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IEA OECD ETSAP news

ANNEX VII CONTRIBUTING TO THE KYOTO PROTOCOL

ETSAP to Have Key Role in IEA *Energy Technology Perspectives*

For a closer look at the role of technology in future energy markets, the Secretariat of the International Energy Agency (IEA) is initiating a new project, *Energy Technology Perspectives*. Drawing on the broad range of expertise encompassed by IEA activities, *Energy Technology Perspectives* will report on scenario analyses run with several MARKAL models on the national and supranational levels. With coordination by the Secretariat, experts from ETSAP will do the modeling.

The analysis will build on the report of the impact of new energy technologies contained in the Year 2000 edition of IEA's hallmark publication, *World Energy Outlook* (WEO). The work will be global in scope, using world regions defined by the WEO, with some countries modeled in detail to address domestic policy issues. Analysis will be focused on the time period up to 2050, taking into account developments through 2025 as they will be projected in WEO-2002.

Carmen Difiglio, the head, and Fridtjof Unander of the IEA Energy Technology Policy Division, described the new program at the May 2001 ETSAP workshop in Venice, Italy.

"This is a new project on how market deployment of new energy technologies can affect fuel markets, greenhouse gas emissions and energy security," said Difiglio. "We want to know what a future global energy system may look like. The driving forces will be economic and demographic, but technology will determine the amount of energy needed and to some degree the mix of fuels that will be required."

The MARKAL family of models was selected by the Secretariat because they are bottom-up models that describe energy systems by the types of technology needed for energy supply, conversion, transmission and end-use. MARKAL has been used for energy and environmental planning in more than 35 countries. There are supranational MARKAL models of Europe and North America, and the model has already been used for modeling the interaction of global regions.

The models will be used to analyze various scenarios in which different economic growth rates, fuel prices, and environmental concerns are assumed. The scenarios will illustrate various possible paths beyond 2030 for the global and regional energy systems, reflecting different market conditions and policy interventions. These scenario assumptions will be transformed into projections for energy service demands for different world regions and end-uses. Energy service demand levels will be made sensitive to prices in a manner consistent with the IEA World Energy Model, which is used for the WEO. The work will be closely coordinated with the IEA Economic Analysis Division.

The model results will provide a comparative assessment of the potential of various types of technology and fuels to satisfy the demand for these services. The sensitivity of the model results to various assumptions will be examined.

"We expect this project to fill in the long-term technology piece of energy planning," said Difiglio. "WEO-2000 investigated the impact of new technologies more closely than previous IEA projections. The *Energy Technology Perspectives* project will take an even more detailed view of technology development, focusing on the long term. The

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Information on ETSAP, its activities and members is also provided on the Internet. The home page contains the latest news, general infomation on ETSAP, and links to: ETSAP members; ETSAP 'outreach' activities; description of the MARKAL model and its users; archives of new items; selected publications and the ETSAP Newsletter.

In this issue

project will collect and assess state-of-the-art technology information, drawing on relevant IEA projects with Implementing Agreements. The information collected will include estimates of 'technology learning effects', that is, cost reduction as the cumulative production of a technology increases.

"An important aspect of the work is to develop data for technology learning to increase understanding of how the cost of energy from advanced and conventional technologies changes as these technologies are deployed in the market. For this purpose, the IEA will utilize the informal international collaboration on its project, *Experience Curves for Energy Technology Policy* (EXCETP) and information from the European Union project *Systems Analysis for Progress and Innovation in Energy Technologies* (SAPIENT).

"Substantial emission reductions will most likely be achieved with technologies that are not yet commercially available and would therefore be deployed over a longer time horizon. The long capital turnover rates imply that policy choices made today will impact the energy system several decades from now. In the meantime, niche markets are required to gain experience and to achieve cost reductions through technology learning."

