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ENERGY PRICES, TAXES AND CARBON DIOXIDE EMISSIONS

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INTRODUCTION

Taxes levied on the carbon content of fuels (so-called "carbon taxes") are being considered in many OECD countries as a possible policy instrument to reduce carbon dioxide emissions in order to prevent or slow the process of global warming. This paper first reviews the policy response in Member countries to the threat of global warming. It then discusses the links between carbon emission intensities and current energy prices, touching also on the relative price effects of current energy policies and the implicit carbon taxes reflected in present energy taxation **of** different fuels. Finally, the likely size of carbon taxes associated with given emission constraints are considered.

I. GLOBAL WARMING AND THE POLICY RESPONSE

The International Panel on Climate Change (IPCC) recently submitted its report on the scientific assessment of climate change (IPCC, 1990). The build-up of greenhouse gases in the atmosphere – the main ones being carbon dioxide (CO_2), chlorofluorocarbons (CFCs), methane (CH_4) and nitrous oxide (N_2O) – associated with the Panel's "business-as-usual" projection may result in a rise in global mean temperatures in the range of 0.2°C to 0.5°C per decade over the next century. According to the IPCC, slowing down the rate of warming to 0.1°C per decade would require more than a halving of GHG emissions from current levels[1].

Policy should aim at equating the marginal cost of reducing GHG emissions with the marginal benefits from avoiding global warming[2]. However, little is known about the damages associated with climate change, so that the marginal benefits of avoiding it are difficult to estimate. The valuation of damages is further complicated because they are likely to occur only after several decades (OECD, 1991*a).* More is known about the cost of reducing GHG emissions, for which the future increase in fossil-fuel related CO_2 emissions is of crucial importance[3]. World-wide energy-related emissions of CO_2 are currently almost ***6*** billion tons per year, with the OECD countries accounting for about half[4]. If few or no steps are taken to curb energy-related emissions, the IPCC estimates that they could reach 25 billion tons by 2100[5].

The 1988 climate change conference in Toronto suggested that countries should aim at a reduction of CO_2 emissions by 20 per cent from the 1988 level by 2005 and by 50 per cent in the long run. A 20 per cent reduction from the 1988 level implies a reduction of close to **40** per cent compared to the business-as-usual development by 2005. Virtually all OECD countries have already expressed their willingness to limit their emissions and the reductions announced are in a number of cases close to the

Table 1. **Status of commitments to reducing greenhouse gas emissions**[1]

	Gases included	Action	Base year	Target year	Comments
United States	All GHGs	Stabilisation[2]	1990	2000	No CO_2 target
Japan	CO_2	Stabilisation	1990	2000	– on per capita basis – implemented if others act likewise
Germany	CO_2	25% reduction and higher reduction in eastern Länder	1987	2005	Putative
France	CO_2	Stabilisation	1990	2000	Putative
Italy	CO_2	Stabilisation	1988	2000	Non-binding resolution
		20% reduction	1988	2005	
United Kingdom	CO_2	Stabilisation	1990	2005	Implementation if others act likewise
	All GHG	20% reduction	1990	2005	
Canada	CO_2, N_2O, CH_4	Stabilisation	1990	2000	
Austria	CO_2	20% reduction	1988	2000	Still needs Parliamentary approval
Belgium					EC target[3]
Denmark	CO_2	20% reduction	1988	2005	Implementation plan adopted
Finland	CO_2	Stabilisation	1990	2000	Putative
Greece					EC target[3]
Ireland					EC target[3]
Luxembourg					EC target[3]
Netherlands	CO_2	Stabilisation	1989/90	1995	Unilateral action committed
		3 to 5% reduction	1989/90	2000	
Norway	CO_2	Stabilisation	1989	2000	Preliminary; putative
Portugal					EC target[3]
Spain					EC target[3]
Sweden	CO_2	Stabilisation			– conditional on like action and only applies to sectors not subject to international competition
Switzerland	CO_2	At least stabilisation (reduction after 2000)	1990	2000	Planning target
Australia	CO_2, N20, CH4	Stabilisation	1988	2000	Interim planning target
	CO_2	20% reduction	1988	2005	Implementation if others act likewise
New Zealand	CO_2	20% reduction	1990	2005	Putative
EC	CO_2	Stabilisation	1990	2000	Putative

1. All countries have agreed to phase out most CFC's by the year 2000 or earlier.
2. No target for CO_2, N_2O or CH_4. Stabilisation of GHGs is achieved primarily by reducing CFC emissions.
3. Countries would agree to EC wide target.

