THE 1991 INTERNATIONAL ENERGY WORKSHOP: THE POLL RESULTS AND A REVIEW OF PAPERS

A. Manne
Stanford University, California, USA

L. Schrattenholzer
International Institute for Applied Systems Analysis, Laxenburg, Austria

K. Marchant
Organization of the Petroleum Exporting Countries, Vienna, Austria

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Foreword

In the tenth year of its existence, the International Energy Workshop (IEW) held its annual meeting at IIASA. In addition to analyses of the IEW survey of expected crude oil prices, economic growth, primary energy consumption and production, and energy trade, the 1991 meeting featured sessions on the forthcoming establishment of the common energy market in the European Community, the prospects for the development of the energy systems in the economies of the former Soviet Union and Eastern Europe, and the global environment.

This report is divided into three sections. The first section, prepared by Alan Manne and Leo Schrattenholzer, presents and analyzes the latest poll results. The next section, prepared by Keith Marchant, reports on the papers presented at the IEW meeting. The final section, prepared by Keith Marchant with the assistance of Garry Brennand of OPEC, briefly summarizes the proceedings of the special session held on the final morning of the event.

PETER E. DE JÁNOSI
Director
IIASA

The 1991 International Energy Workshop: the poll results and a review of papers

Prof Alan Manne, Dr Leo Schrattenholzer and Keith Marchant

IN THE MIDDLE of each year over the past decade, the International Energy Workshop (IEW) has attracted energy experts from across the world to present their latest research and to discuss and analyse topical issues affecting the industry. A highlight of this event is the Workshop's own poll of energy projections, based on the results of a survey conducted among leading international energy specialists in the months leading up to it. This year, as with every second year, the Workshop was situated in the small, scenic Austrian town of Laxenburg, just south of Vienna. The main sessions took place on 18–20 June 1991, while on the morning of the 21 June, there was a specialized energy modelling forum.

During the 12-month period which had elapsed since the previous Workshop, held at the East-West Centre in Honolulu, the Middle East crisis had rocked international oil markets, impacting upon the energy industry at large and threatening to reverberate through key sectors of the world economy. It seemed surprising, therefore, that this crisis received relatively little attention in the 1991 Workshop. The likely explanation for this was that the heat of the crisis was contained within the period between the two Workshops, and that, by June 1991, the international oil market had settled down to a relatively high degree of stability. During the final quarter of this period, the market was arguably more stable than it would have been had no crisis occurred, since, with around 4.5 million barrels per day of crude withdrawn from the world market, as well as significant refining facilities, there was less competition among producers to meet demand. OPEC's production agreement was suspended for the duration of hostilities, enabling the 11 Members who were unaffected by United Nations sanctions to raise production to capacity levels, in order to meet the shortfall. In this way, prices soon settled back at around their pre-crisis levels, and remained generally buoyant, without experiencing the nervousness associated with suppressed production potential.

The Workshop participants could therefore concentrate their attention on other, more fundamental energy issues. The proceedings were concentrated in three main areas: the forthcoming establishment of the internal energy market in the European Community; the major political and economic upheavals in the Soviet Union and the former Eastern European centrally planned economies (CPEs); and

Prof Manne is from Stanford University, California, US, Dr Schrattenholzer from the International Institute for Applied Systems Analysis, Laxenburg, Austria, and Mr Marchant from the Organization for the Petroleum Producing Countries, Vienna, Austria.

the global environment. Very loosely, for the sake of convenience in this paper, they could be referred to as the short, the medium and the long term. Not only does such a categorization reflect the chronological order of events, but it also mirrors the levels of uncertainty. For example, the energy profile in the Soviet Union cannot be established to any great degree until fundamental political issues have been sorted out; on the other hand, while many political issues still plague the European Community, it does nevertheless have a clearer vision of the future than its Eastern neighbours.

There is, of course, a strong linkage among the three groups. This is particularly true where the environment is concerned. As far as the two regions are concerned, the proposed European Energy Charter, if it comes into force, will help bridge the vast gulf between Eastern and Western European energy interests; until then, it appears that there will remain a piecemeal relationship.

This paper is divided into three sections, relating to this year's Workshop. The first section, prepared by Prof Manne and Dr Schrattenholzer, presents and analyses the latest poll results. The next section, prepared by Marchant, constitutes a report on the papers presented at the Workshop; it is divided into the three abovementioned areas of discussion — the energy market, the former CPEs and environmentalism. The final section, prepared with the assistance of Garry Brennand, Assistant Econometrician at the OPEC Secretariat in Vienna, briefly summarizes the proceedings of the special session held on the final morning of the Workshop, when recent developments of various energy models were presented and discussed.

Finally, copies of most of the papers referred to in the text can be obtained from Dr Schrattenholzer at the International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria.

1. Recent IEW poll results

Beginning in 1981, the IEW has compared different groups' projections of crude oil prices, economic growth and primary energy flows. Each edition includes projections that are no more than three years old. The July 1991 edition reports on more than 220 responses from about 60 different organizations and individuals from across the world.

A typical IEW poll result consists of frequency distributions, as in **figure 1**. This shows projections of the international price of crude oil, expressed in constant currency units, in 1990 US dollars per barrel. Each group's response is plotted as one asterisk. Even for those projections published in 1990, there was strong disagreement about what the actual price of crude oil would turn out to be for that year. As we look further into the future, there is even more disagreement, but there is a clear tendency for the median price of crude to rise over time.

The latest oil price projections — those with a 1991 publication date — are shown in **figure 2**. They show a higher level of consensus over the actual oil price in 1990, and there is a more pronounced increase through the year 2020.