The results of the project are expected to include:

- A technology database covering existing and advanced supply, conversion, and end-use technologies. The goal is to develop a consistent database for all competing energy technologies, rather than technology assessments that promote only a particular technology
- A global MARKAL model developed collaboratively by ETSAP and the Secretariat
- Reports and publications providing key findings of the project
- Methodology and data that will continue to support technology analysis within the IEA
- Information to help develop alternative technology and policy scenarios for WEO-2002, which will be prepared concurrently.

"Finally, we expect that the information developed with the assistance of the parties to IEA Implementing Agreements will feed back to them to help achieve their objectives of technology deployment," said Difiglio. "It provides an opportunity to exploit the resources of the Implementing Agreements in a fundamentally new way, and in turn to provide them with important insights about deployment strategies and niche markets."

The *Energy Technology Perspectives* project itself closes another loop. The ETSAP Implementing Agreement grew out of multinational collaborative project under the aegis of the IEA that originally developed the MARKAL model. Its purpose was to help the Secretariat establish priorities for technology research and development that were published in a 1980 report.

Joint Meeting Held with Italy's Kyoto Club

Together with its workshop in Venice, Italy, in May 2001, ETSAP held a joint seminar with the Kyoto Club, an Italian industry group for sustainable development, on *Climate Change: An Experts' Update and Markets' Response*.

The group was welcomed by Gianpietro Marchiori, deputy chairman, Unindustria Venezia, who said that alternatives to address climate change can be put off no longer, and that industry must be an integral part of developing solutions. Massimo Colomban, chairman of the Kyoto Club and founder of the Permasteelisa Group, discussed the activities of the group, which was started in 1998. The first step has been education: many businesses need to be informed. The group aims at cost-effective reductions in the consumption of energy, water, and other resources, not just compliance with mandatory measures.

"Green is good," said Colomban, "and green is money."

Roberto D'Agostino, Alderman for Environment of the Venice City Council, spoke of the public measures taken by the city to protect the environment. Just a few centimeters above sea level, Venice is in a state of unstable equilibrium, he said. The consequences of failed climate negotiations would be tragic for Venice, part of the heritage of whole world. The city is taking a proactive role in improving the environment through reduced air pollution, development of an energy plan, education of administrators and managers, and the promotion of sustainable technology.

Tom Kram, ETSAP's project head, provided an overview of the Third Assessment Report of the Intergovernmental Panel on Climate Change, in which he participated, to provide an update of the global backdrop for analytical activities like MARKAL as well as local initiatives like the Kyoto Club.

Linking Local Air Pollution Control with Global Warming Policy

Reducing greenhouse gases will also reduce local air pollution, and thus the corollary benefits should be counted in evaluating the cost of reducing greenhouse gas emissions. Reducing local air pollution also reduces greenhouse gas emissions, and therefore reduces the cost of reaching a greenhouse gas reduction target. Belgian analysts have calculated that combining the two emission reduction policies would achieve the same benefits at lower cost.

Stef Proost and Denise Van Regemorter of Center for Economic Studies at the Catholic University of Leuven have used the MARKAL model of the Belgian energy system to compare the benefits of a combined policy of reducing local air pollution and reducing greenhouse gas emissions with doing each alone.

"Both global warming and local air pollution are linked to energy consumption, and their abatement possibilities are interrelated," Van Regemorter said in reporting their work at the ETSAP workshop in Venice in May 2001. "This interaction has to be integrated in the modeling framework for a correct policy evaluation."

For this purpose, a damage function was added to the MARKAL objective function that takes into account the environmental cost of local air pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOC), and particulate matter (PM). The local environmental problems considered were those due to acid deposition, and ambient air quality linked to acidifying emissions and ozone concentration. The evaluation of the benefits of reducing local pollutants was based on the bottom-up damage function approach developed by the ExternE project of the European Commission. (See "Calculating Environmental Benefits with MARKAL," ETSAP News, Vol. 7, No. 2, May 2000.)

The MARKAL database was extended in three ways:

- Emission coefficients for the local air pollutants from each technology, together with emission abatement technologies
- Coefficients for the translation of emissions into concentrations, including the transportation mechanism
- Environmental impacts due to local air pollution, and their monetary evaluation.