Source: IEA.

Toronto target (Table 1). Most countries aim either at a stabilisation of CO_2 emissions at 1990 levels by early in the coming century or a reduction by 20 per cent. Currently the Inter-governmental Negotiating Committee (INC) is preparing a framework convention on climate change for possible signature at the 1992 United Nations Conference on Environment and Development. An international agreement on the policy response is important because it would make little sense for countries to take action unilaterally. A single country, even if it phased out its emissions completely, would not affect global warming[6].

While many countries have announced rather ambitious reduction targets, most have not yet legislated the means to reduce emissions. Discussion in Member countries to date has focused on improved information and regulatory measures aiming at greater energy efficiency and fuel-switching. Governments appear to generally favour "command-and-control" solutions rather than economic instruments. While there seems to be scope to improve energy efficiency substantially (IEA, 1991 and Williams, 1990), regulatory measures are unlikely to be least-cost policies if adjustment possibilities differ significantly among energy users – as appears to be the case. Interest in a "carbon tax" – a tax on the use of fossil fuels in direct proportion to their CO_2 emissions – has therefore increased, because it would give each energy user the same incentive to abate and leave the least-cost abatement decision to the individual. It would also give economic agents the right signals to search for new technological solutions. So far, only Finland, the Netherlands, Norway and Sweden have introduced small carbon taxes, although many EC countries have expressed their willingness to support a Community-wide carbon tax.

II. ENERGY PRICES, TAXES AND EMISSION INTENSITIES

A. The relationship between energy prices and CO_2 emission intensities

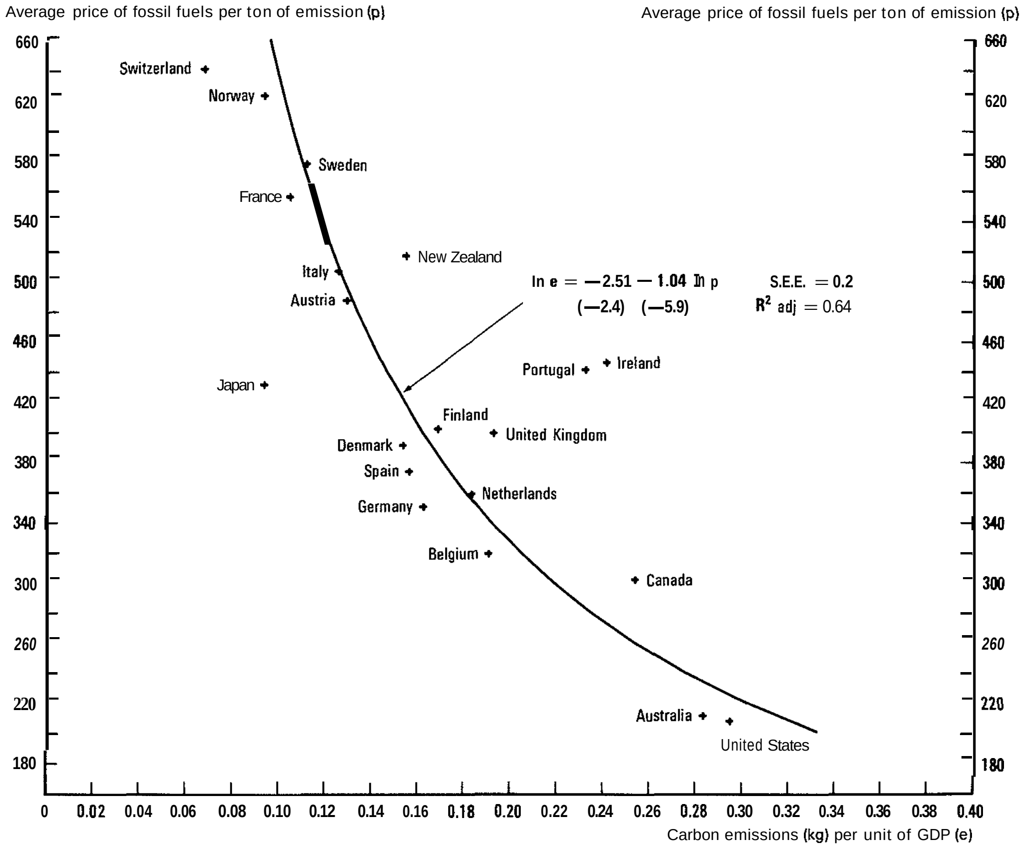
Man-made CO_2 emissions are closely linked to the combustion of coal, oil and gas. These fossil fuels emit CO_2 in relatively fixed proportions, with emissions per unit of energy being higher for coal than for oil and gas[7]. Emissions vary, therefore, with the amount of fossil-fuel use and its mix. A reduction in emissions from fossil-fuel use can be achieved by:

i) a change in demand patterns and technology towards less use of energy; and
ii) a change in the mix of fuels, i.e. substitution from fossil fuels with a high carbon content (i.e. coal) towards ones with a low carbon content (e.g. natural gas), or from fossil to non-fossil fuels (mainly hydro and nuclear energy).

