Tackling urban Co2 emissions in Toronto.

by L.D. Danny Harvey

Toronto, Canada wants to reduce its carbon dioxide emissions by 20% by the year 2005. A community energy-saving program and better land-use planning are two strategies that are being implemented to reduce pollution. The city is conducting research on other ways to reduce emissions.

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In January 1990, the Toronto City Council unanimously adopted a resolution declaring an official reducing the city's net carbon dioxide [CO.sub.2] emissions to 20 percent below the 1988 level of emissions by 2005. Inasmuch as the council is also hoping for a 20-percent increase in population by 2011 to reduce urban sprawl (which in itself would limit regional [CO.sub.2] emissions), meeting this net [C0.sub.2] reduction target would require an eventual per-capita emission reduction of 33 percent. In 1991, the city of Toronto was joined by 12 other European and North American cities and by Metro Toronto (an area including the city and five other municipalities) to form the Urban [CO..sub.2] Project, through which participating cities are developing inventories of energy use and [CO.sub.2] emissions, exchanging information on successful programs to use energy more efficiently, and developing strategies to reduce their carbon emissions by between 15 and 25 percent by 2005 (see [THE URBAN [CO.sub.2] PROJECT].

What justifies these actions by Toronto and other cities to reduce [CO.sub.2] emissions prior to commitments by their national governments and prior to a global agreement on a global emission reduction target? First, safeguarding future global food production and allowing sufficient time for ecosystems to adjust to climatic change require, as an almost certain minimum, stabilization of total global energy-related [CO.sub.2] emissions at the current level as well as restraints on other greenhouse-gas emissions and on deforestation. A global target of emission stabilization implies that emissions from industrialized countries must be reduced to permit emission increases by developing countries as they build a modern infrastructure and increase their material standard of living. Stabilizing global emissions while allowing a 50-percent emission increase from developing countries, for example, would require a 26-percent reduction from industrialized countries as a whole, and equity considerations would suggest an even larger reduction from high-emitting, economically strong countries, such as Canada and the United States. The likelihood of Toronto's 20-percent reduction target proving to have been unnecessary is therefore exceedingly small.

Second, the cost of achieving a given absolute [CO.sub.2] emission limit by a given date will be lower the sooner policies are in place to maximize energy efficiency. As soon as such policies are in place, normal rates of equipment and power-plant turnover and building stock renovation will achieve significant gains in energy efficiency. Also, there are significant cost advantages and energy savings in designing new buildings to minimize energy use rather than having to retrofit them at a later date. In addition, policies that shift land-use planning back to more compact, pedestrian-oriented cities would, over a period of several decades, significantly reduce growth in transportation demand as compared with business-as-usual projections.(1) Delaying implementation of such policies until there is greater scientific certainty might later require accelerated capital turnover, which would significantly increase costs, especially if the impacts of greenhouse-gas emissions are judged to be worse than is presently believed.

Finally, numerous studies have documented many countries' potential to reduce their energy use substantially without compromising the delivery of energy services and at a net cost savings. This prospect makes energy efficiency measures attractive in their own right, irrespective of the threat of climatic change. A comprehensive analysis of electricity use in the city of Toronto indicates that Toronto's 33-percent per-capita emission reduction target can be achieved (at least for electricity) at a net economic savings even without considering the additional benefits of local job creation, skills development, and the stimulation of new manufacturing industries. Significant emission reduction and cost savings opportunities are also available on the supply side, through local trigeneration of electricity, heat, and chilled water as part of a district heating and cooling system.

Toronto's Strategies

In 1992, Toronto's Special Advisory Committee on the Environment (SACE) published a two-volume report entitled The Changing Atmosphere: Strategies for Reducing [CO.sub.2] Emissions.(2) The report contains a comprehensive set of strategies for reducing [CO.sub.2] emissions at the municipal level. The city of Toronto has adopted several policies and programs that reflect these strategies.