The monetary cost of emissions of greenhouse gases was not estimated in the manner of the local air pollutants. However, in the policy simulations, greenhouse gas emissions are implicitly monetized through the shadow price associated with the constraint on greenhouse gas emissions.

MARKAL was employed in a partial equilibrium framework in which the problem for the decision-maker deciding on pollution reduction policies can be represented as the maximization of welfare, calculated as the sum of consumer and producer surplus. Taken into account are the production possibilities, the damage from pollution, and the abatement possibilities. At the optimum - considering, for example, only carbon dioxide and sulfur emissions - this implies that the

- Marginal productivity of energy equals the cost of energy plus the damage from sulfur dioxide and carbon dioxide emissions, and
- Marginal cost of sulfur dioxide emission reduction equals the damage from unabated sulfur dioxide emissions.

Three policy scenarios were simulated with MARKAL:

- *Local air pollution control.* An environmental tax was imposed on SO_2, NO_x, VOC, and PM equal to the total damage (in Belgium and abroad) due to the pollutant emitted in Belgium.
- *Greenhouse gas emission reduction.* By 2010, greenhouse gases must be reduced by 7.5 percent below the 1990 level, following the burden sharing agreement in the European Union to comply with the Kyoto Protocol. Greenhouse gas emissions are assumed to decline at the same rate after 2010 to a reduction of 15 percent by 2030. This target must be met in Belgium with no tradable permits or other flexible mechanisms to be used.
- *Both local air pollution control and greenhouse gas emission reduction.*

These were compared to a reference scenario in which neither type of emission reduction is required.

The comparison among scenarios is at this stage focused on cost differences, and not on the technological options to reach the environmental targets or the distribution of cost among sectors. The principal results are shown in Table 1 and illustrated in Figure 1.

Local air pollution control. Imposing a tax on local pollutants equal to the damage they would otherwise generate reduces both local air pollution and greenhouse gas emissions. The reduction occurs through investment in abatement technologies and a decrease in the demand for energy services because of the increase in price. Investment in abatement technologies has an impact on local pollution, whereas the decrease in demand reduces both local pollution and greenhouse gas emissions. Welfare is reduced, but the total welfare change remains positive when environmental benefits are included. Environmental benefits are measured by the monetary value of the reduction in local environmental damage.

Greenhouse gas emission reduction. With the imposition of a constraint on greenhouse gas emissions, local pollutants as

Table 1. Differences from the reference scenario in welfare and environmental damage from 1990 to 2030.

	Local air pollution control	**Greenhouse gas emission reduction**	**Both**
Welfare, excluding environmental benefits (bBF)	-42	-184	-204
Environmental benefits (bBF)	+91	+61	+119
Welfare, including environmental benefits (bBF)	+49	-123	-85
Greenhouse gas emissions (Mtons)	-487	-1760	-1760

Units:
Mtons = millions of metric tons
bBF = billions of Belgian francs from 1990 to 2030 discounted.

well as greenhouse gases are reduced. The emission reductions result from improvements in energy efficiency and a decrease in the demand for energy services. The reduction in welfare that accompanies the reduction in greenhouse gas emissions is partially offset by the gain in welfare due to local environmental benefits.

Both local air pollution control and greenhouse gas emission reduction. With the combination of emission controls, the interactions among pollutants are taken into account. The environmental benefits of the two combined policies (labeled "Both" in the figure) are greater than with local air pollution control alone, and much greater than with greenhouse gas emission reduction alone.

