GOOD PRACTICE GREENHOUSE ABATEMENT POLICIES: ENERGY SUPPLY AND TRANSPORT

OECD and IEA Information Paper
FOREWORD

The document on the energy supply sector was prepared by Gene McGlynn (OECD) at the request of the Annex I Expert Group on the United Nations Framework Convention on Climate Change and as part of the OECD Environment Directorate and IEA programmes of work. Discussions at an Annex I Expert Group round table on energy supply measures on 16 September 1999 also was very helpful, especially presentations by Richard Kettle (UK), Midori Tani (Japan), Tracy Terry (US), Ture Hammer (Denmark) and Gwen Andrews (Australia).

The document on the transport sector was prepared by Gene McGlynn with input from Philippe Crist (OECD), Lew Fulton (IEA), and Mary Crass (ECMT). However, the papers do not necessarily represent the views of the OECD, the IEA or the ECMT, nor are they intended to prejudge the views of countries participating in the Annex I Expert Group. Rather, they are Secretariat information papers intended to inform Member countries, as well as the UNFCCC audience.

The Annex I Parties or countries referred to in this document refer to those listed in Annex I to the UNFCCC (as amended at the 3rd Conference of the Parties in December 1997): Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, the European Community, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland, and United States of America. Where this document refers to “countries” or “governments” it is also intended to include “regional economic organisations”, if appropriate.

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Further information, including other papers and presentations from the policy roundtables, is available at: http://www.oecd.org/env/cc/

To purchase the OECD Publication, National Climate Policies and the Kyoto Protocol, and other OECD publications, visit the OECD Online Bookshop at http://www.oecd.org/bookshop or send an email to sales@oecd.org.
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Preface

Climate change is one of the major global environmental challenges facing policy makers today. Greenhouse gas emissions arise from nearly every facet of modern life. Radical reductions from current emission levels in OECD countries, through changes in both technology and behaviour, will be necessary to achieve the long-term goal of stabilising greenhouse gas concentrations. This publication examines issues affecting implementation of climate change abatement policies in two key sectors - energy supply and transport.

The UN Framework Convention on Climate Change (UNFCCC) does not set out legally binding emission targets, but requires industrialised countries to adopt programmes and policies that aim to stabilise greenhouse gas emissions at the 1990 level in 2000. The Kyoto Protocol of the Convention establishes, for the first time, internationally agreed, quantified and comprehensive greenhouse gas targets for all industrialised countries. The Protocol calls on these countries, in aggregate, to reduce their emissions by around five per cent by 2008-2012 relative to 1990 levels.

Meeting the Kyoto targets could require OECD countries to reduce emissions in the 2008-2012 period to a level some 20 to 30 per cent below trend on average. The Protocol and the Convention provide cost-effective flexibility to mitigate emissions across the range of gases and sectors. Low cost opportunities to mitigate greenhouse gases exist in the forestry, agriculture and waste sectors, and some countries are exploiting these options. However, CO₂ emissions from fossil fuel combustion dominate greenhouse gas emission trends. Growth in the commercial, residential and transport sectors are likely to be the main drivers of future emission trends, along with the structure of energy supply. To be effective, domestic policy in the OECD will thus need do more to stimulate investment in cleaner technology and energy sources, encourage materials and energy efficiency, and changes in consumer behaviour.

While notable progress has been made in a few countries, policy action is partial and fragmented. New policies are necessary to achieve the Kyoto targets. Adaptive policy experimentation and learning from experience will be beneficial. OECD analysis suggests that gradual phasing in of action starting now will cost less than waiting for cheaper abatement technology to emerge in the future. More effective frameworks for action are needed now to help meet Kyoto targets cost-effectively, and to ensure success of future negotiations aiming to achieve the ultimate objective of the UN Framework Convention on Climate Change.

While there is no single formula for tackling climate change, and different countries require different policy mixes, studies to date point to a number of elements of a framework for “good practice”:

Getting prices right is a key to cost-effective responses. Subsidy reform (especially for energy and agriculture) can have both economic and environmental benefits. For example, OECD case studies indicate that abolition of selected fossil fuel subsidies could reduce CO₂ emissions from the energy sector by one to eight per cent. Fiscal policies that ensure consistency between economic and greenhouse gas objectives, including eco-taxes, may be especially effective.

Mitigation policies should use markets where possible. Domestic emission trading is a leading example of how environmental policies can operate in a market framework to achieve emissions reductions in a least cost manner. To be effective, such systems require good monitoring and effective enforcement as well as clear property rights to unambiguous emission limits. Several OECD countries are developing prototype systems and these may provide valuable experience for international emission trading as foreseen under the Protocol.
A mix of other policies will be required. Lack of information, mixed incentives and other market failures mean that voluntary approaches, standards, green government purchasing, incentives and seed funding in R&D, for example, will still be required. Policies will also need to target consumer behaviour. “Soft” policies provide information, training and raise public awareness and may be key to long term innovation. Cost-effectiveness is a key criterion in the design and implementation of these measures.

Closer monitoring and assessment of emissions and the impact of measures is also required. As we move to legally binding targets, it will be important that monitoring systems provide information that is transparent, accurate and reliable to support the Kyoto Protocol and its flexibility mechanisms.

Good institutions will be necessary to meet the multi-faceted challenge of climate change. This requires early engagement of many ministries, different levels of government and other stakeholders to build consensus and to take action. A key is achieving multiple benefits simultaneously, for example, to curb fossil fuel and unsustainable land use, while at the same time improving the local environment.

Finally, international co-operation is important. Countries are working to reduce emissions simultaneously, and can learn from each other. This requires regular contact between countries to share their experiences. International co-operation may also help give governments the resolve to reform subsidies and market distortions that lead to higher greenhouse gas emissions.

As part of its work supporting effective implementation of the UNFCCC, the OECD and IEA have conducted analyses of policies in the energy supply and transport sectors, and facilitated international dialogue between policy-makers. The Annex I Experts Group\(^1\) has held a series of roundtables on domestic policies, which included background analysis by the OECD and IEA Secretariat, and presentations and discussion by national delegates of country experience. This publication contains the overview papers from the discussions on energy supply and transport. Examination of other important areas of domestic policy is part of the ongoing work of the OECD and IEA on this important topic.

\(^1\) The Annex I Expert Group is an ad hoc group of government officials from Environment, Energy and Foreign Affairs ministries from countries that are listed in Annex I to the UNFCCC, and those that have acceded to Annex I commitments. Annex I countries include most OECD member states and some countries from central and eastern Europe and the Commonwealth of Independent States that are undergoing the process of transition to a market economy.
1. Greenhouse gas abatement options in the energy supply sector

1.1 Scope

Stationary energy use accounted for 64 per cent of total Annex I greenhouse gas emissions in 1990 and around 60 per cent in 1996\(^2\). About 98 per cent of the emissions from this sector are CO\(_2\). Business-as-usual projections indicate a rapid increase in these emissions to 2010, so further abatement efforts will be needed to meet the objectives of the Kyoto Protocol. While measures to increase energy efficiency from the demand-side will be important to this effort, the focus of this paper is on measures taken to reduce greenhouse emissions from the supply side.

1.2 Background and trends

Growth in emissions from stationary energy use has been relatively subdued over most of the last 25 years, with CO\(_2\) emissions only 16 per cent higher in 1996 than in 1971. This is the result of conflicting drivers of emissions in this sector. Both GDP per capita and population have risen, leading to greater levels of output and energy use. However, the energy intensity of production (i.e. the final energy consumed per unit of production) has fallen by almost 40 per cent from 1971 to 1996. Combined with a small fall in emissions intensity (i.e. tonnes of CO\(_2\) per unit of final energy consumed) largely due to an increase in nuclear and some shifts to natural gas, this has not quite offset the increases in output, leading to a small increase over time in emissions (see Figure 3). This suggests that, to achieve the reductions in the energy sector required to meet Kyoto targets, even with continuing energy efficiency improvements, will require attention to the supply side of the equation.

Outside OECD, Annex I emissions are dominated by transition economies of eastern Europe and the Former Soviet Union, where massive falls in GDP following economic and political restructuring around 1990 have led to significant falls in energy-related emissions in most of these countries.

Growth in emissions from energy industries was strong in most countries other than EITs. Growth in this sector occurred even in some EIT countries where overall emissions declined. For Annex I as a whole, however, emissions from this source grew by only one per cent from 1990-96, compared with an increase in overall emissions of two per cent\(^3\). This is due to the decline in EIT emissions from this sector and to a large fall in Germany and the UK for reasons of economic and sector policy changes. In the case of the UK, subsidy reform resulted in significant reductions in emissions.