The response of fossil-fuel demands and emissions to output and relative price changes depends crucially on energy technologies already embodied in existing capital. As there is usually little flexibility built into the existing capital stock, more efficient technologies in terms of energy use tend to change energy use only slowly. Econometric estimates based on time-series data, therefore, typically show low short-run price elasticities of fossil-fuel use, while long-run elasticities vary considerably across empirical studies.

As energy prices have differed considerably among OECD countries for a long period of time, cross-country experience may provide a better gauge of the long-run effect of energy price differences on emission intensities. There appears to be a strong inverse relationship between the implicit price of carbon emissions and emission intensities (Chart **1).** In North America, where the price per ton **of** emission is low on average, the emission intensity is high relative to other OECD countries. **In** Japan and some European countries with relatively high prices, emission intensities are much lower. A regression of emission intensities on average prices per ton of emission indicates a negative unitary elasticity, i.e. a 1 per cent rise in average prices per ton of emissions leads to a **1** per cent fall in emission intensity. A disaggregation shows that

Chart 1. **Prices per ton of emission and emission intensities**
1988, dollars



Note: Based on IEA data for energy prices, fossil-fuel use and emissions. In order to calculate economy-wide prices per ton of emission, fuel prices per ton of oil equivalent are weighted by emission factors. The prices per ton of emission are estimates, which cover about 75 per cent of energy products. While the availability of data for fossil-fuel use does not pose a problem, prices for energy products had to be estimated in several instances.

elasticities differ by fuel. The elasticity is somewhat above one for gas and somewhat below one for oil products, both being well determined. For coal, however, the correlation between prices and emission intensities is weak, reflecting severe distortions in coal markets in many countries (see below).

The simple relationship between price and emission intensity in Chart 1 suggests that increasing the U.S. price per ton of emission to the Japanese level might eventually halve the **U.S.** emission intensity. This would still leave its emission intensity substantially higher than in Japan, owing ***inter*** *alia* to differences in climate, size of residential floor space and supply of mass transit facilities (McDonald, 1990). Due to the apparent non-linearity of the relationship between price and emission intensity, halving the emission intensity in Japan would require a much sharper absolute price increase than in the case of the United States.

Governments influence emission intensities by energy conservation policies (e.g. grants for housing insulation, energy efficiency standards), by utility regulation (environmental regulations or restrictions on the supply of nuclear energy), by taxing energy-using goods (for instance, special car ownership fees) and through the provision of infrastructure. Objectives of energy policy have so far been guided by energy security considerations, revenue objectives (financing of infrastructure) and social considerations (e.g. the desire to protect employment in coal industries in some European countries). Environmental measures have **so** far mainly affected coal-fired electricity plants **so** as to reduce emissions which cause acid rain[8]. The effect on emission intensities of policy measures which do not affect energy prices is difficult to include in the regressions reported in Chart 1. As most countries pursue energy conservation policies, regulations are likely to have reduced emission intensities everywhere by differing degrees. However, the strong correlation between prices and emission intensities suggests that price differences are a major determinant of differences in emission intensities.

B. Energy taxes, subsidies and prices

While prices of primary energy sources are mostly determined in world markets, domestic fuel prices and prices per ton of emission differ significantly across countries mainly because of:

i) taxes (excise taxes and value-added taxes);
ii) subsidies (grants, deficiency payments, etc.); and
iii) price support measures (for instance, trade restrictions or special long-term agreements between coal producers and consumers).

Even after taking account of such policy measures, prices may differ among countries due to differences in refining and distribution costs as well **as** market structures. Part of the explanation for the existing structure of domestic fuel prices is related to attempts to internalise some of the externalities associated with fuel use[9].