Institutionalizing Change

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The initial steps in Toronto's [CO.sub.2] emission reduction strategy can be viewed as a process of institutionalizing change. These steps included the declaration of an official reduction target in January 1990; the establishment of an Energy Efficiency Office in January 1991; and the establishment of the Toronto Atmospheric Fund in December 1992. Each of these actions was recommended by SACE in its first report to the city council in October 1989. (SACE itself was established as a result of the June 1988 World Conference on the Changing Atmosphere, which was held in Toronto and attended by a member of the Toronto City Council.)(3)

The official reduction target, although legally nonbinding, flags [CO.sub.2] emission reduction as an important priority and helps sustain bureaucratic and political attention to this issue. The Energy Efficiency Office plays an important role in data collection and analysis (with support from outside consultants); community outreach involving professional groups, such as developers, architects, and building owners and operators, as well as citizen groups; review of the energy performance of new building developments; development of a program for retrofitting city-owned buildings; and development of a community-based retrofit program that targets all buildings in the city. The Toronto Atmospheric Fund has been allocated $25 million from city coffers to endow efforts to achieve the [CO.sub.2] reduction target.

Data Collection and Analysis

The municipal government of Toronto is currently collecting and analyzing emissions data. Urban [CO.sub.2] emissions stem from the direct use of fossil fuels, such as petroleum products and natural gas burned for transportation, heating buildings, and, in some cases, industrial uses, as well as from the generation of electricity by burning coal, oil, or natural gas. Emissions of methane--another important greenhouse gas--occur because of leaks from natural gas distribution systems, landfills, and sewage treatment facilities and during the mining of coal used to generate electricity. Forty percent of the city's emissions come from the direct use of natural gas, and about 50 percent result from energy use in commercial and institutional buildings.(4) (See Figure 1 on this page for a profile of Toronto's [CO.sub.2] emissions in 1988 by energy source and by sector and Table I on page 39 for an estimated breakdown of the city's energy use by end use.)

A $1.2-million study of the economically attractive potential for reducing electricity use through improved end-use efficiency and fuel switching has been completed by consultants hired by the city.(5) This study identifies an economic potential to reduce electricity demand in 2005 by 41 percent as compared with the projected demand if the efficiencies of all energy-using equipment were frozen at their current levels and current building practices were unchanged. The potential reduction is 31 percent as compared with the 1988 base.(6) About 70 percent of the savings are from the commercial sector, and 24 percent are from the residential sector. (See Figure 2 on page 41 for the relative contributions of specific end uses to the total savings within each of these sectors.) Although nuclear power and hydropower together provide about 80 percent of the electricity generated in Ontario, about 90 percent of the electricity supplied on the margin (beyond the normal demand) is coal-fired. Electricity savings in Ontario will therefore largely reduce coal-fired electricity generation, leading to disproportionately large [CO.sub.2] emission reductions. Studies of the economic potential for reducing natural gas and oil use should be complete by the end of 1993.

Community-Based Retrofitting

A key element of Toronto's [CO.sub.2] emission reduction strategy is likely to be a community-based retrofit program that will target the full, economically attractive savings potential in all residential, commercial, and institutional buildings in the city. The framework for this program is currently being developed, but the proposed key elements are that the program be self-financing; that a positive cash flow to building owners arise from day one; that the program involve a comprehensive approach to energy efficiency; and that it combine energy and water savings. The city's primary role would be that of facilitator, bringing together sources of private capital, power utilities as key delivery agents, contractors and suppliers of energy-efficient equipment, and individual building owners and occupants. Work is about to begin on a retrofit of all city-owned buildings and facilities to the full, currently available cost-effective energy savings potential as identified by outside consultants.

Prior to a citywide retrofit program, a two-year pilot project will be undertaken. Competitive bids have been received from outside consultants for the design of the pilot project, a process that will take up to one year, beginning in mid 1993. Thus, the full-scale retrofit program cannot realistically begin before mid 1996. That will be eight years after the World Conference on the Changing Atmosphere, which precipitated Toronto's current [CO.sub.2] emission reduction target. This lag, in a jurisdiction that appears to be genuinely committed to [CO.sub.2] emission reduction, is comparable to the 10-year delay that some atmospheric scientists have advocated should pass before countries even make a policy commitment to limit greenhouse-gas emissions. Yet, if countries do delay, the lag would be in addition to the 10 years, so that action would probably be

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postponed by a minimum of 18 years.