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\(^2\) From UNFCCC “official” national statistics, excluding LUCF. Based on available data. A number of countries, including some large emitters, have not yet reported data for 1996.

\(^3\) Source: UNFCCC “official” national data. Data for Liechtenstein, Lithuania, Russian Federation, Slovakia, Slovenia, Ukraine were unavailable. 1995 data used for Iceland, Italy, Luxembourgh, Japan, and Spain. 1994 data used for Portugal. Excludes LUCF sector. If data for missing EITs for whom data is lacking were included, both energy industry and overall emissions would likely decline. It should also be noted that increases in some countries and declines in others nearly cancel each other out. As a result, the overall change in Annex 1 emissions is very small, so small changes would lead to large changes in percentage outcomes. Therefore, aggregate figures should be treated with caution.
There is no direct match between the stationary energy supply sector as defined in this paper and UNFCCC inventory categories. However, “Energy Industries” would be the focus of many abatement measures in the energy sector, and account for a large percentage of emissions in most Annex I countries. Those countries where this is not the case are those which rely heavily on renewables or nuclear power for their electricity needs. Even these countries need to pay careful attention to the energy supply sector in the future if energy demand grows and the potential for further major hydro or nuclear power is limited. For example, while energy industries accounted for only 20 per cent of national emissions in Sweden in 1996, growth in this sector accounted for 73 per cent of total emission growth. On average, “energy industries” accounted for 46 per cent of the total change in national emissions from 1990 to 1996.4

Figure 1: **Contributors to CO₂ emissions growth from stationary energy OECD 1971-1996**

- GDP per capita
- Population
- CO₂
- Emissions Intensity
- Energy Intensity

*Source:* IEA Energy and CO₂ statistics.

4 Does not include countries where energy industries moved in the opposite direction to total emissions.
Table 1 shows the breakdown of emission sources from Annex I countries in 1996. Stationary energy use accounts for around 60 per cent of total emissions. The largest sub-sector is “energy industries” which includes electricity generation as well as refining. Electricity production accounts for the largest and growing proportion of these emissions. From 1971 to 1995, Annex II CO₂ emissions from electricity as a percentage of total energy CO₂ emissions grew from 26 to 35 per cent, despite improvements in the average emissions intensity of electricity production. (Ellis and Treanton 1997). This is due to the steadily increasing share of electricity consumption in total final consumption (see Table 2), and the relatively high emissions per unit of delivered energy from electricity. Table 2 also shows the different patterns of energy use among different sectors, significant declines in direct combustion of coal and oil, and the growth in direct combustion of natural gas.

<table>
<thead>
<tr>
<th>Source: emissions in Annex I, 1996</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel Combustion</strong></td>
</tr>
<tr>
<td>Energy Industries</td>
</tr>
<tr>
<td>Industry/Construction</td>
</tr>
<tr>
<td>Transport</td>
</tr>
<tr>
<td>Residential/Commercial/Agriculture</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td><strong>Fugitive Emissions from Fuels</strong></td>
</tr>
<tr>
<td><strong>Industrial Processes</strong></td>
</tr>
<tr>
<td><strong>Agriculture</strong></td>
</tr>
<tr>
<td><strong>Waste</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

Source: UNFCCC “official” national data. Not all countries have reported data for 1996.

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5 That is, the 82 per cent from energy combustion less the 22 per cent from transport. This figure is not exact since some fugitive emissions are from leakage in gas supplies and so rightly belong with energy supply. Also, the energy used to refine transport fuels could be allocated to transport but this is not done here.
Table 2: Shares of fuels in final consumption, OECD

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industrial</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>18%</td>
<td>15%</td>
<td>16%</td>
<td>11%</td>
</tr>
<tr>
<td>Oil</td>
<td>39%</td>
<td>37%</td>
<td>31%</td>
<td>32%</td>
</tr>
<tr>
<td>Gas</td>
<td>23%</td>
<td>25%</td>
<td>26%</td>
<td>28%</td>
</tr>
<tr>
<td>Electricity</td>
<td>14%</td>
<td>17%</td>
<td>22%</td>
<td>24%</td>
</tr>
<tr>
<td>Renewables</td>
<td>4%</td>
<td>5%</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td>Heat</td>
<td>1%</td>
<td>2%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Commercial</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>8%</td>
<td>6%</td>
<td>4%</td>
<td>1%</td>
</tr>
<tr>
<td>Oil</td>
<td>51%</td>
<td>43%</td>
<td>34%</td>
<td>33%</td>
</tr>
<tr>
<td>Gas</td>
<td>23%</td>
<td>23%</td>
<td>24%</td>
<td>26%</td>
</tr>
<tr>
<td>Electricity</td>
<td>18%</td>
<td>26%</td>
<td>36%</td>
<td>38%</td>
</tr>
<tr>
<td>Renewables</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Heat</td>
<td>0%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Residential</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>15%</td>
<td>11%</td>
<td>8%</td>
<td>3%</td>
</tr>
<tr>
<td>Oil</td>
<td>35%</td>
<td>27%</td>
<td>20%</td>
<td>19%</td>
</tr>
<tr>
<td>Gas</td>
<td>28%</td>
<td>33%</td>
<td>35%</td>
<td>38%</td>
</tr>
<tr>
<td>Electricity</td>
<td>15%</td>
<td>22%</td>
<td>29%</td>
<td>29%</td>
</tr>
<tr>
<td>Renewables</td>
<td>5%</td>
<td>5%</td>
<td>6%</td>
<td>7%</td>
</tr>
<tr>
<td>Heat</td>
<td>1%</td>
<td>2%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>15%</td>
<td>12%</td>
<td>11%</td>
<td>6%</td>
</tr>
<tr>
<td>Oil</td>
<td>43%</td>
<td>38%</td>
<td>32%</td>
<td>32%</td>
</tr>
<tr>
<td>Gas</td>
<td>23%</td>
<td>26%</td>
<td>27%</td>
<td>29%</td>
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<tr>
<td>Electricity</td>
<td>14%</td>
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<tr>
<td>Renewables</td>
<td>4%</td>
<td>5%</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>Heat</td>
<td>1%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Source: IEA Energy Statistics.
Table 3 shows the shares of fuels in electricity generation, with rapid growth in the share of nuclear in the 1970s and 1980s, followed by a levelling out in the 1990s. Among fossil fuel sources, coal has greatly increased its share, with natural gas showing a greater penetration only in recent years. Oil and hydro have lost share, with oil falling to a lower share than all major sources except “new” renewables. These non-hydro renewables have increased rapidly, but from a very small base. The growth in nuclear and coal played the largest, but offsetting roles in changing the emissions intensity of electricity production.

<table>
<thead>
<tr>
<th>Year</th>
<th>Coal</th>
<th>Nat Gas</th>
<th>Oil</th>
<th>Nuclear</th>
<th>Hydro</th>
<th>Other Renewables</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>40%</td>
<td>13%</td>
<td>22%</td>
<td>3%</td>
<td>23%</td>
<td>0%</td>
</tr>
<tr>
<td>1980</td>
<td>41%</td>
<td>11%</td>
<td>17%</td>
<td>11%</td>
<td>19%</td>
<td>0%</td>
</tr>
<tr>
<td>1990</td>
<td>41%</td>
<td>10%</td>
<td>9%</td>
<td>23%</td>
<td>15%</td>
<td>2%</td>
</tr>
<tr>
<td>1997</td>
<td>39%</td>
<td>13%</td>
<td>7%</td>
<td>23%</td>
<td>15%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Source: IEA Energy Statistics.

1.3 Policy context

While a wide range of factors influence emissions from the energy supply sector, a few key influences will be important in setting the context for greenhouse abatement in this sector in future:

Institutional

Importance of other policy concerns - Until recently, greenhouse has been a marginal consideration, if any, in national energy policies. Following the oil shocks of the 1970s, energy (especially oil) security was a major policy driver responsible for many developments on both the supply and demand side. While concern with energy security has lessened in the 1990s, it remains a policy concern, and an important one for many countries. Recent oil price increases may increase concerns over oil security. Other environmental concerns have also been important to energy policy since the 1970s, especially air quality and sulphur issues. In recent years, ensuring competitive and reasonably priced energy supply has been a major energy policy driver, leading to substantial market reform. This is driven in large part by concerns to ensure the international competitiveness of national economies. It is only very recently, and more so since Kyoto, that climate change has become a central concern in energy policy in most countries.
Therefore, many “greenhouse” policies in the energy sector are actually policies implemented for other reasons. While some non-greenhouse energy policies are compatible with or indirectly linked to abatement, others are neutral or lead to increased emissions. The challenge of meeting Kyoto targets means countries may need to design energy policy solutions which meet different policy objectives simultaneously.