Figure 1
International price of crude oil, IEW poll responses dated 1990
1990 $/b

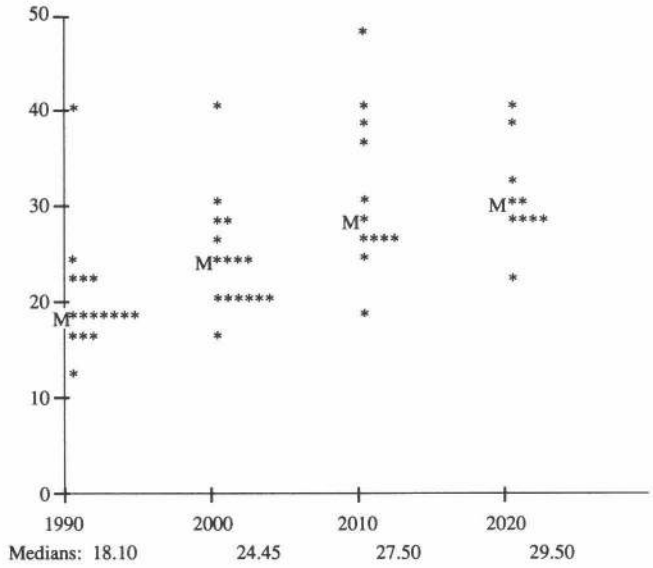


Figure 2
International price of crude oil, IEW poll responses dated 1991
1990 $/b

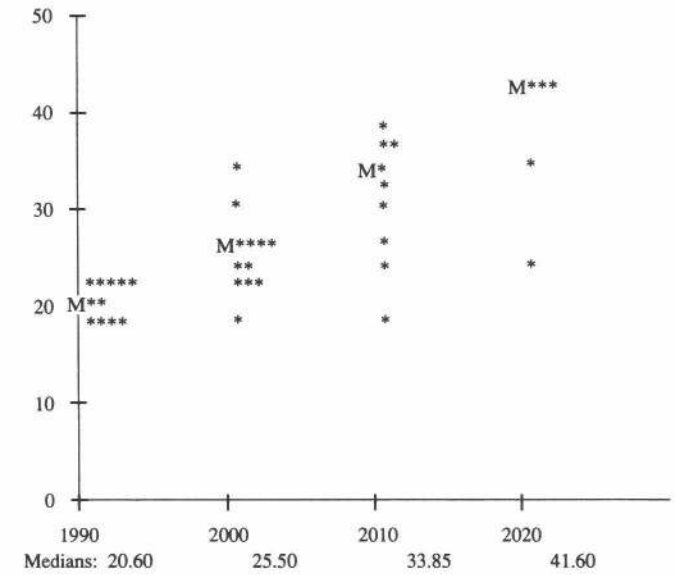


Figure 3
Crude oil prices: actual and successive IEW polls
1990 $/b

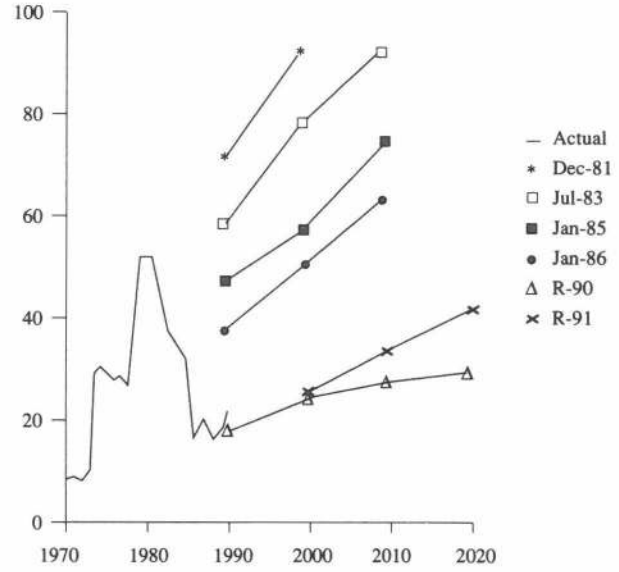
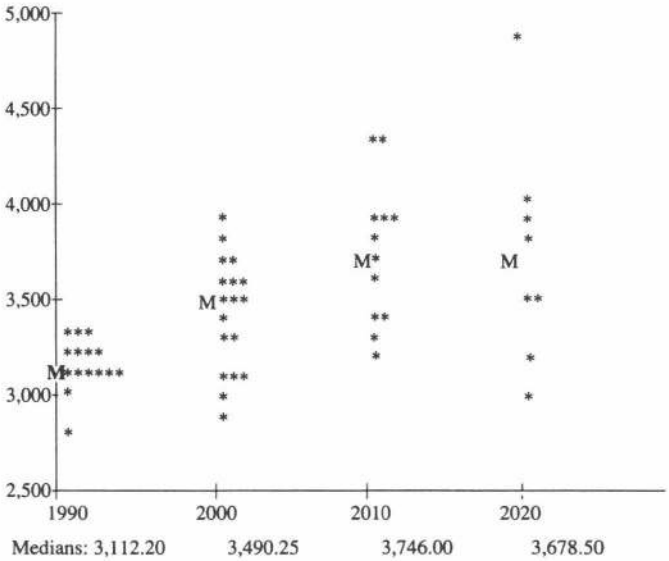


Figure 4
Projections of global oil consumption
mtoe



One of the characteristic elements of the IEW poll is that, although it has had no great success in forecasting the price of crude oil, it seems a relatively straightforward matter to predict what the forecasters say the price is likely to be. Looking back at the projections made in the early 1980s (**figure 3**), we find that the expectations were for an ever-increasing real price. When the actual price of crude oil fell from year to year, the successive projections also fell. And when the price of crude oil started to increase between 1989 and 1990, the projections of future prices also rose.

In contrast, there is greater stability in the IEW projections of quantities. **Figure 4**, for example, shows projections of world crude oil consumption. There is some scatter to these, but it is not a zero-based graph. If one had zero as the base for this graph, one would be dealing with a much tighter looking distribution.

Similarly, the projections of global primary energy consumption (**figure 5**) show much more agreement than the oil price forecasts. There has also been considerable stability over time in projections of crude oil supplies, demands, electric energy supplies, etc.

One of the variables that can be derived from IEW poll results, and which can be compared across countries and regions, is the change in energy intensity. **Figure 6** shows the median indices (with 1990 = 100) of the energy/GDP ratios in the five IEW regions (including the sub-regions) — OPEC, the non-OPEC devel-