There are some gaps in the information on taxation. Using the available partial information, Table 2 attempts to relate current taxes on fossil fuels in 19 OECD countries to the carbon content of the different fuels[10]. Among the major OECD economies, the average implicit tax per ton of carbon is low in North America, intermediate in

Japan, Germany and the United Kingdom and high in France and Italy. For oil products, the implicit tax per ton of carbon is over $200 in all the major European countries. The implicit taxes on specific products such as gasoline and diesel are generally higher still. Taxation of gas is much lower and – with the exception of Sweden and Switzerland – is virtually non-existent for coal.

Table 2. Implicit carbon taxes in 1988

$ per ton of carbon

	United States	Japan	Germany	France	Italy	United Kingdom	Canada
Implicit carbon tax							
Oil and oil products	65	130	212	351	317	297	108
Gas	0	2	23	38	80	0	0
Coal	0	0	0	**0**	**0**	**0**	**0**
Total	**28**	**79**	**95**	**229**	**223**	**106**	**52**
Implicit subsidy and price support for the coal industry							
Subsidy		2	28			10	
Price support		15	49			36	

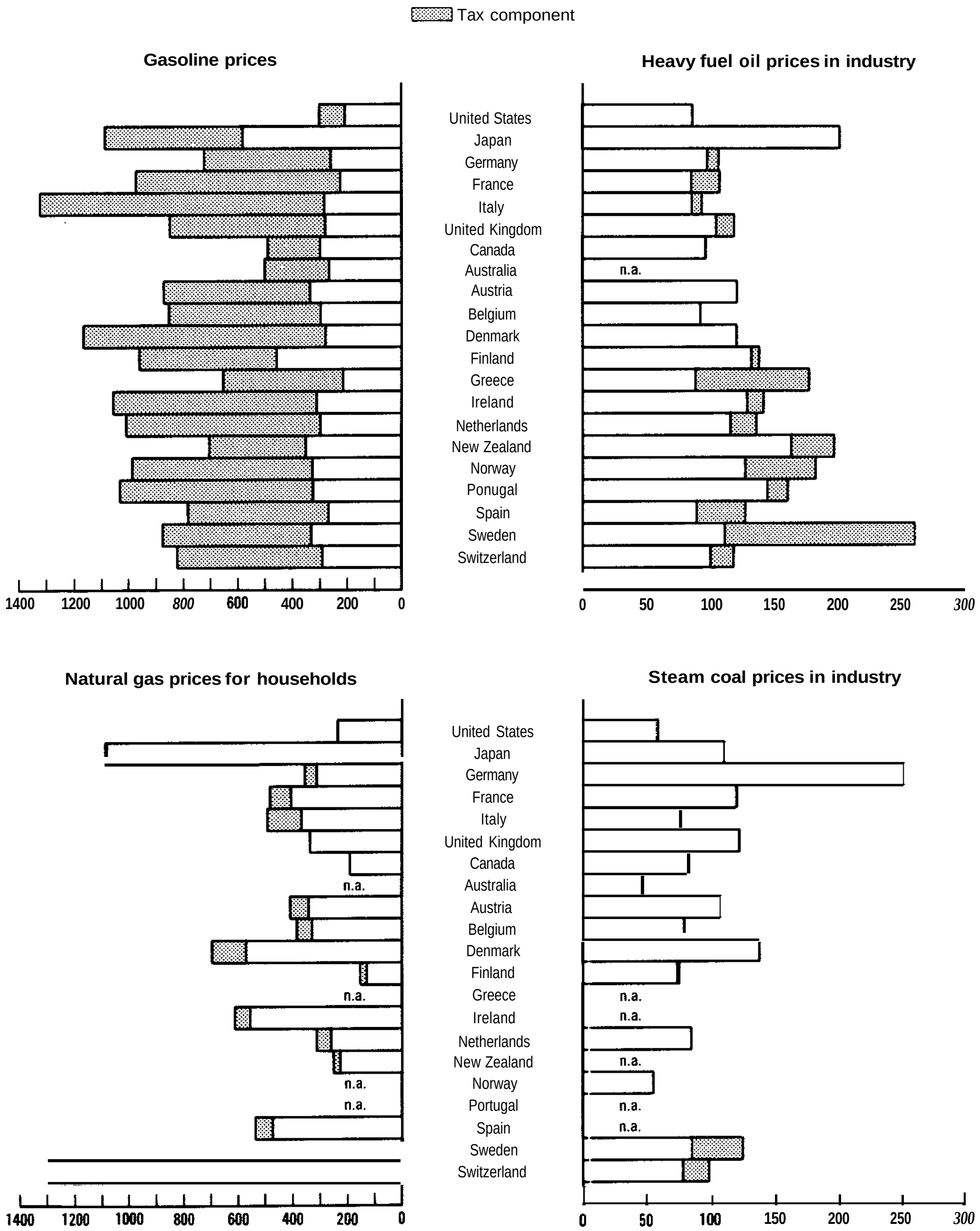
	Austria	Belgium[1]	Denmark	Finland	Ireland	Netherlands
Implicit carbon tax						
Oil and oil products	267	162	297	189	277	221
Gas	39	35	110	0	4	27
Coal	0	0	0	**0**	**0**	**0**
Total	**150**	**86**	**147**	**107**	**138**	**89**