Energy market reforms - Governments have traditionally played a major role in the provision of energy. Electricity generation and distribution assets are often government owned, and many aspects of energy supply are tightly regulated. A number of governments are engaged in reform programmes to open the energy supply sector to greater competition. This has a number of effects, with differing impacts on greenhouse emissions. A key objective of reform is to lower energy prices, so it seems likely that overall consumption will increase, especially as reform can lead to the reductions in demand management programmes. However, there will also be many effects on the supply side. For example, in electricity generation, greater competition could favour investment in combined cycle gas rather than more capital-intensive coal or nuclear power stations. Competition may also enhance pressures to increase the efficiency of existing generating plant and transmission/distribution systems, provide signals for load and generation to locate close to each other so as to reduce transmission losses, or improve peak load management. Central to the effect of market reform on greenhouse will be the incentives it provides for fuel switching. While there appears to be a general view that reform will encourage a shift to nature gas, the environmental impacts of this vary depending on current fuel use patterns. For example, the UK “dash for gas” away from coal will lower greenhouse emissions while some Nordic countries will see a shift to a higher carbon fuel mix away from hydro and nuclear. Some countries have introduced environmental regulations with energy market reforms to better ensure simultaneous achievement of economic and environmental objectives. Abatement measures need to recognise the energy market context, which is increasingly competitive and dynamic.

Technical

Long planning horizons - Most energy infrastructure is long-lived. This means that change is difficult except over long time periods. For example, projections by the US EIA show that by 2000, 77 per cent of electricity supply in 2010 and 63 per cent of supply in 2020 will already have been built. As it is difficult and expensive to substantially change the operating characteristics of existing plant, this means that investors in energy supply must be considering greenhouse outcomes today to make substantial reductions in the Kyoto timeframe, especially as energy supply options can take 2-5 years to plan and construct before they are operational. Effective control of energy demand will further limit the ability to make major changes on the supply side since there will be less turnover of plant. So, interactions between supply and demand abatement strategies can be important.

Increasing electrification - the share of electricity as a source of energy CO₂ emissions has risen steadily for Annex II countries, from 26 per cent in 1971 to 35 per cent in 1995. This increase occurred despite a steady decline in CO₂ emissions per kWh, due to increased use of nuclear power and renewables, switching from coal to gas, and increased production efficiencies. The latter has occurred through technologies such as combined cycle gas turbines (Ellis and Treanton 1998). The share of electricity in final energy consumption is increasing for two major reasons. First, there has been more relative growth in the commercial and residential sectors than in the industrial sectors. These sectors have a relatively higher reliance on electricity as an energy source and there is an increasing range of electrical applications (electronic consumer goods, computers and related communications equipment, etc) for which there are no alternatives. Secondly, in all sectors, the share of energy from electricity has grown substantially (see

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6 Figures for the US only. From EIA 2000, Reference Scenario.
Table 2). This increase comes mostly at the expense of direct combustion of oil products, and reflects government efforts to reduce reliance on oil, as well as natural advantages of electricity as an energy source. Increasing electrification can slow improvements in emissions intensity of energy supply, as it can require up to 3 units of energy for every unit available for final consumption\(^7\). The ratio of TPES/TFC in OECD countries has risen directly in line with the increasing role of electricity in energy supply. If the rate of electrification continues, it will provide an extra challenge to keeping emissions under control, as well as emphasise the requirement for low or no-emissions electricity production.

Nuclear - between 1973 and 1996, nuclear rose from only one per cent of total energy supply to 11 per cent, although most of this growth occurred from plant orders placed before 1980. Nuclear accounted for almost 40 per cent of the total growth in primary energy consumption over this period. However, recent experience suggests that nuclear may play a limited future role in all but a few OECD countries. This means that the successes in reducing emissions intensity of energy supply achieved through nuclear will need to come from other sources. Through the 1980s and early 1990s, switching from coal to gas and increases in the efficiency of generation have allowed this. However, such changes will need to continue, or other zero-emission sources will need to grow rapidly, to continue this rate of decline in emissions intensity. Some countries are already discussing early phaseout of their nuclear capacity, and much existing nuclear capacity will start reaching the end of its life in the first quarter of the next century, further emphasising the importance of addressing the role of nuclear.

1.4 Choosing abatement measures

In developing approaches to greenhouse response, governments will address the key sectors causing emissions, of which the energy supply sector will be key. Countries have a range of approaches available to abate greenhouse emissions from the energy supply sector. In broad terms, these include:

- Switching to zero-emission fuels
  - Increased use of renewables
  - Increased use of nuclear
- Switching to lower-emission fuels
  - Switching from coal or oil to natural gas
- Improving the efficiency with which energy is transformed and distributed
  - Increased use of cogeneration/CHP
  - Improving the efficiency of combustion in “standard” fossil fuel power plants
  - Reducing transmission and distribution losses

\(^7\) This does not mean that electrification necessarily increases overall emissions however. If an electric application is far more energy efficient for the user, it can lead to a reduction in overall energy demand which can offset the increased emission intensity.
There are then a host of potential measures to achieve one or more of these outcomes. Strategic consideration of which approaches offer the most potential and which types of measures are favoured result in selection of a specific set of measures. These choices could include elements of all the above approaches. Factors that could affect strategic assessment of measures could include cost-effectiveness, equity impacts, ancillary costs and benefits (i.e. impacts on other policy goals such as environmental impacts, energy security or innovation), or perceptions of risk and technological potential.

Figure 2 illustrates the role of strategy in moving from technical options to specific measures. The split of sectoral emissions determines the total abatement potential from various sectors and sub-sectors. Consideration of technical options indicates the technical potential of different approaches, and their costs and other impacts. Strategic choices are then made on the range and types of measures undertaken, based on explicit and implicit criteria.

Some measures address all approaches by providing comprehensive signals to abate emissions throughout the economy. For example, carbon taxes or domestic tradable emissions permits would allow companies and individuals to choose cost-effective abatement methods across the range of technical approaches. For technical and other reasons, most countries have chosen not to implement such comprehensive measures. Even those countries that have introduced carbon taxes have also adopted a range of sector-specific initiatives to address emissions. Therefore, it is important that such measures be implemented in an effective and efficient manner. In considering such measures, a good starting point is to consider what, if any, specific benefits are provided by sectoral measures. If these sectoral measures are implemented because of shortcomings in more comprehensive market measures, it will be important that they are designed and implemented so as to effectively address such shortcomings.

Figure 2: **Relationship of sectors, technical approaches and measures**
In considering options to reduce emissions from energy supply, it is important to consider the range of technologies available to meet energy needs. Some energy applications have limited options for technological choice. For example, many household and commercial appliances, and some industrial applications are only available for use with electricity. Others, such as space and water heating, have a range of potential fuel and technology choices.

Within electricity generation, the operating characteristics of nuclear and coal-fired power make them very suitable for base load but not peaking capacity. Oil, gas, and hydro, on the other hand, have more flexibility for matching load, while also being useful for baseload when the economics stack up. In some cases, generation is available primarily for standby or emergency purposes, and it is more difficult to economically justify advanced technologies in these situations. While cogeneration can be highly efficient, it requires a matching of electricity and heating needs which is not always present.

Availability of resources also has strong influences on fuel and technology choice. This is most obvious for renewable sources such as wind, solar and hydro where resource quality and availability is very location-specific. However, access to gas pipelines, transmission grids, coal mines, etc can influence the economics of choices such as fuel, whether to use cogeneration or not, etc.

Within electricity generation, there is a wide range of technologies available, all with different costs and emissions profiles. Table 4 broadly indicates the range of choices. This shows that both costs and emission vary widely within fuel and technology choices. Even the same technology in different locations can vary considerably due to differences in fuel costs, labour costs, load factors, etc. This table also indicates the difficulties in calculating the emissions abatement costs of different approaches, since there is wide variation in both the BAU technology and the alternative. In principle, the cost-effectiveness of options affecting technology in fuel choice in electricity generation is a function of the reduction in emissions relative to BAU divided by the difference in levelised cost. However, in practice, it is difficult to make such generic cost comparisons for a number of reasons, beyond the spread of potential costs and emissions. Reasons include:

- Table 4 only includes generation costs. In some cases, technologies such as local renewable applications or cogeneration can reduce transmission and distribution costs, which can account for up to half of the cost of delivered electricity. It is this delivered cost on which cost comparisons should theoretically be made, although it can be difficult in practice to allocate fixed and marginal costs of transmission and distribution.