In the case of community-based energy retrofit programs, program delivery costs arise in addition to the retrofit costs that are included in engineering analyses of the cost-effective energy savings potential. The delivery costs include expenses for program administration and quality control, and they reduce the achievable savings potential below the economically attractive potential. However, the program delivery cost per unit of saved energy can be kept small--between 15 and 20 percent of purchase and installation costs and possibly less--by targeting the maximum cost-effective potential; simultaneously addressing electricity, oil, and natural gas use in buildings, which requires coordination between energy utilities; combining energy conservation measures with water conservation (which alone typically pays for itself in less than two years) by, for example, having utility agents or consultants who advise homeowners or businesses how to save energy also advise on water-conserving measures; piggybacking the program on other revenue-generating, cost-saving, or required programs, such as electrical or plumbing upgrades and chlorofluorocarbon (CFC) phaseout; and taking full advantage of community-based organizations to disseminate information about the program, gain credibility, and achieve high participation rates. All of these measures will be taken in the retrofit program being developed by Toronto. Failure to adopt these strategies has already resulted in some utility-sponsored energy efficiency program costs exceeding the direct cost of the energy efficiency measures.(7)

The aforementioned analysis of the cost-effective electricity savings potential assumes normal rates of equipment turnover and building stock renovation as well as application of minimal life-cycle cost designs in new buildings. It is therefore essential that programs also be in place to ensure that the opportunities provided by ongoing renovation and new developments are not lost. The citywide retrofit program would then address those energy efficiency opportunities not dependent on renovations. The city lacks the power to require developers to meet specified energy efficiency standards but has nevertheless successfully implemented a policy requesting developers to meet the 90.1 energy performance standard of the American Society of Heating, Refrigeration, and Air Conditioning Engineers for new commercial buildings and the Canadian R2000 energy performance standard for new residential buildings. The city has also requested that the pending revisions to the Ontario building code include these same energy performance standards. However, with careful design, it is cost-effective to surpass these standards substantially.

Energy Systems and CFC Phaseout

State-of-the-art district heating systems can reduce [CO.sub.2] emissions by 10 percent as compared to on-site heating of each individual building. Much larger savings are possible if district heating is combined with electricity cogeneration. For example, if coal-based electricity is displaced by cogeneration (as in the case of Toronto) and natural gas is the fuel used for cogeneration, [CO.sub.2] emissions per unit of electricity generated are reduced by about three-quarters. The amount of electricity that can be cogenerated is limited by the minimum heat load (in summer) of the district heating system. However, steam or hot water can be used in absorption chillers to produce chilled water for cooling purposes without using CFCs or hydrochlorofluorocarbons (HCFCs). Although absorption chillers produce less cooling per unit of energy input than do the electric chillers they would displace, overall [CO.sub.2] emissions in fulfilling cooling and noncooling electric demands would be reduced by about 44 percent.(8) The current HCFC candidates to replace CFC-11 in commercial chillers are HCFC-123 and HCFC-134a. HCFC-123 has an ozone-depleting potential of about 20 percent of that of CFC-11 on a 10-year time horizon,(9) which is relevant to the peak stratospheric chlorine loading expected near the turn of the century and to the possibility of an Arctic ozone hole, while HCFC-134a has a global warming effect of 25 to 30 percent of that of CFC-11.(10) For these reasons, current international agreements call for the phaseout of HCFCs by 2020, although, like previous chlorocarbon phaseout targets, this one might also be moved forward. Therefore, an HCFC-free cooling system has distinct environmental benefits and eliminates the risk of yet another retrofit of cooling equipment.

The phaseout of CFC production in 1996 provides an important window of opportunity. There are 85,000 electric chillers in North America, 65,000 of which were built before 1987 and are incompatible with the substitutes proposed for CFC-11. Retrofitting or replacing these chillers would be costly: For Toronto, the estimated cost is on the order of $100 million. In Toronto, some people envisage creating a series of satellite district cooling systems that would initially use existing chillers and CFC-11 salvaged from existing buildings. Over time, these would be supplemented with an increasing number of absorption chillers driven by steam from the existing district heating system. Later, the satellite cooling systems can be interconnected, the remaining CFC chillers can be retired, and a combination of deep water from Lake Ontario (at 4 [degrees] C) and steam-driven absorption chillers can be used to provide cooling.