	New Zealand	Noway	Portugal	Spain[2]	Sweden	Switzerland
Implicit carbon tax						
Oil and oil products	235	258	205	176	268	224
Gas	0	0	131	19	13	2
Coal	0	0	0	0	6	18
Total	**117**	**182**	**150**	**112**	**214**	**198**

1. Subsidies to coal producers amounted to **$24** per ton of carbon.
2. Subsidies to coal producers amounted to $25 per ton of carbon and price support to **$5** per ton of carbon.
Source: IEA (1990*a*) and IEA (1991*a*).

Pre-tax prices of most oil products differ little between countries, as would be expected for homogeneous goods which are readily available on world markets (Chart 2). Usually the ranking of end-use prices closely mirrors differences in taxation. There are, however, a few exceptions. In Japan and Finland, for instance, pre-tax

Chart 2. Energy prices and taxes for selected fuels
Dollars per ton of oil equivalent, 1988



Source: IEA (1990a).

prices of gasoline are much higher than in other countries, pointing to an important effect of trade restrictions or other market imperfections[11]. It is more difficult to compare national gas prices to a world market price, because of important differences in transportation and distribution costs.

End-use coal prices, while usually untaxed, differ by a large margin between countries owing to severe distortions in coal markets in many European countries (Chart **2).** Steenblik and Wigley **(1990)** have computed so-called producer subsidy equivalents for six countries, which show the amount of assistance to coal producers provided by taxpayers and consumers. The amount of subsidy and price support for coal producers is given in terms of the carbon content of coal in Table 2. Despite subsidisation, price support measures have kept prices artificially high in most of these countries.

III. ENERGY PRICE EFFECTS OF A CARBON TAX

Bringing the structure of fossil-fuel taxation more in line with concerns to reduce CO_2 emissions would lead to significant changes in relative prices. Taxation of coal would increase, together with price increases for gas and some low-taxed oil products. Fuel-switching following such a tax change might result in a sizeable reduction of CO_2 and other emissions from fossil-fuel use[12].

Mechanically, a tax of **$100** per ton of carbon would add **$12** to the world market price of a barrel of crude oil. The same tax would more than double the average steam-coal import price in **1988** from $44 per metric ton of coal to about $104. The gas price would rise by about 60 per cent from its value in **1988** (Panel **A** of Table 3). To put such price increases into context, the real prices of fuels, especially oil and gas, have varied substantially during the **1980s.** The price of oil peaked in **1981** at about **$50** per barrel **(1990** prices). The difference of almost $30 per barrel between the average crude oil price in **1981** and **1990** is equivalent to a tax of about $245 per ton of carbon.

The mechanical effect of a **$100** carbon tax on current end-use prices would vary substantially across countries and fuels. As shown in the previous section, end-use prices of different fuels differ considerably among countries **so** that the addition of the same absolute amount of tax would raise prices by widely differing percentages (Panel B of Table 3). End-use prices would increase most in relative terms in the United States and – apart from the coal price – the least in Japan among the three largest countries.

Chart **1** can also be used as a rough guide to the long-run effect of the imposition of a **$1**00 tax per ton of carbon in the OECD countries. Were the price per ton of carbon in the United States, for instance, to increase from its level of $207 in **1988** to $307 and stay there in real terms, the relationship suggests a fall in the emission intensity of 34 per cent could be expected over the longer term. The same price increase would reduce emission intensities by only about 22 per cent for countries like Germany or the United Kingdom. In Switzerland and Norway, where **1988** base prices were still higher and emission intensities lower, a reduction of only **15** per cent might be achieved. On the other hand, if emissions were cut by the same percentage across countries, this would call for much higher taxes in high-price countries than in low-price countries,

Table 3. The mechanical effect **of** a **$100 tax** per ton **of** carbon on energy prices

