically improved. But not even these very large reductions are sufficient to eliminate environmental problems entirely.

Technical solutions alone are therefore insufficient to achieve the long-term environmental goals. It may also be necessary to use energy more wisely, use more emission-free energy sources and make changes in transport systems and lifestyle. Many structural changes also involve considerably lower costs than the maximum use of emission control technology.

REDUCING EMISSIONS IS OFTEN PROFITABLE

There are several reasons why it is difficult to assess the economic damage that air pollution causes to society – and the benefits of reducing it. Many of the effects simply have no price tag. Despite this a number of attempts have been made to compare the costs and benefits of various packages of measures.

One example is the calculations carried out to assess the effects of the Gothenburg Protocol (see page 152). The annual cost of implementing the protocol was estimated at 2.8 billion euros, and its benefits at 12.8 billion euros by 2010, in other words the benefit is four to five times the cost. The most important item on the benefit side was reduced harm to people's health, mainly as a result of lower levels of harmful particles, but reduced damage to modern materials and agricultural crops also contributed.

The benefit would have been even greater if the member countries had followed the scenario that was proposed to achieve the agreed environmental targets. The cost was naturally higher than for the protocol – 8.5 rather than 2.8 billion euros by the year 2010 – but the benefits would have risen even more, from 12.8 to a massive 42.3 billion euros by the year 2010.

This is not all. The measures are likely to be even more profitable than the figures suggest. The cost-benefit analyses actually exaggerate the costs and underestimate the benefits:

- A number of important plus items, including reduced damage in ecosystems and reduced erosion of objects with a valuable cultural heritage, are not included, since they have no agreed price tag.
- The costs of measures are greatly exaggerated, since they are based solely on the use of technical measures to reduce emissions. In reality it is almost always cheaper to make ef-

Jänschwalde power plant in eastern Germany still burns lignite, but after it had been fitted for flue-gas desulphurization in 1993 its emissions of sulphur dioxide dropped from 157,000 to 20,000 tons a year.

ficiency improvements or switch fuel than to take the most expensive technical countermeasures. In addition the price of emission control technology tends to fall with time – for example the cost of flue-gas desulphurization has halved over the past decade.

Multiple benefits

The cost/benefit analyses that were carried out (for the EU emission ceilings directive, for instance) were based on a conventional energy scenario in which EU emissions of the greenhouse gas carbon dioxide were expected to rise 8 per cent by 2010. If we instead use an energy scenario that takes into account EU promises under the Kyoto Protocol (minus 8 per cent) the cost of the package of measures drops by a full 40 per cent. This is because emissions of sulphur dioxide and nitrogen oxides are reduced "for free" when carbon dioxide emissions are curbed. It therefore pays to attack several problems at the same time!

There are also studies that show that reducing emissions of carbon dioxide largely pays for itself, because emissions of harmful substances are reduced at the same time. There are no secondary benefits of this type if we try to reduce the climate effects of using fossil fuels by pumping carbon dioxide into bedrock or planting more trees.

ESTIMATING THE COSTS OF POLLUTANTS

In 2002 the European Commission published figures showing estimates of the financial costs of several air pollutants to society. They cover the following types of damage:

- Acute (short-term) effects of fine particles, sulphur dioxide (SO_2) and ozone on mortality and morbidity.
- Chronic (long-term) effects of fine particles on mortality and morbidity.
- Effects of SO_2 and acidity on materials used in buildings and other structures of no significant cultural value.
- Effects of ozone on arable crops.

Due to lack of information, some types of damage have been omitted. Among them are the effects on ecosystems, cultural heritage and visibility.

In terms of prices in 2000, the average damage caused in the EU by one tonne of pollutants emitted over rural areas is put at 14,000 euros if the pollutant is fine particles ($PM_{2.5}$), 5200 for SO_2, 4200 for NO_x and 2100 euros for volatile organic compounds. These being average figures, they mask however the great variations between member states, as can be seen from table 8.1. The costs will moreover be extra high when fine particles and SO_2 are emitted in cities, since more people will then be exposed. In a town of 100,000 inhabitants, for instance, costs are estimated at 33,000 euros per tonne of fine particles emitted, and 6000 euros for SO_2. This damage is over and above that for the whole country. The larger the city, the higher the cost will be per tonne of emitted pollutant.