- A proper analysis of relative costs and emissions should be based on full life-cycle emissions. While emissions from actual combustion of energy are relatively easy to calculate and compare, it is harder to correctly allocate the upstream emissions. Venting and flaring from natural gas production, methane emissions from coal mining, processing of nuclear fuel, emissions from cement production in large hydro dams, growing and collecting biomass fuels, and construction of solar panels can all lead to significant emissions. Measuring and tracking these changes through the energy supply chain is difficult, so caution should be used in interpreting these figures. While this paper does not deal directly with measures to reduce upstream emissions, changes to fuel demand will also have upstream impacts. Similarly, upstream measures will affect the effectiveness of measures in the energy supply sector.

- Table 4 does not include other ancillary impacts of different forms of electricity production. For example, there are many non-greenhouse environmental concerns associated with use of nuclear and large hydro generation. Coal-based electricity is a major source of sulphur as well as greenhouse emissions, and cogeneration can lead to increased levels of NOx emissions in densely settled areas. Renewable sources such as wind and wave technology have environmental concerns attached to them,
although these tend to be far more localised. All of these effects have values that should be accounted for in assessing cost-effectiveness. Studies of ancillary effects of energy use indicate that health effects associated with increased air pollution are the dominant source. Recent studies have shown that the ancillary benefits of greenhouse gas reductions policies can be significant, accounting for 60 per cent or more of the costs of abatement.

- Due to different ownership structures for different technologies, there may be different sharing of risks amongst different technologies. For example, risks of outages or accidents from small scale renewables and cogeneration will generally be borne by the user/operator while those for large scale plant will generally split risks be borne by the operators and charged to users. In some cases, such as nuclear, there may be implicit or explicit sharing of risks with governments. These different approaches have implications for the relative valuation of different technologies.

Table 4: Comparison of costs and emissions from different fuel sources and technologies

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Emissions (g CO₂/kWh)</th>
<th>Levelised Generation Cost (cents/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>650-1300</td>
<td>3.5-7.6</td>
</tr>
<tr>
<td>Gas</td>
<td>400-1000</td>
<td>2.4-8.4</td>
</tr>
<tr>
<td>Nuclear</td>
<td>25</td>
<td>3.9-8.0</td>
</tr>
<tr>
<td>Renewables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomass</td>
<td>15-27</td>
<td>2.6-7.8*</td>
</tr>
<tr>
<td>Hydro</td>
<td>3.6-11.6</td>
<td>3.5-6.9</td>
</tr>
<tr>
<td>Solar PV</td>
<td>98-167</td>
<td>19.6-138</td>
</tr>
<tr>
<td>Wind</td>
<td>7-9</td>
<td>4.2-45.7</td>
</tr>
<tr>
<td>Geothermal</td>
<td>79</td>
<td>3.6-17</td>
</tr>
<tr>
<td>Coal</td>
<td>430</td>
<td></td>
</tr>
</tbody>
</table>

Sources: IEA/NEA 1998 (based on generic assumptions at 10% discount rate), IEA 1998b, IEA 1998c, Echavarri, 1998, EC 1995 McDonald et al 1996, IEA GHG R&D. As there are many differences in methodologies and assumptions between these sources, these comparisons should be seen as broadly indicative only.

* - low end of costs based on CHP co-firing.
1.5 Lessons from experience
Governments operate in widely differing economic, social and physical environments, which require consideration in developing national policies. However, based on experiences to date, there are some general observations that can be made in relation to greenhouse abatement actions in energy supply.

At an Annex I Experts Group Roundtable on 16 September 1999, delegates considered presentations on a range of alternative approaches in energy supply. These included:

- The Non Fossil Fuel Obligation (NFFO) - UK
- Nuclear expansion - Japan
- Efficiency Standards for Power Generation - Australia
- Energy Market Reform - USA
- Cogeneration - Denmark

These case studies, which are summarised in the Appendix, highlighted a number of lessons for policy making in this sector:

- With the exception of the Australian efficiency standards, all of these measures were put in place for reasons other than greenhouse response. In some cases, such as the NFFO and Cogeneration in Denmark, greenhouse appears to have grown over time as a policy basis for the measure. It thus appears that greenhouse response can be an “additional” reason for pursuing particular policies, but that it is not yet a primary driver for most energy supply policies.

- With the possible exception of nuclear expansion in Japan, there appears to be a lack of (publicly available) information comparing the cost-effectiveness of alternative approaches to reducing emissions from energy supply. This is despite the fact that this sector, more than many others, lends itself to such analysis. The methods by which governments have chosen specific measures in comparison to others, or the level to pursue particular measures, is not always clear.

- Potential ancillary benefits of measures (e.g. changes in air pollution levels) do not seem to have been included in policy assessment in a systematic fashion.

- The energy market reform process has a number of elements, some of which lead to increases in emissions and some to decreases. Reform generally impacts on the effectiveness and design of other energy supply measures. Countries undertaking reform processes often introduce complementary measures to ensure environmental benefits as well as lower prices.

- Measures actually in place have evolved over time to meet changing needs, priorities and market realities. Effective policies need regular review and redesign (which could include abandonment) to ensure an effective policy mix.

Based on these discussions as well as a review of other information from the OECD, IEA and UNFCCC, a number of broad lessons for policy design, selection and implementation in the energy supply sector can be drawn.
General issues of policy design

Assessing effectiveness

- Business-as-usual trends generally include some positive greenhouse abatement actions already, especially in relation to penetration of natural gas. Any measures will need to achieve savings beyond this to move away from BAU toward achievement of Kyoto objectives.

- The cost-effectiveness of many measures falls if gas is assumed to play a greater role in BAU, since the emissions savings will generally be smaller. Targeting mitigation or replacement of existing sources with the highest emissions intensity may assist effective abatement strategies.

Integrating economic and environmental objectives

- Comprehensive measures such as taxes and tradable permits can generally give incentives for least cost abatement. Where market distortions and other reasons lead to adoption of sector-specific measures, it is important to identify the reason for using such measures, and ensure the measures address these reasons directly.

- Given the challenges of meeting Kyoto targets, maintenance of emission-increasing subsidies to fossil fuel use appear unsustainable. Reform of such subsidies offers considerable potential for no regrets emissions reductions.

Time frames for change

- Electricity generation is dominated by long-term investments. This has a number of implications:
  - Action to achieve significant savings beyond business-as-usual will need to start immediately if the Kyoto commitments are to be met.
  - Any actions will need to provide incentives for investment in lower emissions technologies. These incentives will need to be of sufficient size up-front to make these investments attractive, or there must be relative certainty that on-going incentives will continue for some time.
  - Actions to reduce emissions from new plant will need to achieve significant emissions intensity improvements if they are to contribute significantly to meeting Kyoto commitments, since only a small portion of total plant in 2008-12 is affected.
  - Governments should already be considering their post-2012 emissions profile and potential emission reduction objectives.

- Over short to medium time frames, improvements to existing plant may achieve greater savings than changes to new plant. However, this can require expensive premature retirement of capital if measures are not timed carefully.
Relationships between measures

- Many alternative approaches are competing for the same policy space. For example, renewables, nuclear and gas are all potential fuel sources with abatement potential. If all are promoted for the relatively small portion of total plant to be built between now and 2010, there are significant limits on what can be achieved by any of the options. Current large reserve generation capacities, possibilities for repowering of existing plants and better use of existing capacity as trade increases all may exacerbate this problem. Governments need to consider interactions between alternative approaches, and evaluate whether particular options are more cost-effective in particular niches.

- Where a mix of sectoral measures is adopted, it is important that this mix be co-ordinated to achieve the desired outcome. For example, R&D support may be ineffective without commercialisation incentives, but commercialisation incentives for technology that is not yet sufficiently developed will be wasteful. Similarly, incentives to use certain fuels will be ineffective if distribution infrastructure is not yet in place. And to better ensure greenhouse benefits from energy market reform, it will be important that reform of natural gas and electricity markets move in parallel.

Choice of technical approaches

In relation to the policies countries have adopted to date:

- There is a wide range of regulatory and financial mechanisms to promote the growth of renewables energy. In general, these programmes appear to recognise that promoting renewables is not a pure “no regrets” measure.