Figure 5
Projections of global primary energy consumption
mtoe

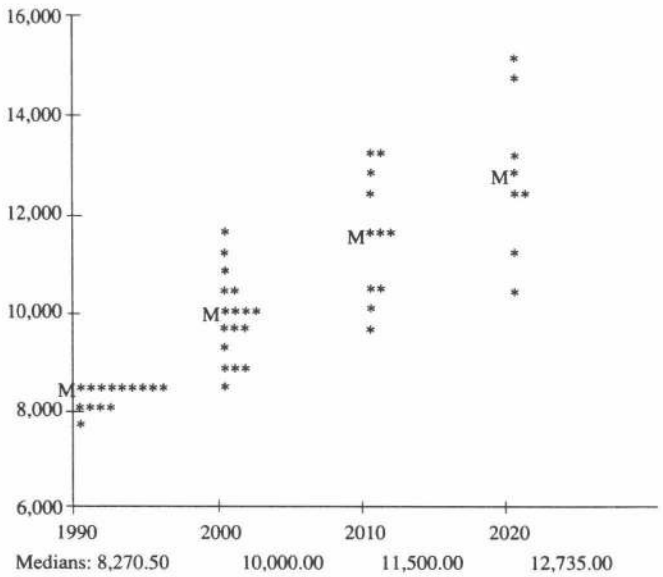
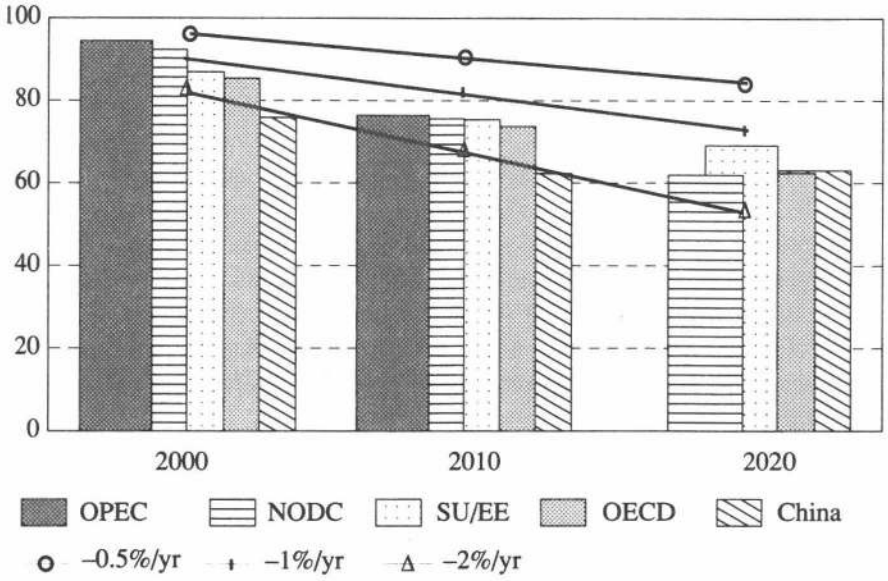


Figure 6
Energy/GDP ratios, medians
1990 = 100



oping countries (NODC), the Soviet Union and Eastern Europe (SU/EE), the OECD and China. All regions, except China, include poll responses for sub-regions. As a reference, the lines corresponding to energy intensity reductions of 0.5 per cent/year, 1.0 per cent/year and 2.0 per cent/year have been included. A number of observations are noteworthy.

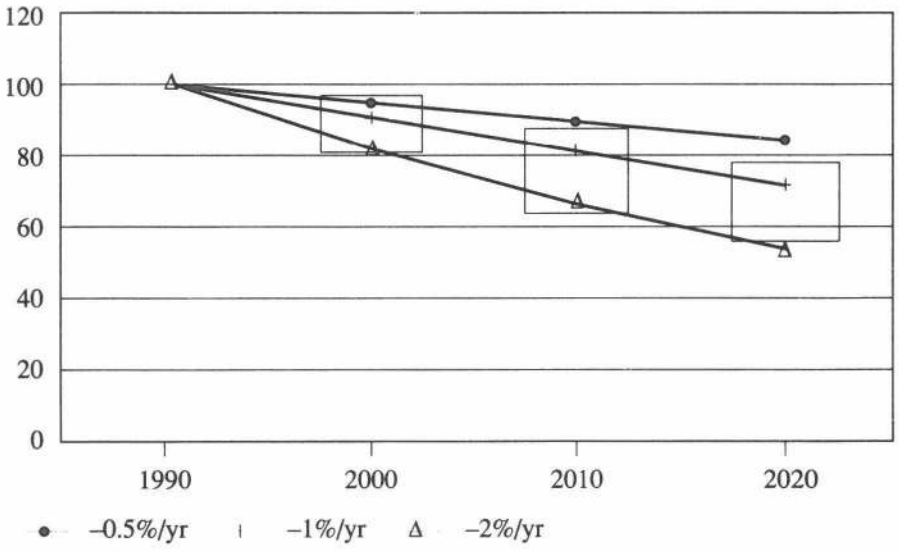
(i) With few exceptions, a 1.5 per cent annual decline rate is typical for all projections (regions and sub-regions). Some of this reduction is price-induced conservation, and some is the result of structural changes.

(ii) In the short run (1990–2000), there are significant differences between the regions. The projections for OPEC countries show the smallest reduction in energy intensity, followed by NODC, SU/EE, OECD and China.

(iii) The projections for China correspond to an average annual energy intensity reduction of 2.0 per cent per year through 2010 (the medians for the year 2020 are not comparable with the other medians, because only the two highest projections extend to that year. The others do not go beyond 2010).

The variability or, respectively, the degree of consensus of poll responses for a given item can be expressed by well-defined ranges. In **figure 7**, these ranges have been calculated for all poll responses taken together and assuming that the projections of energy/GDP ratios are distributed log-normally. With this assumption, the ranges shown are two standard deviations wide and centred around the average. In this way, they cover a total probability of some 68 per cent, leaving about 16 per cent probability for deviations on either side. The lower ends of these ranges coincide well with an annual rate of 2.0 per cent for the reduction in energy intensity. The upper ends begin just above the 0.5 per cent line, dropping to some 0.8 per cent by the year 2020. This figure also shows a phenomenon that has been observed repeatedly in past analyses of IEW results. That is, the variability of poll responses for a given item does not always increase as the date for the projections moves into the more distant future. Here, the range for 2020 is clearly smaller than the range for 2010.

Figure 7
Energy/GDP ratios, 68% ranges
1990 = 100



A good deal of energy-related research has been focused on the increase in global concentrations of greenhouse gases. Accordingly, as is seen in later sections of this paper, this topic was covered extensively during the 1991 IEW. Although the poll responses do not cover greenhouse gas emissions directly, the global emissions of CO_2 can be calculated from the poll responses on the global consumption

of fossil fuels. Using average specific emissions for primary oil, natural gas and coal for the calculation of 68 per cent ranges of annual carbon emissions, we arrive at **figure 8** (the values chosen are 0.78, 0.63 and 1.04 tonnes of carbon per toe of oil, gas and coal, respectively, and are based on Rotty and Masters (1985) and Ausubel et al (1988)). These IEW poll ranges are compared with the historical record and with three scenarios of the Intergovernmental Panel on Climate Change (IPCC). The IEW poll results are somewhat higher than the IPCC's 'business as usual' scenario. At the same time, the two IPCC scenarios, 'low emissions' and — even more so — 'accelerated policies', appear rather optimistic. This should come as no surprise. These two IPCC scenarios are normative by design, whereas the IEW poll responses tend to reflect likely developments.