US$, **1988**

	A. Price effect on primary energy sources		
	Crude Oil	Coal	Natural Gas
Unit of measure	Barrel	Metric ton	Ton of oil equivalent

	Gasoline			Steam coal			Gas price for households		
	United States	Japan	Germany	United States	Japan	Germany	United States	Japan	Germany-
End-use price, ($)	**299.5**	**1 084.5**	**720.4**	**58.4**	**110.7**	**252.3**	**234.2**	**1 086.7**	**353.2**
Price increase, per cent	**26.0**	**7.2**	**10.8**	**167.8**	**88.5**	**38.8**	**25.6**	**5.5**	**17.0**

1. **IEA** country average import price.
2. OECD average steam coal import price.
3. EC average import price by pipeline.

Source: IEA (1990*a*).

pointing to important benefits which could be achieved by trading emissions. An OECD-wide $100 carbon tax might reduce emissions by about 25 per cent over the longer term. Cutting emission intensity further by the same absolute amount, would increase the tax to around $300 per ton of carbon.

The likely size of carbon taxes required to achieve certain emission targets has been analysed in several studies (see Barrett, 1990; Nordhaus, 1990; and Hoeller ***et** al.,* 1991). They show that the tax has to be sizeable and, given underlying growth, to increase over time, just to stabilise emissions at current levels. The tax rates estimated to be necessary for the stabilisation of emissions at the 1990 level by the end of 2020, range from **$30** to $150 per ton of carbon. The level of tax for a 20 per cent reduction would be much higher, and vary considerably among regions. For example, simulations with OECD's GREEN model suggest that carbon taxes might have to rise to over $200 per ton of carbon in North America and Europe and to over $900 in the OECD's Pacific region to achieve such an emission constraint (Burniaux ***et** al.,* 1991 and 1991*a).* For North America and the Pacific region, such carbon taxes are roughly in line with the historical cross-country pattern as shown in Chart 1. For Europe, the chart would suggest somewhat higher carbon taxes.

The large differences in tax levels between the studies reflect different assumptions about substitution possibilities, technological developments and the aggregate repercussions of the introduction of a carbon tax. Sensitivity analyses using OECD's

GREEN model or the work by Edmonds and Barns **(1990)** show that assumptions concerning energy prices, income elasticities, inter-fuel substitution elasticities and energy efficiency improvements explain much of the differences. Varying these parameters in a range consistent with empirical studies can easily double or halve tax rates.

Currently the supply of non-fossil fuels (at present mainly hydro and nuclear power) is limited because of physical and environmental considerations. With a sharp increase in fossil-fuel end-use prices, it is likely that research could lead to a major expansion of the use of non-fossil fuels (for instance, solar energy). Such "backstop" technologies are usually assumed to come on-stream early in the next century. The supply price of backstop technologies puts an upper cap on the carbon tax needed to achieve emission targets; fossil-fuel use could be expected to decline following the penetration of energy markets by backstop energy sources.

IV. CONCLUSIONS

Cross-country experience suggests that in countries with high energy prices CO_2 emission intensities are low. Emission intensities differ considerably across countries as do energy prices, mainly because of large differences in taxation. Current taxes on oil products are already high in many OECD countries and represent an implicit carbon tax on oil products of over $200 per ton of carbon in all the major European countries. The use of coal, on the other hand, is generally not taxed and in some countries is even subsidised. A reform of fossil-fuel taxation in line with carbon content would lead to major changes in the level and structure of energy taxes. For example, coal prices would probably rise sharply in many countries and it is likely that there would be price rises for gas and some oil products.

As end-use prices currently differ considerably across countries, adding a $100 carbon tax to current prices would raise prices of fuels by widely differing percentages. Prices would increase most in relative terms in low-price countries and least in high-price countries. If the elasticity of emissions with respect to the price per ton of emission were about unity – as suggested by cross-country experience – a **$100** tax per ton of carbon would lead to much larger reductions in emissions in low-price than in high-price countries. The same simple cross-country relationship suggests that a **$100** tax – introduced in all countries – could reduce emissions by about 25 per cent in the OECD area in the long run.