- Nuclear energy continues to be heavily subsidised through large government R&D spending. While this spending is focused in a small number of countries, its magnitude means that nuclear continues to receive around half of government energy R&D spending.

- There also appears to be relatively wide government support (regulatory and financial) for cogeneration/CHP. However, it is not clear that these measures in general move beyond no regrets, rather than attempting to deal with institutional difficulties in reaping the economic and environmental benefits of these technologies.

- In relation to other approaches (fuel switching, efficiency of generation and transmission and distribution), governments seem more reluctant to move beyond “no regrets” policies. The most common measure to implement these approaches is energy market reform, where greenhouse outcomes are not the primary objectives. In many cases, these approaches do appear to yield greenhouse benefits on the supply side. However, it is uncertain that reliance on such mechanisms will be enough to achieve the Kyoto target, especially as these approaches are the only ones to address emissions from existing plant, which will dominate total energy use and emissions in 2008-12. Also, it is important to recognise that reform processes will vary in their environmental (and economic) impacts, and in some cases greenhouse emissions may rise. While reform can deliver incentives for efficiencies, fuel switching and cogeneration, there is no guarantee that it will do so, or to what extent. Greenhouse policy-makers have an interest in the pace and nature of energy market reform given its potential impacts on greenhouse emissions.

Overall, there appears to be a heavy focus on making reductions through investments in new plant. However, the relatively small addition to new plant to the year 2008 means that more attention to reducing emissions in existing plant may be required. Table 5 indicates some considerations that will affect choice amongst alternative approaches. For each of the approaches discussed in this paper, this table shows:
Technical Emissions abatement potential in the Kyoto time frame (i.e. to 2012) and the long term. This reflects both levels of savings from individual application of these approaches and potential penetration rates.

Rationale for government involvement - apparent reasons for governments to intervene in various ways to support these approaches to reducing emissions. While greenhouse emissions are clearly a concern, there are also many other relevant issues, many of which are essentially “ancillary benefits” of greenhouse reduction policies.

Abatement cost - the cost of promoting this approach beyond business-as-usual relative to the savings achieved. Because of many location- and technology-specific factors, this can only be broadly indicative.

Other considerations - other factors that could affect choices to use this approach as a greenhouse abatement measure. Cost constraints are not included, as they are an element of abatement cost analysis.
<table>
<thead>
<tr>
<th>Approach</th>
<th>Technical emissions abatement potential (Kyoto timeframe/long term)</th>
<th>Rationale stated for government involvement (other than greenhouse savings)</th>
<th>Abatement cost (i.e. costs relative to BAU technology)</th>
<th>Other (non-cost) considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Energy Supply Measures</td>
<td>Limited by rate of new construction, cost of retiring existing plant/ 100%</td>
<td>See below</td>
<td>Varies – see below</td>
<td>Preference for demand side abatement?</td>
</tr>
<tr>
<td>Renewables</td>
<td>Limited by cost/ Unlimited if storage is addressed</td>
<td>Other environmental benefits</td>
<td>Cost-effective in niche applications. High cost in many mainstream applications, but costs falling. Some community willingness to pay extra for renewable energy</td>
<td>Some localised environmental concerns</td>
</tr>
<tr>
<td>Nuclear</td>
<td>Zero in many countries, Limited due to approval &amp; construction times/ Potentially all electricity generation if concerns addressed</td>
<td>Other environmental benefits</td>
<td>Depends on discount rates and fossil fuel costs; but generally high rising with market liberalisation</td>
<td>Concerns over potential accidents, nuclear waste disposal and weapons proliferation.</td>
</tr>
<tr>
<td>Fuel switching to natural gas</td>
<td>Limited by turnover rates and inability to convert many existing plants/ Very large, limited only by fuel accessibility</td>
<td>Enhanced competition in energy markets</td>
<td>Generally low for electricity generation, especially for new plant and in competitive markets</td>
<td>Infrastructure availability.</td>
</tr>
<tr>
<td>Cogeneration</td>
<td>Perhaps a doubling of current rates/Limited to 30-40% (?) of electricity generation</td>
<td>Enhanced competition in energy markets Information failure in markets Other environmental benefits</td>
<td>Low where application is appropriate</td>
<td>Limit on suitable sites</td>
</tr>
<tr>
<td>Enhanced combustion efficiency</td>
<td>Significant in new plant but limited in existing plant/Large</td>
<td>Enhanced competition in electricity markets Local industrial/residential development</td>
<td>Gradual improvements very cost-effective; rapid change can be costly</td>
<td>Changes to fuel may swamp changes available through this approach</td>
</tr>
<tr>
<td>Reduced transmission and distribution losses</td>
<td>Limited/Limited unless colocation of load and generation is much greater</td>
<td>Enhanced competition in electricity markets</td>
<td>Small changes cost-effective. Colocation depends on transmission pricing signals.</td>
<td>Few perceived ancillary benefits of this approach to make beyond no regrets actions attractive</td>
</tr>
</tbody>
</table>
1.6 References


IEA (1998b), Renewable Energy Policy in IEA Countries: Volumes I and II.


First and Second National Communications of Annex I countries, and Indepth Reviews of National Communications of various countries by the UNFCCC.
2. Domestic climate policies and measures in the transportation sector - Roundtable summary

On 18 February 2000, the Annex I Expert Group (AIXG) held a one-day roundtable, chaired by Andrej Krancj of Slovakia, on domestic climate policies and measures in the transportation sector. This roundtable was one of a series convened by the AIXG to share experiences in member countries with implementation of domestic policies to abate climate change. The roundtable covered recent developments at the national level, technology and social innovation, in passenger and freight transport.

A summary of the roundtable follows. This publication also includes the background papers prepared for each of the three sessions.

Session 1: Transport and climate change: an overview of key issues

Gene McGlynn (OECD) briefed the group on background information, indicating the rapid growth in transport sector emissions, apparent ineffectiveness of policies to date, comparisons with the stationary energy sector indicating the more significant challenges in transport sector abatement, and possible elements of a policy framework. John Dodgson (NERA, for ECMT) then presented a framework for quantification of the impacts of transport sector policies, indicating the importance of careful modelling of changes in the vintage and stock of motor vehicles, rates of technological progress, and relationships between different abatement measures. Maurice Girault (France) outlined some elements of proposed new greenhouse abatement actions of the French Government, indicating the apparent difficulty in reaching the Kyoto target in transport without significant economic cost, and the importance of actions at the European level. Martin Kroon (Netherlands) outlined actions the Dutch government was implementing, with a strong focus on enhancing driver awareness of the environmental consequences of driving behaviour and recognition that transport choice was affected by motivations other than transport alone. The discussion included a number of views on pricing, including the relative importance of the size of increases versus the predictability, importance of charges other than petrol taxes, demand elasticities of fuel prices versus elasticities of parking or other factors, and the importance of how petrol tax revenue is spent. There was also discussion of the size of potential no-regrets measures, the need to integrate environmental concerns in sectoral policies, and the importance of road quality. There was a general view that more attention to the specific concerns of EITs was needed.

Session 2: Technological change in the transport sector

Lew Fulton (IEA) presented the issues paper on voluntary agreements, indicating the ambition and innovation of the EC agreement and the availability of technologies to meet the target. He also pointed out potential difficulties with the agreement, including the need for governments to deliver on fuel quality outcomes and the need for complementary measures to ensure market demand for more efficient (and more expensive) vehicles. These could include fuel consumption-based fees (or “feebates”, fees combined with rebates), and incentives for the adoption of advanced, “next generation” technology. Gunter Hoermandinger (EC) briefly discussed some of the implementation steps associated and indicated that the EC is working with the auto industry and others to monitor the agreement and consider follow up steps. Frazer Goodwin (Transport and Environment) questioned the speed and efficacy of the EC VA, but indicated it did have potential if it were strengthened. In the discussion, questions were raised as to

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8 This paper was written by Gene McGlynn, OECD.
whether VAs provided adequate support for downsizing of the vehicle fleet, how transparency of VAs can be reached, how VAs could be enforced, whether VAs were preferred to regulation and whether limiting VAs to specific markets could lead to problems of competitiveness and global shifts in the nature of markets that would make VAs globally less effective.