Figure 8
Global carbon emissions, 68% ranges
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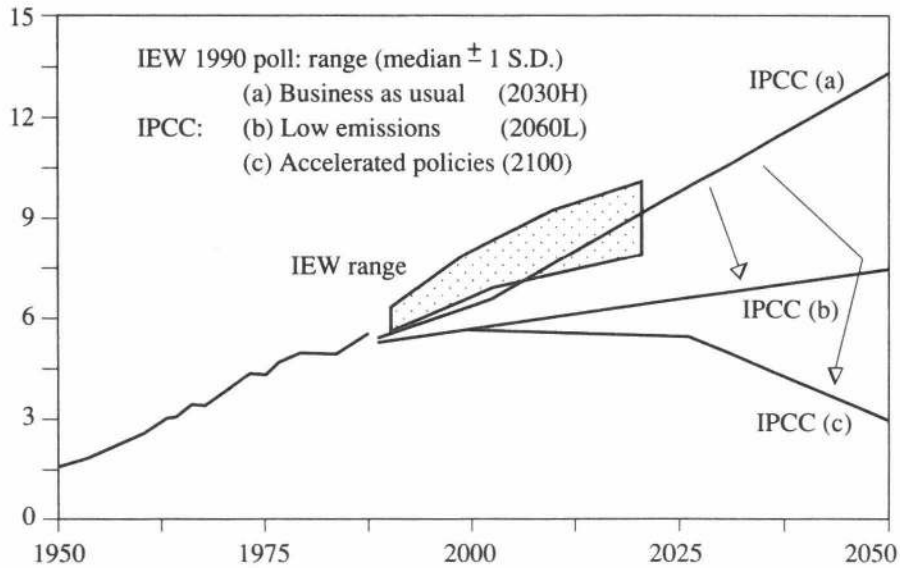
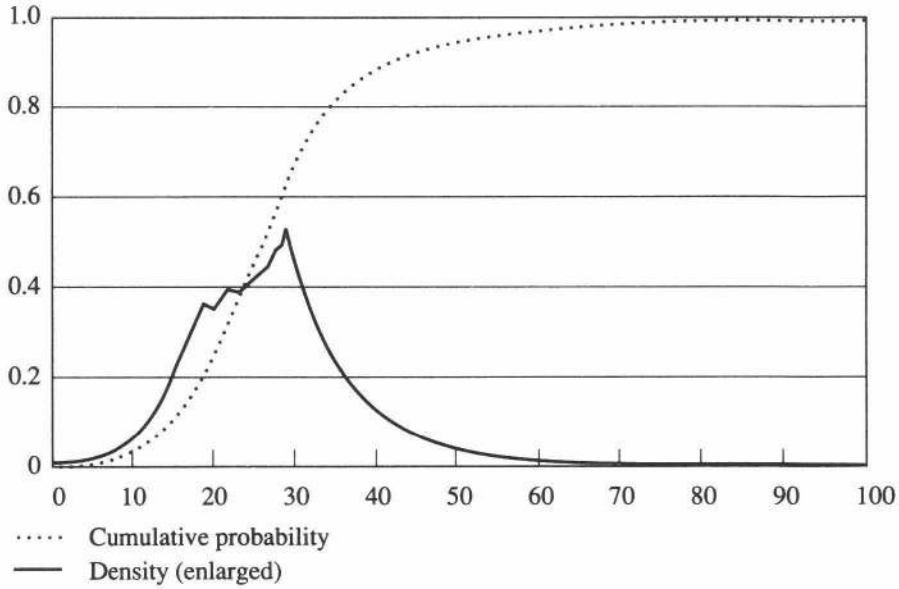


Source: IPCC and IEW

The presence at the Workshop of energy analysts from across the world was taken as an opportunity for organizing an ad hoc 'Delphi poll' on the international oil price in the year 2000. A questionnaire was distributed among the participants, asking for estimates of: (i) the average oil price; (ii) the ten per cent percentile (i.e., that value of the oil price which is expected to be exceeded with a probability of 90 per cent); and (iii) the 90 per cent percentile (i.e., that value of the oil price which is expected to be exceeded with a probability of ten per cent). The individual

estimates were smoothened and aggregated. The resulting density curve and its integral (the cumulative probability) are depicted in **figure 9**. This shows a comparatively flat part of the probability density between $19/b and $29/b (1990 purchasing power), averaging between $26/b and $27/b. The ten per cent and 90 per cent percentiles are $16/b and $41/b respectively.

Figure 9
IEW oil price for the year 2000, "Delphi poll", June 1991
1990 $/b



2. A review of papers

a. The European Community's internal energy market

The impending establishment of the internal energy market for the European Economic Community (EEC) gave this topic special relevance to the 1991 Workshop. Even at that late stage, the pace and magnitude of the event was unclear, since many political issues remained unsolved, especially those construed as affecting the individual sovereignties of member states.

Pariente-David made a visual presentation of the principal issues at stake and their current status. She highlighted the wide disparities prevailing among the 12 member states, with just half a year remaining until the starting date. For example, an examination of the discrepancies in excise taxes on oil products at the beginning

of 1991 (in European currency units/1,000 litres) would reveal, for unleaded gasoline, differences of more than two and a half times between the highest level of taxes, in Italy, and the lowest, in Greece; for diesel, the difference was almost a factor of five. Pariente-David concentrated the latter half of her presentation on natural gas, a sector which was expected to be greatly affected by the establishment of the energy market.

The electricity industry had a similar monopolistic character to natural gas, prompting Odell to contend that, "for gas and electricity, the continuing nationalistic organization and ambience of the industries creates massive scope for Europeanization ... Economics, politics and the environment are now combining to put natural gas at the centre of the Euro-energy sector, and Euro-policy should be orientated to enhance and accelerate this development. Consequential expansion of the gas market, an emphasis on economic rather than technical efficiency and liberalization (both within and between countries) will then collectively ensure a highly dynamic — rather than a staid and comfortable — gas industry across the continent: and, equally importantly, open up the technical economic possibilities of an alternative, a more dispersed and a more competitive supply system for electricity."