NOTES

1. The links between emissions, concentration of GHGs and global warming are discussed in OECD (1991).
2. Apart from the adverse effects of climate change, there are other externalities from fossil-fuel use (for instance, damage by acid rain caused by SO_2 emissions) which should in principle be reflected in the relative prices of fuels (Nicolaisen ***et al.,*** 1991).
3. Emissions of other GHGs – mainly methane and nitrous oxide – should not be neglected, although it is difficult to devise policy instruments to reduce them, as sources of methane and nitrous oxide are diverse and emission rates uncertain. The use of most CFCs will be banned by the year 2000. With the phase-out of CFCs, the contribution of energy-related CO_2 emissions to the global warming potential could rise to over 70 per cent.
4. In addition, deforestation in tropical zones currently adds about 20 per cent to world-wide emissions. In principle, any agreement on CO_2 emission reductions should take account of the emissions from deforestation.
5. Projections of emissions vary across global models. For example, Manne's (1991) estimate is 42 billion tons by 2100, with the share of OECD countries in world emissions dropping to below 25 per cent. There are also strong regional differences in the growth of CO_2 emissions, with those in China likely to grow far more rapidly than those in OECD countries.
6. Even for the OECD countries acting together, it would be impossible to reduce ***global*** CO_2 emissions significantly, as a virtual phase-out of fossil-fuel use in OECD countries would be outweighed by increases in non-OECD countries over the next decades (Edmonds and Barns, 1990). In addition, imports of energy-intensive goods – if untaxed – would increase sharply. If energy-intensive sectors of production were to shift location to countries with relatively low or no carbon taxes, global emissions could even increase. These considerations have so far made countries reluctant to introduce large carbon taxes unilaterally.
7. Per ton of oil equivalent, coal, oil and gas emit about 0.98, 0.80 and **0.60** tons of carbon respectively. While CO_2 is emitted when fossil fuels are burned, prices and taxes are usually expressed per ton of carbon: 3.7 tons of CO_2 are equivalent to one ton of carbon emitted.
8. Present energy policies in Member countries are described in IEA (1990).
9. Road transport is a significant source of pollution apart from generating GHGs, giving rise to lead emissions, low-level ozone creation, acid rain and noise. Another externality from road transport is congestion. All these externalities would argue in favour of relatively high taxes on automotive fuels, even in the absence of the threat of global warming (Pearson and Smith, 1990). Apart from CO_2 emissions, nitrogen oxides (NO_x) and sulphur dioxide (SO_2) emissions from coal burning – important contributors to acid rain – would argue for additional taxes on coal. An SO_2 emission charge for coal-fired utilities exists in France and Sweden while the United States recently introduced a permit trading system for utilities. In most countries, utilities face rather stiff regulatory measures for reducing emissions of pollutants other than CO_2. While the cost of regulatory measures also affects relative fuel prices, it is difficult to estimate cost wedges in the absence of detailed plant data.

10. The calculations in Table 2 are based on the price and tax data in IEA (1990*a*) and emission data in IEA (1991*a*). The estimates for the different fuels include excise taxes and VAT for households. However, a split between household and business consumption of diesel and gasoline is not possible. The calculations assume that all gasoline is consumed by households (includes VAT) and all diesel is used by businesses (excludes VAT). Taxes on electricity end-use (mainly VAT) have not been taken into account, but taxation of fossil-fuel primary energy inputs into electricity production has been. Since coal is used as input in the production of electricity, to a larger extent that other fuels, the omission of end-use taxes on electricity implies that Table 2 gives an exaggerated picture of the difference between implicit carbon taxation of coal compared to other fuels. For the United States, local taxes on fossil-fuel use are not available in IEA (1990*a*). An estimate for import duties for Japan and the United States is included, while small import duties in Austria, Finland and Portugal are not taken into account. In a few instances tax data are not available: in these cases a zero tax is assumed. Where tax or price data were available in previous years, but not for 1988, estimates were made.

11. Price distortions in domestic fuel markets are also likely to be large in many non-member countries. Until recently prices in Poland, Hungary and the CSFR were less than half those in Germany. Low prices are likely to have been an important reason for the higher pollution intensities in those countries. Calculations by Unterwurzacher and Wirl (1991) suggest that raising fuel prices in Poland, Hungary and the CSFR to German levels could reduce CO_2 emissions by approximately 30 per cent from the 1990 levels. Also in the USSR, China, India and other countries outside the OECD, prices for fuels are often below world market prices (Burniaux ***et** al.*, 1991 and Hauglund ***et** al.*, 1990).