Session 3: Policy responses in freight transport

Philippe Crist (OECD) briefed the group on the importance of freight transport, the rapid growth in freight volume and the likely inability of technology to outweigh the growth of freight volume and reduce emissions. He also indicated the potential emission reductions through logistics management, and the wide spread in emissions performance among different fleets, but the lack of policy frameworks to support such improvements. Shinji Nakagawa (Japan) identified approaches the Japanese government is taking to reduce freight emissions, including promoting more efficient use of large, efficient vehicles, and infrastructure to support inter-modal freight transport. Discussion included the difficulties of targeting small trucks, the potential importance of information technology in creating and managing transport demand, the low percentage of total costs accounted for by transport, and the need for careful data analysis to understand real differences in emissions intensity of modes.
3. Greenhouse abatement policies in the transport sector: an overview

3.1 Background
The transport sector accounts for 20-25 per cent of Annex I GHG emissions. From 1990 to 1996, transport sector GHG emissions grew by around ten per cent in the OECD, accounting for more than half the total growth in emissions. In most EIT countries, emissions from the transport sector account for less than ten per cent of total emissions, and fell from 1990 to 1996 due to economic restructuring and GDP declines. However, this was not universal, and recent trends indicate that emissions from this sector may now be increasing in many EIT countries. Road transport is the dominant source of emissions in both passenger and freight movement. Roughly speaking, passenger transport accounts for 60 to 70 per cent of emissions.

Emissions from road transport are a function of many factors, which can be classified as:

- Activity - the level of transport tasks undertaken
- Structure - the split between different modal shares (road, rail, air, water)
- Intensity - the efficiency with which energy is used to complete travel tasks
- Fuel - the types of fuel used to power transport

These can be broken down further. Modal activity, in passenger or tonne-km, depends on vehicle activity, vehicle capacity, and actual capacity utilisation. Modal intensity in turn can be decomposed into vehicle intensity (fuel/km) and utilisation. Vehicle intensity depends on a vehicle’s size and characteristics (like speed, weight, and power), and on actual driving conditions. All of these variables are subject to policies that provoke changes in technologies and changes in consumer or user habits and behaviour. Good policy analysis depends on understanding these variables ex ante, and detailed evaluation to follow their evolution over time.

3.2 Drivers and trends

Activity
The level of transport activity relies on the underlying demand for mobility of people and goods, the nature of transport infrastructure and load factors. These are in turn driven by growth in wealth and trade, consumer tastes, lifestyles, urban development patterns and other factors. Historically, GDP growth and the expansion of the transport sector have been strongly correlated, while road transport has grown even faster.

While patterns vary somewhat from country to country, general trends in the last 20 years or so in passenger transport include:

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9 This paper was written by Gene McGlynn, OECD.
10 Excluding land use change and forestry, and bunker fuels.
Increasing levels of car ownership (which has impacts both on levels of travel and modal split)

In road transport, falling average load factors (persons per car) due to more (mostly single-person) commuting trips, smaller households and higher car penetration. By contrast, load factors for aviation are much higher as a percentage of capacity and have increased in recent years.

Increasing average distance travelled per capita, due to changes in urban settlement, patterns of work, shopping and leisure, falling costs of motoring and growing road networks.

Increasing road passenger-kilometres travelled per capita in the OECD, up by about one to two per cent per year. Meanwhile, growth in domestic and international passenger air traffic has been even more rapid, at five to seven per cent per year.

Figure 3 shows how car passenger travel, in passenger-km/capita, has grown with GDP/per capita.

**Figure 3: Car driving and per capita GDP 1970-1995**

Freight transport is closely linked to economic activity and to patterns of production, consumption and land use. It is influenced by expanding international trade, changes in company structures, changing consumer demands and increasing use of modern communication technologies. In general, domestic freight movements account for over 75 per cent of tonne-kilometres travelled and the bulk of these movements are comprised of relatively short trips. A particularly striking feature has been the growth of goods transport by road: nearly five per cent p.a. over the last 20 years, faster than GDP growth and even faster than car traffic. Figure 4 shows the growth in domestic tonne-km per capita vs. GDP per capita from freight in a number of IEA countries. In the European countries shown, trucking accounts for 50-70 per cent of total tonne-km, while in the large countries (the United States and Australia), rail and inland shipping accounts for 60-70 per cent of the much higher totals relative to GDP.
Structure

Modal shifts in the past have usually been in favour of more energy intensive modes. Road transport dominates in passenger and freight, while aviation exhibits the highest growth but is still small on an absolute scale. While the fuel intensity of passenger air transport (energy/passenger-km) has declined substantially over the last 20 years, it is still a highly energy-intensive mode, along with road. Aviation freight, while difficult to separate from passenger activity is considered by far the most energy intensive freight mode (three to five times the energy intensity of trucks). Rail remains far less energy intensive than either aviation or road, with the exception of some commuter systems that have low load factors. Trends in the different modes are:

- **Road transport**, both passenger and freight, has experienced tremendous growth over the past decades and is the dominant transportation mode with over 91 per cent of passenger travel and 75 per cent of goods transported. The flexibility of the ‘service’ available through individual vehicle use is the result of and results in particular urban structures and life styles (commuting, shopping, leisure and holidays). Patterns of urban development less focused on city centres can make it more difficult for public transit modes to compete with cars. An important rationale behind expanding car use has also been the significant proportion of GDP generated from automobile and related industries in manufacturing countries. In freight transport, trucking has won an increasing share of goods transport, at the expense of rail and inland waterways. Trucking has benefited most from the growth in small volume and high value manufacturing goods and trade relative to bulk material such as coal, minerals or agricultural products where rail and barge still play an important role. The expansion and improvement of road infrastructure, the technological improvements of vehicles (in power, speed and size) and a highly competitive environment have allowed trucks to offer expeditious, timely and door-to-door delivery of high value-added goods. Improved
reliability and availability of road freight is both a cause and effect in the trend towards ‘just-in-time’ production and enables manufacturers to reduce warehousing facilities. Shifts in economic activity to suburban areas have led many firms to move to edge-of-town and out-of-town sites where they are no longer connected to existing rail and port terminals. The interplay between vehicle technology, the increases and flexibility of the service provided and infrastructure provision has fuelled growth of road transport relative to other modes.

- The share of rail transport, both passenger and freight, has been declining over the past decades in almost all OECD countries, except for rail freight in the United States. While passenger transport by rail has experienced an absolute growth over the past fifteen years, it accounts for only six per cent of passenger travel, and a much lower share in N. America. Trends in rail freight show maintenance of transport volume (tonne-km), but a diminishing share with respect to road freight.

- Water-bound transport has also experienced a declining market share, both for inland waterways and short-sea shipping, although these modes have been growing steadily in recent years. For maritime shipping, globalisation of production and expanding trade are driving its development. Like rail freight, maritime transport has seen market share eroded because of lower demands for bulk shipments of raw materials.

- Air transport’s share of total passenger domestic travel is less than three per cent, except in some Nordic countries (six per cent) and in N. America and Australia (10-12 per cent). However, the international aviation industry has grown prodigiously over the past thirty years. Demand side drivers include economic growth, globalisation of commerce and industry, higher disposable incomes, and increased leisure time. On the supply side, falling airline tariffs due to enhanced competition, technical efficiency improvements and the relatively low cost of aviation fuel due to lack of taxes are also factors. While aviation still accounts for only a small proportion of total greenhouse emissions, the release of greenhouse gases at high altitude leads to greater global warming effect than equivalent ground level emissions, so this sector is of concern, especially due to its rapid growth.

**Intensity**

Fuel intensity is generally measured either as energy use per passenger-km or tonne-km of freight. While there have been significant and continuous improvements in automobile engine technology over the years, cars are becoming heavier (in part to accommodate more accessories such as air conditioning, electric windows, stereos, etc but also for safety reasons), more powerful, roomier and with larger engines. These increases in “hedonic” attributes have offset technical improvements, so that overall fuel intensity of vehicles has fallen only slowly, or even increased.\(^{11}\) In recent years, especially in the United States, there has been rapid penetration of sport utility vehicles into the market. Together with passenger vans and pickup trucks, these now account for more than half of US passenger vehicle sales, and similar trends are appearing in other OECD countries. In addition to these trends, the load factor of automobiles and other household vehicles has fallen steadily in virtually all countries, from over 2 people in the early 1970s to around 1.5 in the mid 1990s, which also limited the net decline in the energy intensity of passenger vehicles.

\(^{11}\) The exceptions to this were the United States and Canada, where vehicle fuel intensities improved dramatically from 1974 to 1990 due to combined effects of pricing, regulation and other policy and behavioural changes. However, as North American efficiency figures have approached those of other countries, there may be less scope for such dramatic improvements.
transport. Figure 5 shows the fuel intensities (and approximate carbon emissions/km) of the on-road fleets of a number of IEA countries.