Meeder, on the other hand, was satisfied with the manner in which the European gas industry had evolved so far, and was optimistic about its future, "as long as it will be allowed to continue to operate in a political environment which has the right priorities. However, the introduction of common carriage in the gas sector can change this security of supply into insecurity of supply and, from the producers' or suppliers' point of view, into insecurity of demand." He believed the European Energy Charter could support the achievement of the EC's main energy objectives if the following conditions were fulfilled: "no bureaucracy; market mechanism first priority; not a vehicle for regulation; (and) free transit of energy across Europe."

Dreyfus/Koklauner retained the theme of the gas industry but switched the spotlight elsewhere, by utilizing as a case study North America's experience with open access to natural gas pipeline transportation. The authors pointed out that the North American gas market was historically, politically and technically unique and that its experience of deregulation was not directly transferable to Europe's open access proposals. The European proposal would be less likely to induce a large number of independent transactions or the entry into the market of many new merchants. The North American experience, however, "highlighted a set of generic conditions that must be met for the political and economic stability of gas markets," and this would be of particular relevance to Europe. These revolved around: the responsibility of governments to ensure future reliable services for domestic gas users who had made their own arrangements with foreign suppliers; the means of pipeline grids administering the transactions arranged by third parties; the equitable resolution of competing claims upon available transmission services; the planning and arrangements of the portfolio of future supplies, to sustain the new

markets which grew up around an assortment of independent transactions; and the impact upon investment in major supply ventures and the project financing of new liquefied natural gas and pipeline facilities, if there were the possibility that independent merchants had a claim to capacity.

The European electricity power supply industry was presented as a more complex affair by Kalaydjian, who saw an abundance of different systems spread across the continent. He identified an apparent contradictory movement towards more *diversification* among the organization types of national system and more *integration* of all national systems into a common power exchange zone. But he added that, according to the European Commission and the Community's Member States, it was possible to combine both. He noted some 'hard' issues which defied straightforward answers, concerning the "kind of relationship (which), on a competitive basis, may be established between undertakings, subject to various regulatory and institutional constraints, and exhibiting various asset ownership structures." The paper discussed the pros and cons of the introduction of third party access (TPA) to the European electricity system, claiming that "this would be a straightforward tool to carry out competition if there were some clear evidence of TPA's reliability and efficiency." He then branched out into other means of making the generation business more competitive, including open and closed generating pools, the fostering of independent power producers on the avoided cost principle, and independent bidding. Kalaydjian concluded: "All debates about competition in power generation raise the asset specificity issue. Electricity is rightly regarded as a special case: economies of scale in power supply requires coordination between generation, transmission and eventually distribution. Vertical integration exists, none the less, to various, more or less strict, more or less loose degrees ... Such structures may thus endure, even in the frame of competitive generation."

The third and final energy source to be treated as a separate subject at this year's Workshop, in the context of the forthcoming European internal energy market, was coal. Trumpy pointed out that, for the next century, Europe — East and West — had a favoured position in energy autonomy only in coal, and then rued the recent demise of the European Community's coal industry "as a strategic sector and a source of national pride." The coal industry was now seen as a cost to the Community and its member states. Yet, "except for the problems of subsidies to EC coal production, the single market already exists for coal." It was the most 'private sector' of the energy industry. Nevertheless, Trumpy contended that the coal industry suffered a competitive disadvantage, because of state aid to oil and gas companies and to utilities, particularly nuclear power.

In general, Odell believed that the completion of the single energy market would be 'relatively unimportant' in determining changes in European energy consumer costs in the 1990s — given that a number of other factors (i.e. energy security costs, environmentally-inspired energy taxes, and the protection costs for

communities exposed to the forthcoming near demise of indigenous deep-mined coal) would lead to significantly higher real energy prices. But the integrated energy market was justified, in his view, as a symbol of Europe's integration, given the high profile which marked energy issues, and as an essential objective in the Community's attempt to create 'level playing fields' for competing energy enterprises.

b. The other side of Europe: the former CPEs

The stark contrast between the energy profiles of Western European nations and their Eastern European neighbours, including the Soviet Union, manifested itself clearly at the Workshop. Two developments, which had occurred more or less simultaneously, had seriously disrupted the energy outlook for the former CPEs; the first was the recent series of political and economic upheavals which had resulted in sweeping changes to systems which had dominated the region since World War Two; and the second was the environmental debate.

For the sake of convenience, this section, on the former CPEs, has been divided into two: the Soviet Union and the rest of Eastern Europe. Such a division is especially helpful when it comes to examining the oil sector, where, up to recently, there was a long-established supplier/receiver relationship between the Soviet Union and the individual Eastern European states. The diminution of this relationship has exacerbated the energy supply problems facing the former CPEs of Eastern Europe, since they have had to look to the world market and pay competitive prices for much of their oil. This is a completely new situation for them in economies ill-equipped to compete effectively with advanced industrialized societies.

a) Eastern Europe

Balabanov/Dietz summarized the energy problem facing the Eastern European states as follows: "For 1991, in accordance with the contracted delivery options ... a further 28 per cent (or even higher) reduction of Soviet oil exports to Eastern Europe will be taking place, hence smashing Soviet oil deliveries to the former Eastern European CMEA members to below the 50 per cent mark, as compared to 1989" (Soviet oil exports to Eastern Europe in 1990 were 31.4 per cent below their 1989 level). In their concise resumé of the Eastern Europe energy predicament, they pointed out that not only was Soviet crude output falling, from 623 million tonnes of oil equivalent in 1988 to 570 mtoe in 1990 and an estimated 500 mtoe in 1991. Not only *ipso facto* were their total net oil exports falling in actual and projected terms. But the proportion of exports to Eastern Europe was falling at a much greater rate than that to the remainder of the world, i.e. from 58 mtoe in 1988 to 39 mtoe in 1990 and an estimated 20 mtoe in 1995.

Balabanov/Dietz found no simple short-to-medium term solution for the energy needs of these five countries: Bulgaria, Czechoslovakia, Hungary, Poland and

Romania. Natural gas offered the best possibilities, however, as "the only available and acceptable option in the Central European context." Environmental considerations were taking their toll on the coal sector, partly "due to the stricter pollution controls demanded by Western Europe." Oil, despite the supply problems with the Soviet Union, was nevertheless still benefiting from the longstanding infrastructural arrangements between the two regions. But crude would have to be imported increasingly from the world market, and the requisite rapid adjustment process was already creating its own tensions across the industry.