HOW CAN IT BE DONE?

There is no shortage of opportunities to reduce emissions of pollutants. Many of them are cheap or even profitable to society. The following is a selection of possible measures.

Regulation

Direct regulation has been the most widely used control method in the past. Emission standards have had a major influence on cutting emissions from combustion plants and vehicles. Strictly formulated requirements have in many cases encouraged the development of efficient new emission control technology. Air quality standards have also had some restraining effect.

TABLE 8.1. Estimated costs of damage from emissions in rural areas and at sea. Euros per tonne of pollutant emitted.

	SO_2	NO_x	$PM_{2.5}$	VOCs
EU countries				
Austria	7200	6800	14000	1400
Belgium	7900	4700	22000	3000
Denmark	3300	3300	5400	7200
Finland	970	1500	1400	490
France	7400	8200	15000	2000
Germany	6100	4100	16000	2800
Greece	4100	6000	7800	930
Ireland	2600	2800	4100	1300
Italy	5000	7100	12,000	2800
Netherlands	7000	4000	18,000	2400
Portugal	3000	4100	5800	1500
Spain	3700	4700	7900	880
Sweden	1700	2600	1700	680
United Kingdom	4500	2600	9700	1900
Average EU15	5200	4200	14000	2100
Sea areas				
Baltic Sea	1600	2100	2500	1000
North Sea	4300	3100	9600	2600
English Channel	5900	5400	12000	1900
Eastern Atlantic	4500	4800	9100	1500
Mediterranean	4700	6200	10000	1700

Standards are not only used to control emission and levels, but also factors such as electricity consumption. For example, consumer standards for refrigerators in the US have helped reduce their energy consumption by two-thirds since 1978. Similar systems also exist for reducing the fuel consumption of cars.

Removing subsidies

The price of services or goods often decides how much is consumed – if the price is low, consumption is high.

Each year enormous sums are given as direct subsidies for fossil fuels. According to the Worldwatch Institute, individual countries subsidized their domestic coal industries to the value of 63 billion dollars a year in 1999. If these subsidies were reduced or removed, coal would be a more expensive fuel and demand would fall.

Another issue is whether subsidies should be used to increase the use of "environmentally good" commodities, such as wind power or train travel. Most economists believe not. Subsidies often lead to a turnaround in the market place and result in artificially high consumption. Subsidies can possibly be used to help a new technology get over the initial threshold. But in the long run it is preferable to have fair pricing that includes the environmental costs of different goods and services. Such a pricing system would not make train travel cheaper, but it would be more expensive to fly and travel by car.

Putting a price on the environment

One problem is that in many countries it costs nothing, or very little, to pollute the air. This leads to "over-consumption" of our common natural resource, the air. But if what is free today is given a price, and the resulting cost is charged to the polluter, it reflects more fairly what the use of various energy sources, for instance, actually costs society. "Dirty" energy, such as coal power, would become more expensive, while the price of "clean" energy, such as wind power, would remain un-

If each power generator had to pay for the environmental effect it caused it would increase the cost of power from coal and make wind power more competitive at the same time.

changed. Economists call this the "internalization of external costs".

A major benefit of environmental charges or taxes compared with regulation is that they often result in the cheapest and simplest measures being implemented first. One difficulty is deciding the level they should be set at to achieve the desired effect on emissions. Introducing economic incentives is a slow process in many countries, but once they are in place they work quickly and effectively. In Sweden there are several successful examples of the use of charges and taxes to reduce emissions of pollutants (see factfile page 143).

Differentiated charges and taxes are a further type of economic incentive. For example, a very large proportion of ships in Swedish waters run on low-sulphur oil, thanks to the differentiation of shipping dues and port fees based on sulphur emissions. The system is designed so that "dirtier" ships pay more than before, and "cleaner" ships pay lower fees, but total revenues are unchanged.