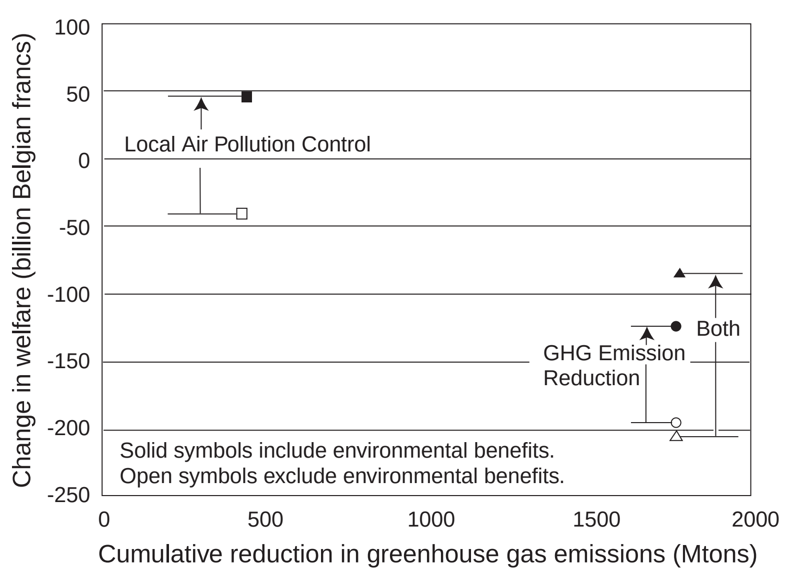

Figure 1. Differences from the reference scenario in welfare and environmental damage from 1990 to 2030. The global environmental benefits of reduced emissions of greenhouse gases are not monetized.

"This exercise has shown the importance of examining jointly interrelated problems for policy design," says Van Regemorter. "Our results show that combining both policies produces the same overall benefits at a lower cost.

"This is only a first step, and our analysis will continue in two directions. The definition of local air pollution policy should be related to the different agreements Belgium has signed for this type of pollution. The implications for the choice of policy instruments must be further examined as it is a crucial element for a full explanation of the interaction between pollutants."

Reference

S. Proost and D. Van Regemorter. Interaction between local air pollution and global warming policy and its policy implications (preliminary version). Center for Economic Studies, Catholic University of Leuven. 2001.

Concept Studied for Recycling CO_2 from Vehicles

In Japan as in other countries, automobiles are the source of a large and growing proportion of carbon dioxide emissions. For large emission reductions in the long term, major changes will be needed. To this end, a team from Kanazawa Institute of Technology (KIT) and the Japan Atomic Energy Research Institute (JAERI) has evaluated a novel concept for recycling carbon dioxide emissions from vehicles.

The concept was described by Shigeru Yasukawa at the May 2001 ETSAP workshop in Venice, Italy. Yasukawa, a professor at KIT, originally represented JAERI on ETSAP. The team also includes Kohei Kato of KIT, and Osamu Sato and Kenji Tatematu of JAERI.

"The thermal energy produced in an internal combustion engine cannot be fully converted to mechanical work," said Yasukawa. "To reach higher efficiencies, auto and bus designers have turned to fuel cells, which generate electricity without combustion.

"Hydrogen is the ideal fuel for a fuel cell. However, hydrogen presents problems for on-board storage, one of which is safety. Such an inflammable fuel could be a safety hazard, for example, in the event of an accident in a densely populated area."

The Japanese team therefore proposes to use methanol as the on-board fuel. Methanol is more chemically stable, and can be safely stored in a fuel tank. Each vehicle would be equipped with a mini steam reformer that produces hydrogen for the fuel cell from methanol as it is needed. Carbon dioxide, which is a by-product of the reforming process, is liquefied in the vehicle using off-duty power. The liquefied carbon dioxide is then returned to the fuel station, where it is transformed to dry ice and shipped back to a methanol production plant. This plant can be at a high-temperature nuclear reactor also used to produce hydrogen. Here, the dry ice is used to cool turbine outlet gas or wet steam, and the carbon dioxide is recovered and re-used to produce methanol.

In this process with carbon dioxide recycling, about 95 percent of the heating value of the methanol is converted to useful energy. The hydrogen fuel cell is about 83 percent efficient.

To analyze the potential of this concept in the context of a future national energy system, the MARKAL model of Japan was used. For the scenario projections, a number of assumptions were made as to the future development of the country. Although the population of Japan is expected to decline beginning about 2005, GDP is projected to grow at an average annual rate of about 1.1 percent over the next 80 years. Passenger and freight transportation are projected to grow at rates of 0.7 and 0.44 percent per year, respectively.