12. There is strong complementarity between different emissions. The interaction between abatement of different emissions from fossil-fuel use has been highlighted in several studies. Glomsrød ***et** al.* (1990) have shown in model simulations for Norway that the introduction of a carbon tax would reduce emissions of sulphur dioxide, nitrogen oxides, carbon monoxide and particulates roughly in line with the reductions of CO_2. While the reduction of CO_2 emissions by 26 per cent by 2010 would reduce Norwegian GDP by 2.7 per cent below baseline, benefits from reducing other pollutants and from cutting traffic accidents and traffic noise would offset roughly two-thirds of the GDP loss due to the CO_2 emission ceiling. Bergman (1990) calculates that the sharp emission reductions for sulphur dioxide and nitrogen oxide emissions between 1980 and 1993 to which the Swedish Government is committed, may lead to a stabilisation of CO_2 emissions at their 1980 level. In the absence of reductions in other pollutants, CO_2 emissions might have grown at a rate of 3 per cent per year.

BIBLIOGRAPHY

Barrett, S. (1991), "Economic instruments for climate change policy", in OECD, *Responding to Climate Change – Selected Economic Issues,* Paris.

Bergman, L. (1990), "Energy and environmental constraints on growth: a CGE modeling approach", *Journal of Policy Modeling,* 12(4).

Burniaux, J-M., J.P. Martin, G. Nicoletti and J. Oliveira-Martins (1991), "The costs of policies to reduce global emissions of CO_2: Initial simulation results with GREEN", *OECD Economics and Statistics Department Working Papers,* No. 103 (June).

Burniaux, J-M., J.P. Martin, G. Nicoletti and J. Oliveira-Martins (1991*a*), "GREEN – A multi-sector, multi-region dynamic general equilibrium model for quantifying the costs of curbing CO_2 emissions: A technical manual", *OECD Economics and Statistics Department Working Papers,* No. 104 (June).

Edmonds, J. and D.W. Barns (1990), "Factors affecting the long-term cost of global fossil fuel CO_2 emissions reductions", mimeo., Washington (December).

Glomsrød, S., T. Johnsen and H. Vennemo (1990), "Stabilisation of emissions of CO_2: a computable general equilibrium assessment", *Discussion Paper* No. 48, Central Bureau of Statistics, Oslo (April).

Hauglund, T. O. Olsen and K. Roland (1990), "Stabilising CO_2-emissions by carbon taxes – a viable option?", ECON report No. 1990/11, Oslo.

Hoeller, P., A. Dean and J. Nicolaisen (1991), "Macroeconomic implications of reducing greenhouse gas emissions: a survey of empirical studies", *OECD Economic Studies,* No. 16 (Spring).

IEA (1990), *Energy Policies and Programmes of IEA Countries, 7989 Review,* Paris.

IEA (1990*a*), *Energy Prices and Taxes,* Paris.

IEA (1991), *Greenhouse Gas Emissions: The Energy Dimension,* Paris

IEA (1991*a*), *Energy and the Environment: Transport System Responses in the OECD,* Paris (forthcoming).

Intergovernmental Panel on Climate Change (IPCC) (1990), "Policymakers summary of the scientific assessment of climate change", WMO and UNEP, New York (June).

McDonald, S.C. (1990), "A comparison of energy intensity in the United States and Japan", Pacific Northwest Laboratory, Washington.

Manne, A. (1991), "Global 2100: Three scenarios for reducing carbon emissions", paper presented at the OECD's Comparative Modelling Exercise in Washington, mimeo. (March).

Nicolaisen, J., A. Dean and P. Hoeller (1991), "Economics and the environment: a survey of issues and policy options", *OECD Economic Studies,* No. 16 (Spring).

Nordhaus, W.D. (1990), "A survey of estimates of the cost of reduction of greenhouse gas emissions", mimeo. (February).

OECD (1991), *The State of the Environment,* Paris.

OECD (1991a), ***Estimating the Benefits** of **Greenhouse Warming Abatement*** (forthcoming).

Pearson, M. and S. Smith (1990), "Taxation and environmental policy", ***IFS Commentary,*** No. 19, The Institute for Fiscal Studies (Januaty).

Steenblik, R.P. and K.J. Wigley, (1990), "Coal policies and trade barriers", ***Energy Policy,*** Vol. 18, No. 4 (May).

Unterwurzacher, **E.** and F. Wirl (1991), "Wirtschaftliche und politische Neuordnung in Mitteleuropa: Auswirkungen auf die Energiewirtschaft und Umweltsituation in Polen, der **CSFR** und Ungarn", ***Zeitschrift** fur **Energiewirtschaft*** (forthcoming).

Williams, R.H. (1990), "Low-cost strategies for coping with CO_2 emission limits", ***The Energy*** *Journal,* Vol. 11, No. 3, pp. 35-59.