**Figure 5: On-road fuel intensity and carbon intensity of cars**

Energy intensity of freight traffic is a complex function of many factors. For road freight, these include mix of heavy and light trucks, traffic conditions, driving behaviour, load factors and levels of packaging, and the fuel efficiency of the vehicles themselves. In most OECD countries, there has been an increase in the share of smaller trucks, which have emissions intensities far higher than alternative modes (see Figure 6) for both technical and logistical reasons. While evidence is not complete, it appears that various factors have combined to leave the energy intensity of trucks relatively constant. However, the increasing share of road freight, has led to an increase in aggregate intensity of the freight sector. Figure 7 shows the energy intensity of trucking in a number of IEA countries over time. The wide spread reflects all of the aforementioned factors. Note intensities have fallen markedly in some IEA countries.

In passenger aviation, energy consumption per passenger-km has decreased rapidly compared to other modes due to high technological efficiency gains, stock renewal (and growth) and substantial increases in load factors.
Figure 6: Lifecycle GHG emissions for European freight transport modes

Source: INFRAS.

Figure 7: Energy intensity of trucking
Fuel

Petroleum fuels dominate motor vehicle transport almost entirely. Typically, petrol comprises 85 per cent or more of total transport fuel use, with most of the remainder being diesel. Diesel dominates the heavy truck segment. While there have been some attempts to introduce alternatives such as ethanol, natural gas and electricity into the mix, the combined share of these fuels in OECD countries is less than one per cent. International interest in these fuels suggest greater future potential for these fuels. A few countries have been more successful in substituting LPG and diesel for petrol, strongly supported by highly differentiated pricing. The greenhouse impacts of these petrol substitutions are limited as both LPG and diesel have significant emissions and lower fuel prices lead to some increases in travel volume.

Hybrid electric/petrol vehicles have recently been commercialised in Japan and the United States in small numbers. Due still high cost per vehicles they are not likely to command large shares in new vehicles sales in the next five to ten years but offer, once penetrating in larger numbers, a large potential for fuel savings.

Summary of trends

The overall result of these trends has been rapid growth in emissions. Transport activity is growing quickly, while road and aviation transport wins increasingly larger modal shares. Technological efficiency improvements are largely balanced by increased demands for power and weight, or reduced load factors, and there is very limited penetration of low- or zero-emission fuels. Overall, increases in activity levels more than offset efficiency gains. While the levels of emissions and the rates of increase differ from country to country, and even some saturation may be evident, the general trend is that emissions keep rising with rising GDP.

Low and declining oil prices for the past 15 years or so have supported the growth of transport emissions. Until very recently, oil was at historically low levels in real terms. Constraints on market supply have recently pushed prices to levels not seen in a decade. Should these prices persist, a number of underlying trends may be altered toward lower intensity, as happened following the oil price shocks in the 1970s and 1980s.
Box 1. **Transport in EIT countries**

EIT country targets under the Kyoto Protocol range from 92 to 100 per cent of base year levels; but large economic declines during transition have seen overall emission levels fall well below these levels. Nevertheless, some of the more rapidly growing EIT countries may require further actions to keep emissions below target levels in the first commitment period. Trends in transport in EIT countries have been somewhat different than for OECD countries, although complete data are not always available. Since economic restructuring of these economies, the underlying transport drivers appear to be moving in similar directions, but from a different base.

In 1990, transport accounted for less than ten per cent of greenhouse gas emissions in most EIT countries, a much smaller share than for the OECD. In many EIT countries, more than 40 per cent of passenger-kilometres are on public transport, and rail’s share is greater than in most OECD countries. However, following restructuring, the share of rail and buses has fallen dramatically. In Central and Eastern European EIT countries, from 1989 to 1995, passenger-kilometres on rail fell by about one-half and on bus by about one-third. Meanwhile, volumes in passenger cars doubled. Increases in public transport fares, lower investment in infrastructure, as well as greater competition from passenger cars, accounted for these trends. Rates of car ownership are far lower than in OECD countries and are expected to continue to rise quickly. Additionally, rapid imports of used cars from Western Europe and expansion of production of western cars in Eastern Europe has boosted the size of fleets with larger cars.

In freight, overall volumes declined substantially from 1989, but began to stabilise and then increase from around 1993, especially with expanding trade links to Western Europe. Road has shown the most rapid recovery, with tonne-km returning to pre-reform levels by 1995, due to expanded roadways and fuel distribution networks. Rail is still the dominant mode for freight transport, accounting for 66 per cent of goods transport in 1994.

EIT countries have been recipients of considerable funding from international financial institutions for transport infrastructure. 46 per cent of European Investment Bank (EIB) transport funding in 1996 went to road projects, and another 12 per cent to air, while 53 per cent of European Bank for Reconstruction and Development (EBRD) transport funding from 1992-96 went to road. Rail projects accounted for 36 per cent and 26 per cent of funding, respectively. This preference in investment funding is expected to lead to relative declines in the capacity and quality of rail infrastructure relative to more environmentally-friendly modes. However, in some EITs, notably the Czech Republic and Poland, there has been considerably more focus on rail.

Policy-making in EIT countries faces special challenges. Institutional and data collection institutions are not always strong and environment does not always figure strongly in the political agenda. Macroeconomic imbalances and weak financial institutions, perceived economic and political risks have constrained affordable capital. In addition, foreign direct investment is focused in only a few countries. Environmental issues are rarely incorporated in company management structures. The position of many EIT countries at the crossroads between Eastern and Western Europe means that external forces will drive transport demand to a considerable degree.

Overall, EIT countries start from a positive basis for sustainable transport, with high reliance on rail-based and public transport. However, recent shifts in transport structure and increases in activity as economies grow, could lead to rapid increases in emissions in these countries. At the same time, market and policy frameworks require further development to manage these environmental challenges.

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12 Bulgaria, Hungary, Poland, and Romania use years other than 1990 as base years for commitments.

13 Bulgaria, Czech Republic, Estonia, Hungary, HR, Latvia, Lithuania, Poland, Romania, Slovak Republic, Slovenia.
3.3 Policy-making in the transport sector

Quantitative assessment of the effectiveness of transport policy measures is difficult. However, most analysts would agree that there has been limited success (at best) among Annex I countries in controlling greenhouse emissions from the transport sector. While the rapid growth in underlying demand is clearly an important reason, there are number of other factors that complicate policy-making in this sector, including:

- Unlike in the stationary energy sector, transport emissions come from dispersed sources. There are no point-source emitters, so policies often work through indirect means.

- Alternative fuel options are somewhat limited in the transport sector, as most fuels do not provide major GHG reductions compared to gasoline. Those that do, such as ethanol, tend to be quite expensive. Most vehicles capable of running on zero-emission fuels, such as hydrogen fuel cells, are still at the prototype stage of development. Electric vehicles can be very low emission in countries with low GHG electricity generating capacity, but these vehicles are also relatively expensive. The lack of easy fuel-switching options limits the range of cost-effective policies.

- Transport patterns are closely linked with patterns of urban development, lifestyles, trade, and consumer demand. Many of the underlying factors of demand have long time frames for change and are politically sensitive.

- Transport is a highly emotive and political topic, and many policies to affect transport demand (especially through pricing) have encountered stiff and widespread opposition. For many people, cars are more than just transport. As all citizens are direct consumers of transport services, policy changes have a very wide base of stakeholders. This in part seems to explain why there appear to be many opportunities for cost-effective emissions abatement in this sector which are not implemented.

- Effective policies to address transport emissions will sometimes be outside the environment field altogether. For example, tax treatment of company cars (noting that in some countries more than half of new cars are company cars) and mortgages (which can have effects on the nature of housing demand and urban form) can be important to the success of policies.

Annex I countries have implemented a wide range of measures to address emissions from the transport sector. Effective policies would need to systematically address the main drivers for increases in emissions, and support underlying trends leading to lower emissions. Given the many factors supporting higher emission levels, there may be a need for a diverse, well-designed policy mix. In France, for example, a scenario to achieve Kyoto target levels in the transport sector includes large rises in fuel prices, reductions in public transport prices, changes to operations in road freight markets, driver training, enhanced traffic management and enforcement, supplementary measures to the EC Voluntary Agreement, support for alternative vehicles and improved transport and land use planning. Such packages can be difficult to assess, as there are many interrelationships and feedback loops. However, careful assessment of alternative policy approaches is necessary to determine an effective and efficient policy package. So, enhanced analytic capacity in assessing potential policies, as well as regular review of policies in place, are important to good practice.