Presentations made on individual Eastern European countries highlighted the wide range of energy problems now facing them, in the light of the recent economic and political upheavals, the burgeoning environmental issue and their specific indigenous resource endowments. Balandynowicz *et al*, when writing on Poland, summarized the common difficulties facing these countries as stemming from:

a) Strongly autarchic economic policies, which, for example, discouraged imports of fuel and other commodities;

b) Unrealistic pricing systems, which systematically under-priced all raw materials, especially fuels;

c) Management inefficiencies; and

d) Environmental degradation.

Various policy recommendations were made for the Eastern European states. Balandynowicz *et al,* for example, produced a list of objectives for the Polish energy sector, where in 1989 coal accounted for nearly 78 per cent of primary energy consumption, as: the achievement of efficient, secure supplies of fuel and energy; the assurance of the efficient use of energy, through the proper reflection of the costs of supply in prices; the establishment of viable self-financing enterprises with hard budgets; and the assurance of the social costs of energy production.

The case for coal was also strong in Czechoslovakia, and Balajka drew attention to the social disruption which could occur after cutbacks in this sector. After reviewing the country's general energy outlook, he concluded: "The future development of the energy system in the CSFR will be determined by the social, economic and political situation in middle Europe, as well as by the stronger environmental requirements. From the renewable energy sources, only geothermal heat and the waste heat from power plants could play some role in the energy balance of the next few decades. Waste combustion, as well as biogas production, could also play some role, but this will be limited by environmental requirements. The new emission standards will require additional investment in energy technologies based on

fossil fuels, namely coal combustion. Nuclear energy will be used mainly for base load electricity supply, while heat supply will be limited to the region near nuclear power locations. The use of new Western nuclear technology, such as that based on high temperature reactors, cannot be competitive at the present (exchange rate) of the krone to Western currencies."

Török and Praznovszky broadened the scope of the discussion by using Japan's post-World War Two economic development experience, backed up by recent Asian examples, as a model for Eastern Europe, with particular reference to Hungary. Their aim was to identify conditions for achieving an 'upwardly unstable' economic development process, with the emphasis on institutional developments (micro) as a pre-requisite for adjustments and 'coping' strategies. The authors applied the term 'upwardly unstable' to the kind of economic structure that resulted from the post-war Japanese method of 'intersectoral dialogue' to overcome the shortcomings of a command economy.

Möller explored the predicament facing Eastern European countries from another, non-energy, angle, and that was the required means and financial magnitude of bringing their per capita GNPs up to the average European Community level by the year 2005. He concluded that this would prove well beyond the capability of domestic savings — in every case — and would thus rely heavily upon imported capital. He concluded that capital to the tune of $600 billion over the next eight years was a rational estimate of the requirement, "this estimate being below the figure which is currently borrowed by the so-called Third World countries." Hungary was excluded from his analysis, as presented in his paper, and it was unclear whether an allowance for this country had been made in the figure of $600 bn. There was similar uncertainty over the inclusion of the former East Germany.

b) The Soviet Union

Möller did, however, contrast the plight of the Eastern European former CPEs with that of the Soviet Union, which would require a capital inflow of $1,850 bn in the next eight years and nearly two trillion dollars from 2000 to 2005 to reach EC per capita GNP levels, a sum which was "far beyond the realm of possibility." The author concluded that the Soviet Union could make good some of the shortfall by a substantial increase in energy exports to the OECD nations — an option which was, by and large, not available to the Eastern European states. But even here there were drawbacks. First, there was price instability on the world oil market, with the perennial danger of a price collapse ("What will happen when the world energy prices fall to an even lower level of $10–12/b?"); gas prices were not exempt from this instability, since, in most contracts, they were linked to oil prices. And secondly, there was the problem of the productivity and competitiveness of Soviet oil and gas production. "The only solution for the Soviet Union," he concluded from his model simulation, "would be to use more than 70 per cent of the

production surplus, induced by imported capital goods, as exports to the lender countries. Only with this strategy, and not with the export of energy alone, will it be possible to enlarge the capital stock of the Soviet Union" to meet the per capita GNP parity target by 2005.

One of the major problems with studying the energy system in the Soviet Union, especially in the context of comparative analysis with other parts of the world, was the shortage of reliable data. Dobozi made this point in his presentation on the impact of market reforms on Soviet energy consumption over the next ten years. Practical solutions had to be found for this shortage; Dobozi, for example, used United States government estimates for Soviet gross domestic product and principally British Petroleum data for energy.

Dobozi drew up five scenarios running to the year 2000, to illustrate the implications for energy consumption and the energy/GDP ratio of alternative market-based pricing options, under a set of assumptions about the price responsiveness of Soviet energy users. These scenarios indicated that "a marked reversal in the long-standing consumption and energy intensity trends is possible, with appropriate market-oriented pricing, exchange rate policy and the establishment of micro-incentives for energy consumers to act as cost minimizers."

Nekrasov emphasized the enormous non-economic burden the economy continued to carry. "The entire system of economic management was created under the pressure, and with the continuing support, of the non-economic load ... The depth of structural deformations does not make it possible to shift to economic methods of management and draw nearer to the market."

For the energy sector, he noted: "Orientation towards accelerated energy development has resulted in lower production growth rates and volumes and the loss of quality standards." The coal industry had been pushed into the background since the mid-1960s, when oil and gas were given top priority in state investment policy, while the nuclear development programme had 'collapsed' after Chernobyl. Only natural gas was capable of developing dynamically in the near future, but even here there were production problems.

He concluded, linking up with the environmental issue: "Under the present conditions, the task is to establish a new approach, which would promote the formation of socially acceptable fuel, energy and ecology balanced options of economic growth, providing a simultaneous solution to the (restructuring) process of the energy complex ... and the natural environment."

Netschayev concentrated on the theme of short-term Soviet priorities: "The exploitation of fuel relied for a long time on techniques that result in the rapid short-term expansion of production at the cost of longer-term recovery methods. One consequence of this has been the eastward movement of production to new but more remote and costlier areas ... The growth of energy equipment prices was also rapidly accelerating in the 1980s. The unit costs of oil exploitation increased in 1986–90 by more than 50 per cent."