Trading emission rights

One drawback of environmental taxes, as well as emission standards, is that the effect on total emissions cannot be reliably predicted. If the aim is to reach a certain target within a given time period then the trading of emission rights may be an alternative. This method has been used since 1995 for emissions of sulphur dioxide from power plants in the US, where it has resulted in significant cost savings. The attraction is that it places a ceiling on total emissions. If it is expensive to reduce emissions at one power plant, emission rights can be bought from another plant where the cost of reducing emissions is lower. As a result of such trading the total cost is expected to be half what it would be if the requirement was imposed on each plant individually.

When it comes to the climate issue, trading in emission rights is a subject of hot debate. In strictly economic terms it is clearly an advantage if measures are taken where they are cheapest – the effect on the climate will be the same wherever emissions occur. However, the ability to buy extra emission allowances somewhere else could mean that the transition by industrialized countries to a sustainable energy system – which must take place sooner or later – is delayed.

Eco-labelling and purchasing requirements

Another market-based method of reducing emissions of air pollutants is the eco-labelling of cars, fuel, wood-burning stoves, goods freight, etc. Classification and eco-labelling make it possible to introduce differentiated taxes and charges as described above. Consumers can also use the system to choose the products that are best for the environment. Companies, authorities and individual consumers can also specify their own environmental requirements when deciding on a purchase. The combined effect is that manufacturers make better improvements to their products and do so faster than required by legislation.

FINANCIAL CARROTS

In the early 1990s Sweden introduced a sulphur tax and a levy on emissions of nitrogen oxides, both of which contributed to a reduction in acidifying emissions.

The **sulphur tax** was introduced in 1991 and applies to oil, coal and peat. However, fuels used in shipping, refinery processes and in industry are exempt. The tax rate is 30 kronor per kilogram of sulphur emissions. Between 1990 and 1995 the average sulphur content of heavy oils dropped from 0.65 to 0.35 per cent. For light heating oils and diesel oil it fell from 0.2 per cent to less than 0.1 per cent. The sulphur tax is estimated to have helped reduce Swedish emissions by almost 20,000 tonnes of sulphur dioxide per year, which is nearly 30 per cent of the overall reduction between 1989 and 1995.

The **nitrogen oxides charge**, which was introduced in 1992, applies to stationary combustion plants above a certain output. The levy is 40 kronor per kilogram of nitrogen dioxide emissions, but the money that is collected is paid back to the plants in proportion to the amount of useful energy they supply. A plant that has high emissions in relation to the energy it produces gets little or nothing back, while those with low emissions in relation to their energy production make a significant profit. The charge is estimated to have made a major contribution to the halving of emissions per unit of energy produced by the plants involved between 1990 and 1996.

Both the sulphur tax and the nitrogen dioxides levy have been highlighted as examples of well-designed incentives by the OECD and in an inventory by the European Environment Agency.

The consumer as decision-maker

The individual's choice has a big influence on his or her environmental impact. This applies to everything: from the food we eat, to the way we live, heat our house and how we travel from day to day and when on holiday.

In principle the customer is always right. If we do not want to buy artificially fertilized and pesticide-sprayed carrots, fuel-guzzling cars or electricity from coal power then these products will not be manufactured.

Power to change

By combining a variety of measures it is possible to avoid most environmental problems. A combined strategy could entail increasing the incentives that lead in the desired direction and at the same time weakening or removing those that have the opposite effect. Investment in research and development also plays an important role in building a sustainable future.

But what is needed in order for something to be done? Society is after all made up of people with many different viewpoints. Those who want to develop a sustainable society relatively quickly have not had the strongest voice so far. A fundamental requirement for change is the development of strong opinion in favour of an environmentally sound society, both among individuals and among decision-makers in industry and politics.

For this to happen it requires better knowledge at all levels about both the problems and the opportunities. The spreading of information and knowledge are therefore important tools, initially to gain acceptance for the necessary political decisions. With stronger public opinion on the environment, politicians will feel they have the support to push through effective legislation, including economic incentives.

Last but not least, information can help increase the proportion of the population who choose environmentally healthy products when shopping, which is clearly very important in light of how individual behaviour affects the overall environmental situation. The scope for changing people's lifestyles by means of information alone is however relatively limited according to several studies.