The energy system model of Japan contains about 300 kinds of technologies and 110 different energy carriers, and it tracks ten kinds of environmental emissions including carbon dioxide. Each technology is characterized by its performance characteristics, including efficiency, and the cost of investment, operations and maintenance, and fuel. The transportation sector includes both freight and passenger vehicles. Alternative vehicle fuels include gasoline, diesel oil, methanol, and electricity.

In the model, the system for using motor vehicles with recyclable carbon dioxide consists of a set of technologies. Each automobile is equipped with a hydrogen fuel cell, mini methanol steam reformer, and carbon dioxide recovery unit. The infrastructure consists of fuel stations that collect liquid carbon dioxide and convert it to dry ice, trucks to transport dry ice from the stations, and high-temperature nuclear reactors where the plants for the production of methanol and hydrogen are located.

To simulate increasingly stringent restrictions on the emissions of carbon dioxide, a surcharge to penalize carbon dioxide emissions is assumed to increase linearly from zero in 2000 to $250 per ton of carbon dioxide in 2080.

In the modeling results, the automobile with recoverable carbon dioxide begins to be used when the surcharge rises above $60 per ton - about 2020 - leading to an annual reduction in carbon dioxide emissions that rises to about 35 million tons per year in 2080.

"With this system, 95 percent exergy efficiency is attained," said Yasukawa. "Compared to direct use of hydrogen as a fuel, the concept offers safety and security."

Reference

S. Yasukawa, K. Kato, O. Sato, and K. Tatematu. Greenhouse gas emission reduction by CO_2 returnable motor vehicle. Presented to ETSAP Workshop, Venice, Italy, 17 May 2001.

Goal Programming with MARKAL

A new variant, goal programming, has been proposed for addition to the MARKAL family of models. Like the majority of other mathematical programming models, MARKAL normally optimizes a single objective function, usually minimizing the expected cost of an energy system over a period of time. Restrictions on the energy system, such as the maximum allowable emissions of pollutants, are represented by "hard" constraints that must be satisfied. Goal programming is a more flexible approach where reductions in pollutant emissions are set as targets and included in the objective function. These targets may be met, exceeded, or not met, depending upon the specification of other targets, such as total energy system cost, and the set of options available to meet the targets. As a result, multiple goals can be represented in the planning problem.

"Goal programming can be used to identify a spectrum of alternatives for decision makers to consider," according to Lorna A. Greening, an energy and environmental economic consultant based in Los Alamos, New Mexico, USA. "More alternatives can be explored, the number of arbitrary assumptions is reduced, and the policy discussion is focused on the crux issues."

Greening's work was reported by Gary Goldstein, her collaborator from International Resources Group (IRG), at the ETSAP workshop in Venice in May 2001. The work is supported by the Office of Atmospheric Research Programs, U.S. Environmental Protection Agency, and was performed in collaboration with John A. ("Skip") Laitner, Senior Economist for Technology Policy from that office.

Policy formulation involves numerous stakeholders with different values and perceptions of risk. For such a group, no single purpose exists that can be described by a single mathematical function that is optimized. The group decision process consists of an examination of tradeoffs between alternatives in light of different values and criteria for acceptance of an alternative. For the electrical sector in particular, many factors such as dispatchability, availability, fuel choice, and environmental emissions of various pollutants, must be included in the decision process.

Goal programming can be used to screen alternatives with different technical attributes. A set of feasible alternatives can be divided into a subset of Pareto-efficient (or non-dominated) and Pareto-inefficient solutions. A Pareto-efficient set of solutions includes all alternatives that approach the goals more closely, but no one alternative is better in all respects than another. As a result, goal programming can be used to identify co-benefits from reducing multiple pollutants, and compromise solutions to complex policy and planning problems.