Netschayev summed up the views of many Soviet specialists when he remarked: "It is rather complicated today to predict the future development of the energy sector and the future demand for energy in the USSR. The uncertainty of energy demand and supply is a consequence of the general uncertainty and instability of the economic and political situation in the USSR."

This would be of no comfort to the Baltic republics, whose case was put by Salay, at a time when they were still struggling for their independence. All the economic uncertainties of the Soviet Union were there in force. On top of that was the fact that, with the exception of oil shale in Estonia, the Baltic republics had limited domestic energy resources. They utilized almost exclusively fossil fuels, making them highly dependent on supplies from the Soviet Union. But these supplies were becoming increasingly unreliable, at a time when the three republics were asserting their rights to managing their own energy supply and use. Long-term energy strategies were being developed by the republics, but the main focus was on immediate energy supply.

c. The environment

The environmental issue was studied at length at the Workshop, both as a subject in its own right and as a sub-topic in other discussions. At what could be described as the 'grassroots level', Löfstedt presented the results of a survey of public perceptions of climate change and energy use. His survey was carried out in summer 1990 at Umeå, a university town of 87,000 inhabitants situated in the north of Sweden. As he admitted himself, he was not operating in an indifferent, apathetic community: "Together with the Dutch and Germans, Swedes have the reputation of being one of the most environmentally conscious people in Europe." To gather his data, Löfstedt utilized random telephone surveys, non-random direct interviews, three focus groups of energy producers, consumers and 'spokespeople' from political parties, and regional newspaper analysis.

His results showed the following. First, the citizens of Umeå conserved energy mainly to save money. Even though Sweden had the second lowest electricity prices in Europe, local people still regarded economics as the primary motivation to save energy, and not moral or environmental reasons. Secondly, even citizens who reported environmental reasons for conserving energy did not perceive a link between the risk of global climate change and energy use. Of the 21 per cent who cited environmental reasons, 16 per cent did so because they wanted to reduce all kinds of pollutant emissions. Lack of knowledge was perceived as the main reason for the failure to perceive the linkage. There was considerable confusion between the global climate change debate and the ozone 'hole' debate. And thirdly, although citizens of Umeå possessed limited knowledge of climate change, they perceived it as threatening, with 77 per cent of the telephone respondents indicating that the greenhouse effect would produce undesirable consequences.

The issue of priorities with environmental measures was elaborated upon by several speakers. Kolstad and Barrantes explored the implications of learning on the optimal control of emissions. They stated that, in their 'highly simplified' global warming model, "the suggestion is that a rapid rate of learning should (allow us to tolerate) higher current emissions than if we were not learning." An increased rate of learning raised optimal current period emissions, because it meant greater flexibility which made it easier to correct mistakes. While acting soon would reduce potential adverse effects, waiting would be advantageous *ex post* if the problem turned out to be less serious than expected.

Manne and Richels expressed the issue in terms of 'buying greenhouse insurance'. They posited: "Suppose ... we take the view of a thrifty purchaser of insurance who knows that the climate experts are currently deadlocked on the chances of a global calamity if we follow a 'business-as-usual' policy. What steps should we take today to reduce the risk to future generations?" They noted that three forms of greenhouse insurance dominated current discussions: continued intensive scientific research to reduce climate and impact uncertainties; the development of the new supply and conservation technologies to reduce abatement costs; and immediate reductions in emissions, in order to slow down climate change. They envisaged the issue as finding the right blend of options, and analysing the interactions among them.

They concluded that the size of the hedge against unacceptably rapid changes in climate was quite sensitive to the quality and timing of the climate research results. Their analysis, using Global 2100, showed that there could be a major gain in reducing climate-related uncertainties — to the tune of around $100 billion for the United States alone. They found that the value of information was also quite sensitive to one's confidence in its timeliness and reliability; relatively small increases in accuracy could yield substantial dividends. The optimal hedging strategy was also sensitive to the prospects for new supply and conservation technologies. "The near-term policy implications are clear," they stated. "There is less need for precautionary emission cutbacks if we undertake a sustained commitment to reducing climate uncertainty and to developing new supply and conservation options. Better climate information reduces the need to hedge against a potentially hostile future. Improved supply and conservation technologies will enhance our ability to deal with such a future, if it should occur."

There were numerous approaches to research into the costs of emissions control. Nordhaus sketched out the latest developments in his research into the establishment of a simple cost-benefit framework for determining the optimal control of carbon dioxide and other greenhouse emissions. In a preliminary and tentative paper, he explained how he was planning to introduce a model of the economy and the climatic system which allowed for different policies in the transition path from those in the ultimate steady state.

Peck and Teisberg adopted the Manne-Richels modelling approach to determine optimal time paths of emissions control under alternative assumptions about the damage cost function. They added to this approach a representation of the time path of the global mean temperature as a function of greenhouse gas emissions, and a representation of the costs resulting from a global mean temperature increase. Their optimal time paths could be summarized by the time paths of the corresponding optimal carbon taxes. Their work indicated that, with plausible assumptions, an optimal carbon tax would tend to rise over time — a result which contrasted with the 'hump-shaped' carbon taxes implied by the CO_2 reduction policies currently under discussion. Their work also suggested that the damage cost function of global warming would have to be both high and non-linear to justify the general level of CO_2 control and carbon taxes implied by these policies.

Sterner, Dahl and Franzen looked at fiscal measures in the context of transportation, in a paper entitled 'Analyzing the effect of coordinated global environmental policies on transport fuel demand and carbon emissions.' The paper began by testing a series of models for gasoline demand in 21 OECD countries, and eventually selecting the lagged endogenous model as the basis for projections (the exception, Sweden, used an inverted-v lag model). In order to assess the effects of changed tax policies, the authors calculated hypothetical domestic gasoline prices for each country by applying different tax rates to the respective pre-tax prices.

The lagged endogenous estimates of long-run gasoline elasticity averaged around –0.8 for price and +1.2 for income, implying that gasoline prices had to rise faster than the income growth rate if gasoline consumption were to be stabilized at present levels. Under assumed income and population growth rates with no tax changes, OECD gasoline consumption and carbon emissions would rise by 47 per cent from 1987 to 2000. Raising all country taxes to the highest OECD level — that of Italy — would instead decrease them by 32 per cent, mainly due to the large reduction in the US.