Because the production of steam in a cogeneration plant

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reduces the electrical output, an attractive alternative would be to run the cogeneration plant in summer for maximum electrical output (with reduced useful heat output) and to use electrically driven ammonia chillers for cooling purposes. cent higher than with the absorption chiller option but about one-third lower than they are at present. Chlorocarbons would still be eliminated, and costs might be substantially lower.

Combined district heating and cooling systems with electricity cogeneration are referred to as "community integrated energy systems." The existing district heating system in Toronto can accommodate 300 megawatts (MW) of cogeneration, and an additional 110 MW of peak electrical demand caused by air conditioning could be displaced through absorption chillers.(11) Total peak cooling demand in the area served by the existing heating system is about 260 MW. Therefore, larger peak load reduction and better overall utilization will be possible if the variation in cooling load can be reduced through, for example, ice storage. The total displaced peak power-in excess of 400 MW--is a large fraction of Toronto's current peak electrical demand of 1,900 MW. If the power plant operated on average at 90 percent of capacity, about one-quarter of the city's current total electricity consumption would be supplied. With a doubling of the area served by the proposed community integrated energy system and realization of a substantial fraction of the cost-effective end-use efficiency potential, Toronto could become largely independent of the provincial power grid. Several turbines in a nearby coal-fired power plant could be retired rather than undergoing expensive refurbishing, and upgrading of some transmission lines and transformer stations serving the downtown core could be cancelled. Total avoided electric utility costs associated with the first 300 MW of cogeneration are on the order of $300 million to $400 million, which equals or exceeds the cost of the cogeneration plant.

To expand the area served by the existing district heating system in Toronto, add cogeneration, and create a chlorocarbon-free district cooling system, all expeditiously, the Toronto District Heating Corporation (TDHC) issued a request for proposals from the private sector to purchase TDHC from the city and carry out the needed investments, which could reach $1 billion if the service area is doubled. Proposals were received from 12 energy and financial consortiums, and negotiations with one of the proponents should begin soon. This action demonstrates what many academic economists and critics of calls to action on global warming have difficulty accepting: It is possible to reduce [CO.sub.2] emissions significantly (and, in the case of TDHC, also reduce emissions of methane, sulfur oxides, and nitrogen oxides and eliminate chlorocarbon emissions) at a profit sufficiently large to attract the interest of the private sector.

Land-Use Planning and Transportation

The high per-capita energy use for transportation in North American cities is largely a result of poor land-use planning, inasmuch as land-use planning decisions have favored low-density suburbs in which distances between residence, work, and social amenities are long and public transit is not economically viable. A number of regional governments, including that of Metro Toronto, have recognized the need to intensify the existing urbanized area to limit further urban sprawl. The city of Toronto has had a long-term policy of increasing residential densities and placing more housing developments, serving people with a mix of incomes, closer to major employment centers. Urban intensification also increases the viability and market for district heating and cooling systems.

Among the actively promoted intensification initiatives is the "Housing on Main Streets" proposal, whereby the city's main streets would be redeveloped with four or five floors of residential accommodation above commercial space at street level. This proposal, while enthusiastically welcomed by planners, architects, and various advocacy groups, is facing major difficulties because of current parking requirements. Given physical constraints housing units would have to be exempted from current parking requirements to be viable. But such an exemption would create fears in nearby residential areas of further pressure on the limited supply of curbside parking spaces. These concerns could be reduced if the majority of the new housing units were marketed as units for which tenants would not be granted parking permits. The units would then be feasible only for those tenants prepared to forgo automobile ownership in exchange for the cost savings and improved livableness associated with housing designs that are possible if the private automobile does not need to be accommodated.