To represent this mathematically, a set of target values can be defined that represent the goals of the parties. For example, these may represent desired reductions in emissions of various pollutants. To obtain the Pareto-efficient set of alternatives for the development of an energy system, the sum of the deviations from these targets is then minimized. In addition to target levels, the decision-makers must agree on a set of weights to be assigned to the importance of deviations above and below each goal.

To illustrate the process, Greening examined the trade-offs between two goals: total energy system cost and emissions of three pollutants between 1995 and 2030. The three pollutants were sulfur dioxide, nitrogen oxides, and carbon dioxide. At present, there are limits in the U.S. on emissions of sulfur dioxide and nitrogen oxides from electric power plants, mandated by the Clean Air Act. There is no restriction on carbon dioxide emissions.

Using the model, a cost target was determined for each 5-year time period by releasing the mandated limits on sulfur dioxide and nitrogen oxides. The emissions targets, starting in 2000, were assumed as follows:

- Sulfur dioxide would be reduced from 11.5 million tons (MT) to 6.75 MT.
- Nitrogen oxides would be reduced from 8 MT to 2 MT.
- Carbon dioxide would be reduced to below estimated 1990 levels.

With these target values, the goal programming formulation of MARKAL was solved, assuming different decision-maker preference weights toward energy system cost and emission reductions. This might mean, for example, strongly demanding low cost energy at the expense of more emissions, versus reducing emissions at any cost. As an example, Table 2 provides a comparison of results for a "neutral" decision-maker, as opposed to a "business-as-usual" scenario. For the neutral decision-maker, equal preference weights were assigned to the cost and emissions goals. For business as usual, the conventional MARKAL solution was obtained assuming the Clean Air Act constraints.

With the technologies currently depicted in the US model, the neutral decision-maker was not able to achieve the specified emission targets. However, the solution in this case did achieve greater emission reductions than the business-as-usual case at a relatively small incremental cost over the 35-year planning horizon. In this example, emissions could be reduced below the mandated values by 17 to 57 percent at an increase in cost of 2.5 percent, or $1.12 trillion. The value of goal programming, however, is that it portrays not just one solution but also other alternative solutions with different trade-offs between costs and emissions depending upon the weights chosen. Some of these are illustrated in Figure 2.

The figure maps the results of a set of alternative goal programming solutions or alternatives, and illustrates the trade-offs between energy system cost and various levels of emissions. Although this graph shows tons of emissions without differentiating among the pollutants, the goal programming formulation actually minimizes the percentage deviation from each pollutant goal. This removes any bias toward the reduction of the pollutant (e.g., carbon dioxide) with the greatest tonnage, and allows for the incommensurability of pollutants and costs in the objective function.

Table 2. Comparison of a goal programming model result with business as usual.

	Business As Usual		Neutral Decision-Maker	
Total Energy System Costs (trillion $1995 US)	$44.94		$46.06	
Emissions (MT from electricity sector)	SO_2:	344.5	SO_2:	286.6
	NO_x:	230.0	NO_x:	98.3
	Carbon:	27,213.4	Carbon:	18,993.9