Some papers explicitly tackled the emissions issue in the context of a particular nation. Schaumann, Schmid and Voß examined cost-effective CO_2 strategies for the Federal Republic of Germany. They noted that, in order to meet the Toronto conference's goals would require a reduction in CO_2 emissions of well over 50 per cent by the year 2005 and of more than 90 per cent by the middle of the 21st century. They drew up three strategies for the year 2005. The first was characterized primarily by energy savings; the second assumed a phase-out of nuclear power by 2005; and the third was based on an increased utilization of nuclear power. They also applied the European Community energy-flow optimization model (EFOM) to environmental issues in the former Federal Republic of Germany. One reference case included no new nuclear plant construction, while the other allowed one large nuclear plant per year from 1998 to 2010. The results suggested that, if CO_2 targets became more strict, the economic benefits of nuclear would increase as a substitute for coal-based power generation.

Novikov *et al* compared some economic aspects of the ecological risk of electricity production from coal and nuclear in the Soviet Union. Both sources of energy had suffered in the environmental debate pertaining to that country, coal from enhanced mass media exposure and nuclear from Chernobyl. A comparison of a nuclear power plant (NPP) with a coal-fired plant which had reliable, high-quality environmental protection equipment installed, gave a (14–40 per cent) advantage to an NPP in the Urals and (35–60 per cent) to one in the west of the Soviet Union. This advantage could be regarded as an economic reserve which would be used for environmental protection and the enhancement of NPP safety, the authors contended. "The question arises whether this margin is enough to reach an acceptable level of safety," they added.

For New Zealand, Read projected that, through fixing CO_2 from the atmosphere by growing more biomass, this country's net emissions targets could be met at acceptable cost. For practical purposes, this meant intensive tree growing, supported by a proposed national policy of 'tradeable obligations' upon energy wholesalers to grow biomass in proportion to the carbon content of the fuel they sold.

Spitzer took the issue of biomass to a global plane when he noted that, in view of the fact that biomass was expected to meet half the world's energy demand in the year 2100, two problems had to be faced. First, the required quantity of biomass corresponded to about 39 per cent of the present annual net production of terrestrial biomass; and secondly, since the specific CO_2 emissions of biomass fuels were higher than those of fossil fuels, the CO_2 emissions by the year 2100 would be about 46 per cent higher than the corresponding emissions from fossil fuels. Such problems were being analysed at present using the Osnabrück Biosphere Model.

The role of methane in climate change was also discussed as a separate topic. Olivier and Swart maintained that, at present, methane contributed 19 per cent of the greenhouse gases which resulted from human activities, compared with 50 per cent from carbon dioxide. They based their paper on the experience of The Netherlands, which is a major natural gas producer and is itself highly dependent on this source of energy for domestic purposes. There, oil and gas production and distribution accounted for about 17 per cent of total methane emissions (enteric fermentation constituted 35 per cent and landfills 29 per cent). The most important policy options for reducing methane emissions were: pre-mining degasification, the recovery of methane from landfills, the flaring of associated gas, vigorous leakage control progammes and the application of three-way catalysts in petroleum-powered cars.

Another important area of research examines the issue of a global strategy for the environment, especially in the context of the North-South divide. As Okogu noted: "As the world moves towards negotiating and signing a convention on the environment, it is clear that the attitudes of rich and poor nations to the issue will very likely differ substantially. This difference is not because one group of coun-

tries likes a clean environment less than another, but because the demand for a clean environment ... depends, among other things, on one's income and the price of the good." His paper drew on the concept of rate of time preference, and said that this would be different between poorer and richer nations. Poorer countries could not afford as much of a clean environment as richer ones, if the cost of this was stagnating their economic development. "Thus, any negotiations on emissions reduction must ... build the differential rate of time preference into the process."

Imran touched upon the same theme when he wrote: "Among the various (environmental) strategies under question, the developing countries will favour those that hurt their growth prospects the least, given the difficulty they face with reducing carbon emissions and the economic trade-off involved." The issue of equity was crucial in devising strategies for these countries, which would enable them to participate in international agreements. "International transfers to the developing countries need to be designed not only as a compensation for environmental compliance, but also as a means of influencing their inter-temporal choices."

Styrikovich called for a global strategy to counter climate change: "The moral obligation of scientists all over the world is to critically summarize the extensive literature, to unify the method of investigation, in order to obtain comparable results, and to disseminate these results among the public and political leaders. It is important that specialists representing various branches of science, including experts on the biosphere ... and, of course, economists and sociologists, participate in this work, since the proposed measures suggest a rapid, dramatic restructuring of — and not a gradual change in — a number of vital, fairly sluggish sectors of industry and agriculture and the established life-style of the planet's population."

3. Energy Modelling Forum Study 12

On the Friday morning, a meeting of the Energy Modelling Forum Study 12 took place. The subject was "Global climate change — energy sector impacts of greenhouse gas emission control strategies." The purpose of the forum was to carry out a detailed study of energy/environment models, involving the comparison of methodologies as well as the assessment of results.

During this session, a clear distinction emerged between two types of model. The majority were very long-term models, most of which extended to the end of the 21st century and were based upon mathematical programming. The models of the Organization for the Petroleum Exporting Countries and the International Energy Agency , however, were econometrics-based and covered a much shorter period of 20 years.

With the long-term models, the values of such key parameters as Autonomous Energy Efficiency Improvement (AEEI) took on particular significance. For example, the OECD Secretariat presented results comparing the forecasts from the different EMF-12 models concerning carbon emissions in the 21st century, and dis-

covered that major differences among the results had arisen only through the use of varying assumptions for the AEEI; once these were unified, the models' results became very similar. But there remains a great deal of uncertainty regarding the appropriate values of the AEEI, and these comparisons indicated just how sensitive the model results are to changes in this key parameter. All the long-term models contained some form of backstop technology, usually synthetic fuels, which would be phased in gradually as fossil fuel resources ran down in the 21st century.

The estimated size of the proposed carbon tax was included in many presentations, and indicated that any environmental policy, which aimed at imposing large reductions in emissions, would require very high level levels of taxation, unless it were accompanied by other effective efficiency measures. For example, a carbon tax of more than $100 per barrel of oil equivalent (i.e. almost $1,000 per tonne of carbon) at 1991 prices would be required to achieve the Toronto target by 2005, if this measure were imposed in isolation.

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2. The following papers, which were referred to in sections two and three, were made available at, or shortly after, the 1991 International Energy Workshop. Copies of most of these papers can be obtained from Dr Schrattenholzer at the International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria.

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3. The full text of the following presentation to the 1991 Workshop was published in the Autumn 1991 issue of the OPEC Review.

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