Another key initiative is the redevelopment of the former railway yards next to the downtown core--the largest urban redevelopment project currently contemplated in North America. To avoid an increase in the generation of commuter trips from outside the downtown core, each new square foot of commercial floor space in the downtown core should be matched by three new square feet of residential floor space in the core, suitable for people with a broad range of incomes and tenure.(12) Although the railway yard's development, as currently planned., provides one-third less residential space than commercial space, other major housing projects on the periphery of the railway lands are planned that bring the overall ratio closer to the desired value. Equally important, the city has secured a commitment from one of the two major

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developers of the railway lands to install a district heating and cooling infrastructure as the development proceeds, irrespective of whether or not commitments to develop heating cooling plants to serve the railway lands have been made at the time the infrastructure is constructed. Thus, whether or not TDHC's current efforts to expand its energy service capabilities succeed, the option to use district heating and cooling in the railways lands will remain viable in the long term.

The Toronto Atmospheric Fund

The Toronto Atmospheric Fund has been established as an independent corporation, separate from the city of Toronto, with its own board of directors who are ultimately accountable to the city council. The $25-million endowment provided by the city will be invested in proven energy efficiency projects with principle plus interest paid back to the fund. A portion of the fund has already been lent back to the city to finance some of the city's own energy efficiency improvements. The interest earned by the fund will be used to support demonstration projects of advanced energy-saving and renewable energy technologies appropriate to Toronto and to support agroforestry and forest protection projects in Central America.

The fund's endowment could be used to leverage a much larger pool of capital for energy efficiency projects if, instead of serving to finance energy efficiency retrofits directly, it acts as insurance on lending from private sources. Because much of the financial community lacks the technical expertise to evaluate energy efficiency proposals, it often perceives such ventures to be of high risk. This perception frequently makes it difficult for private energy service companies to obtain financing. However, if financing of a retrofit is structured so that financing costs are smaller than the projected energy cost savings by a suitable margin, the risk to the fund of providing insurance to the lender would be extremely small. By serving as insurance for energy retrofit cost savings, the fund could not only leverage a significant pool of capital for energy efficiency investments but also earn a higher rate of return on its own investment than if it acted as a direct financier of energy efficiency projects. The fund is still in its infancy, and the city council's current approach is to view it as a simple lender rather than as a leveraging tool. If this view persists, a significant opportunity will be lost.

Links to the Developing World

The Toronto Atmospheric Fund will not only help reduce the city's emissions, however. Stabilizing the atmospheric concentration of [CO.sub.2] in a least-cost manner requires not only reduction of energy-related emissions but also stabilization of the global forest biomass. To this end, it is intended that a portion of the interest earned from the Toronto Atmospheric Fund will be used to finance some combination of agroforestry, forest production, and reforestation projects in Central America.

There has been much discussion of reforestation as a means of offsetting fossil fuel [CO.sub.2] emissions. However, trading off emission reductions against reforestation is undesirable for a number of reasons. First, reforestation is reversible while fossil fuel emissions are not. Second, the albedo and cloud changes associated with reforestation make it impossible to quantify accurately the net radiative heating effect of carbon sequestration through reforestation. Third, allowing reforestation to offset continuing [CO.sub.2] emissions would likely create pressure to carry out "plantation style" reforestation, which may provide the most carbon storage but does not satisfy other important concerns, such as the preservation of biological diversity. Fourth, crediting reforestation against current emissions may direct attention away from measures that are more cost-effective in the long run but much less quantifiable, such as measures that remove pressures on existing forests by promoting more efficient agriculture and more efficient use of biomass energy resources. To the extent that such measures promote rural development and prosperity, they will also lead to reduced population growth and, hence, lower emissions over the long term. Finally, reforestation is highly desirable in its own right, irrespective of the threat of climatic change. Undertaking reforestation or forest protection on its own merits will result in greater attention to the needs of the peoples occupying forested or potentially forested areas; this attention is a precondition for the long-term success of forestry projects. Visits by the author to a number of forestry projects in Central America to determine the type of project suitable for support by the city of Toronto revealed that the local peoples are particularly concerned about water shortages; understand that through forest protection and strategic reforestation they can be assured a year-round supply of water; and will contribute to forestry projects and their long-term success if the issues of concern to them, such as water supply, are addressed.