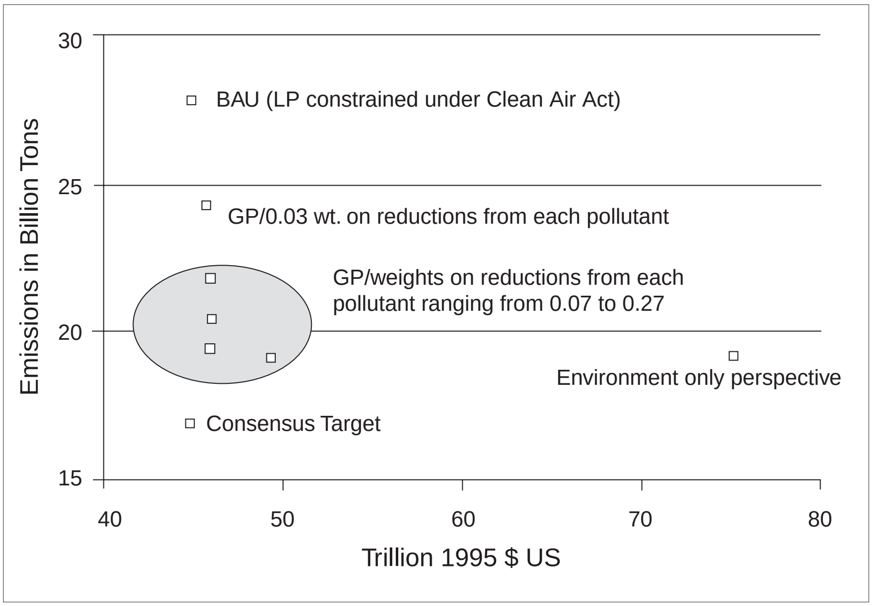

Figure 2. Trade-offs between costs and emission levels.

The consensus target is a “dream point” with a lower assumed energy system cost than the business-as-usual scenario, and emission levels desired by one set of decision makers. The goal programming scenarios depicted in Figure 1 attempted to reach those targets. However, each alternative solution used different preference weights between total energy system cost and emission reductions. For comparison, the business-as-usual result and a point representing a total commitment to emissions reduction at any cost are shown. These represent end-points of a continuum of solutions.

The solutions for a wide range of preference weights (that is, 0.07 to 0.27 for reductions below target levels for each pollutant) cluster relatively tightly within this continuum, as illustrated by the darkened ellipse. This suggests that groups with highly divergent views can reach a consensus on alternatives for future energy system development, and still substantially reduce emissions from that source.

Further, this diagram indicates that greater reductions in the emissions of three pollutants can be achieved using more flexible approaches than mandating fixed reductions for two pollutants under the Clean Air Act. Goal programming identifies the most economically efficient reductions with optimal timing for all targeted pollutants. In contrast, both the amount and timing of emission reductions must be specified exogenously with a standard linear program, i.e., standard MARKAL.

“Although none of the identified solutions achieved the desired targets, the results suggest points for further consideration by decision-makers,” Greening notes. “For example, they might reconsider the emission reduction and cost targets and agree

ECN Policy Studies

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on less ambitious goals. Or they might consider promoting more costly technologies with lower emissions, or conservation measures that use less energy. The use of goal programming therefore provides a tool for evaluating many potential strategies, and leads to the exploration of new options that might not ordinarily be examined."

Currently, two papers are available on request from Greening (LGDoone@aol.com) on the topics of this article. The paper, *Design of Coordinated Energy and Environmental Policies Using Multicriteria Decision Making,* places goal programming within the larger family of multicriteria decision-making with a focus on previous applications to environmental and energy planning problems. A second paper, *Harmonizing U.S. Energy and Environmental Policies Using Goal Programming*, discusses the implementation of goal programming in the MARKAL model of the USA, and provides the results of the full study reported here.

Turin Polytechnic to Offer Master's Course

A master's course in technical economic modeling will be offered by Turin Polytechnic in Italy beginning in 2002. A 13-week pilot course is planned for the spring semester, to be followed in the next school year with a 21-week program.

"In several countries, interest in the use of bottom-up models is growing, especially where cost-benefit analyses of energy-environment policies are needed," says Prof. Evasio Lavagno of the Laboratory for Energy Analysis and Modeling, Department of Energy, at the school. "With the use of fossil fuels limited and environmental issues a major concern, greater knowledge of energy technology systems and technology-oriented modeling is required."

The program aims to train scientists, engineers and economists to model existing and innovative energy systems, to evaluate the impact of policy measures, and to advise decision-makers. The faculty will consist of senior experts in technical economic modeling who are themselves consultants and advisors to national and international organizations.

The course, which will be given in English, consists of a series of modules to build a suitable background for the student to prepare a case study in which he will be tutored by a master teacher. The subject matter includes energy planning, energy balances, environmental emissions, technology characterization and databases, types of models, mathematical programming, MARKAL and its shells, and local energy planning.

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