Key elements in the design of a transport policy framework include:

- The road passenger transport sector tends to receive the bulk of policy attention in transport. An effective policy-mix will also explore options in other sectors. Freight transport, for
example, accounts for 20-30 per cent of transport emissions, and there are abatement options through improved loading and logistics, technical improvements, driver training, alternative packaging and changes in order cycles to substantially reduce emissions at low or no cost. Aviation, while accounting for only a small proportion of total emissions, is expected to be the fastest growing sector for some time. Combined with the higher global warming impact of emissions at high altitude, this growth makes aviation an important area for policy attention. More widely, bunker fuels, though not included in quantitative commitments under the Kyoto Protocol, will require attention as part of a long-term, global response to climate change.

− Many countries’ transport systems are integrally connected with other countries. This is especially true of areas such as the European Alpine regions and Central European EITs. In these situations, there is a need for international co-operation to fully address transport emissions. Furthermore, as fuel and automobile markets are global in nature, there can be constraints on what countries can do acting alone. And international aviation and marine transport may require international solutions. So, while domestic action is central to addressing emissions from transport, international Cupertino can also be an important element of an effective policy response.

− Non-greenhouse considerations, especially air pollution concerns in urban areas, have been the main drivers for environmental policy in the transport sector. While some technologies that may increase fuel economy could increase some kinds of local pollution (e.g., particulates from diesel), other technologies and strategies that emphasise traffic management and modal shifts to ameliorate both air pollution and congestion could restrain GHG emissions as well. Studies of the non-greenhouse benefits of greenhouse reduction policies have shown that these could range as high as USD 200 per tonne of CO\textsubscript{2} abated, largely because of improvements in air quality. Integrated policy design to maximise the range of environmental and social benefits is a challenge for policy-making, but is supportive of enhanced greenhouse response.

In EIT countries, air quality can be a more obvious and significant concern. In this case, the need for effective greenhouse policy to take non-greenhouse effects into consideration is heightened. This is for reasons of good policy-making, as well as recognition of the likely environmental priorities of policymakers.

− Fuel and other transport-related taxes comprise more than 90 per cent of all environmentally-related taxes in OECD countries, with fuels being one of the most heavily taxed expenditure items. Experience following the oil shocks of the 1970s and 1980s shows that significant price rises were successful in reducing some of the least efficient energy uses (especially in the United States), but whether they would be equally effective today is unclear, and the long term price elasticity of fuel demand appears low. There is a correlation between countries with low fuel prices and per capita automobile fuel emissions, although many other factors make an analysis of this relationship difficult.

Price differentials may have greater impacts in fuel choice, as it appears that low diesel fuel prices played an important role in stimulating shifts to diesel cars and have been a basis for promoting LPG use in some countries. Fuel and vehicle charges may also not be the most effective pricing method to address transport emissions, as charges on parking, or roads, or unused freight capacity may provide more direct and effective signals for change. Relative prices across modes also need consideration. Large increases in public transport fares have been an important reason for the increase in automobile
modal share in EIT countries. However, in considering alternatives to fuel price increases, governments will need to consider comprehensiveness and efficiency as well as impact.

Significant changes in transport emission trends seem unlikely without changes to the structure and/or level of transport prices, since price changes are such a cost-effective and comprehensive signal to change behaviour. However, the precise nature of these changes requires careful consideration, including their interactions with other policy measures. The politics of transport price adjustments can make progress in this area difficult and slow, although using some portion of revenue raised directly for transport abatement can help acceptability.

- A number of countries have implemented market reforms in road, rail, air and shipping. This has involved privatisation, introduction of competition and removal of subsidies, though significant market distortions remain. Experience with market reform can have mixed results for greenhouse emissions. Airline deregulation in the United States appears to have led to greater efficiencies in operation but a large growth in overall passenger numbers, and so a net increase in emissions. Policy must pay attention to the role of different modes as competitors when deciding on the timing and nature of reform processes. For example, the slower pace of rail reform relative to road in Europe may have hindered the ability of the rail sector to flexibly respond to market needs and maintain share. Market mechanisms to reflect environmental costs will also be important with increasing reliance on market signals.

For EIT countries, market reform can be more complex and more fundamental. Moving away from heavily-subsidised public transport systems has been a factor in the shift toward car-based travel. Given the magnitude of market changes underway in these countries, it will be important to ensure that environmental considerations are fully integrated into discussions of the nature and pace of reform in different sectors, and the possible need for complementary measures.

- Recently, there have been a number of voluntary agreements with the auto industry, seeking to ensure that the fuel efficiency of new vehicles is significantly improved. The EC agreement is notable both in its ambition and in its extension from fuel efficiency to emissions efficiency, providing more incentive for greenhouse-efficient fuel-switching. Some countries are relying on such agreements as a central element of their greenhouse response actions in the transport sector, but their effectiveness is yet to be tested, and progress has been slow. Complementary measures to improve fuel inputs and support market demand for more fuel-efficient vehicles will likely be required.

Technological improvement in vehicles will be a key element of long-term strategies to reduce emissions. However, governments need to consider if voluntary agreements are the most rapid or effective way to achieve this goal. In either case, the impact on total emissions may be limited, as this technological improvement will not affect the underlying drivers of increasing overall transport demand, and may even exacerbate them if they reduce the effective cost of transport. The slow turnover of the car fleet means that the impact of technological change in the Kyoto time frame could be limited, unless it commences immediately or is accompanied by measures to increase the turnover rate. The long-term potential of technological change is very significant.

Voluntary agreements can also play a role in areas other than vehicle technology. These agreements can play a powerful role in making companies aware of environmental and economic implications of choices, so agreements in sectors such as freight operations or retail delivery operations could be beneficial in raising awareness and commitment. Voluntary agreements in EIT countries may also be effective in helping companies there incorporate environmental issues into decision-making.
While technological improvement will be important over the long-term, it is unlikely that it can deliver levels of abatement consistent with achievement of Kyoto Protocol targets, even recognising that the transport sector may not be required to achieve the same level of abatement as other sectors. In a transition to a sustainable transport future, behavioural change is likely to account for a significant portion of change. Therefore, governments must not rely solely on technological change, and must prepare the way for substantive changes in transport use patterns as well.

The importance of addressing urban development patterns has long been recognised. However, in countries such as the United States, Canada and Australia where development patterns are already highly dispersed, fringe urban settlement continues apace. In the already denser cities of Europe and Japan, the scope for increasing density may be limited. There may still be options for “locally dense” or “mixed use” settlement. Linking urban development to lower transport levels and different transport modes is a difficult, long term challenge for all government authority levels (municipal, regional, national), and demands effective policy integration across a range of issues and levels of government. As such approaches are complex and operate over long time frames, it will also be difficult to assess their performance, raising the need for assessment techniques of matching complexity.

Infrastructure provision is an important element determining future urban development patterns. Relative funding rates for road versus other transport modes may be one long-term indicator of likely future trends. In EIT countries, international financial institution funding patterns may support modal shifts towards road transport to the detriment of the environment. As well as negative environmental implications, this may have direct financial implications if it leads to fewer emission quotas being traded internationally. Making policies more coherent with environmental objectives could be advantageous.

Policies to influence the way people travel (e.g. driver education, on-board instruments, public information campaigns) have been a part of many countries’ emission reduction policies. The cost-effectiveness of such policies is hard to assess and policy makers should build in an assessment process when launching a policy. Approaches could include devices to help drivers monitor their driving performance to minimise environmental (and economic) costs. However, transport choices are not solely based on “rational” criteria but are a complex function of many psychological drivers. Therefore, measures based on assisting “rational” choice will have more impact in the context of broader approaches.

3.4 Conclusions

Greenhouse gas emissions from the transport sector have continued to grow rapidly, despite a range of government policies to address these. This may be due to the inherent difficulties in addressing diverse sources of emissions where there is a range of underlying drivers of emissions growth, or failure to fully integrate environmental considerations in related policy areas, or the political difficulties in addressing a sector where there are so many interested actors. Most likely, it is a combination of all of these. Given the inertia of the transport system, implementation of an effective policy framework is required soon, if transport is not to present a major obstacle to achievement of Kyoto targets, or require larger abatement in other sectors. A comprehensive policy mix that includes pricing, voluntary agreements, regulation, information and institutional reform, and which addresses both technological and behavioural change is likely to be required.
3.5 References

Central European Initiative (1999), Towards Sustainable Transport in the CEI Countries, Vienna.