Thus, rather than offsetting its current emissions, Toronto seeks to complement its own emissions reduction with measures that will help stabilize tropical forests. Moreover, by contributing to rural development and the associated decline in population growth, Toronto will indirectly contribute to the long-term limitation of emissions from the developing world. Because the Toronto Atmospheric Fund's interest will be generated by investing the money in energy efficiency projects, the forestry projects will be financed by the cost savings from emission reductions in Toronto. Thus, emissions reduction in the developed world

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and forest protection in the developing world will reinforce, rather than compete with, each other in the proposed program for Toronto.

Future Steps

Toronto could go a long way toward achieving its current [CO.sub.2] emission reduction target through fuel switching and local cogeneration of electricity, heat, and chilled water. However, more stringent targets may eventually be required. Therefore, the strategies adopted to achieve the present 20-percent target should be designed to facilitate the possible, more stringent targets in the future. Such strategies include placing a strong emphasis on attaining the full, economically attractive improvement in end-use energy efficiency, both for existing and new buildings; implementing policies to increase the density of the existing urbanized area and, thereby, in the long run, significantly improving the viability of public transit and community-integrated energy systems; and switching from electricity to natural gas for space heating in such a way as to allow future flexibility in the choice of energy source. Because electric space heating contributes strongly to Toronto’s peak electrical demand, this end use is largely supplied by coal- fired electricity. Switching to high-efficiency (92 percent) gas furnaces or boilers reduces [CO..sub.2] emissions per unit of delivered space heat by three-quarters. Existing electrically heated buildings can be retrofit with either a centralized gas boiler placed on the roof and a hot water distribution system or a gas distribution system feeding individual integrated gas space and water heaters in each apartment. The second option is slightly more efficient, but the first option allows for an eventual solar-gas hybrid system or for conversion to hydrogen fuel.

A number of economists have at tempted to estimate the potential for, and cost of, [CO.sub.2] emission reduction using highly aggregated models of individual national economies or of the global economy.(13) These "top-down" models do not include many of the options available in the real world to reduce [CO.sub.2] emissions. For example, some of the models exclude fuel switching between coal and gas for electricity generation; few, if any, include end-use fuel switching, as from electricity to natural gas for heating and cooling; and few, if any, allow for the renovation of buildings and other capital stock before the end of their assumed life. The models thus preclude the significant energy savings possible at little incremental cost during renovations. Yet these are three of the most important measures that will be used to reduce Toronto’s emissions. The macroeconomic models also generally assume far less scope for supply-side and end-use efficiency improvements than is identified in most engineering analyses, including Toronto’s own extensive analysis. Not surprisingly, economists relying on macroeconomic models find the opportunities to reduce [CO.sub.2] emissions to be limited and costly. Clearly, "bottom-up" analyses are required to assess the potential for reducing [CO.sub.2] emissions at various costs, including at zero or negative costs (see [TWO APPROACHES TO ESTIMATING THE POTENTIAL FOR REDUCING CARBON DIOXIDE EMISSIONS] for a discussion of top-down and bottom-up approaches).

Most policy analyses also assume a top-down approach in trying to induce [CO.sub.2] emission reductions. The primary tools considered are carbon taxes and regulation. The approach being adopted by the city of Toronto, however, is a decentralized, community-based one whereby the city primarily acts as a facilitator. In other words, a bottom-up approach is needed both to identify the full, economically attractive potential for emissions reduction and to achieve a significant fraction of this potential; top-down cost analysis and top-down policy tools will identify and achieve only a small fraction of the economically attractive potential. This is not to deny that national-level regulations in such areas as automobile, appliance, furnace, and boiler efficiencies are also important or that a small carbon tax could be important in generating revenue to support research, development, and demonstration of new, energy-efficient technologies and renewable energy systems and to finance expansion of urban rapid transit and regional rail systems. However, for a variety of reasons,(14) significant, economically attractive energy-saving technologies that already exist are being adopted only very slowly. Overcoming the barriers that stand in the way of their more rapid adoption will require action at the local level.

While these initial steps are being taken by the city of Toronto to reduce its [CO.sub.2] emissions, other actions recommended by the Special Advisory Committee on the Environment have yet to be implemented. These actions include reforming electricity rates and setting policies to eliminate bulk metering in multi-unit residential buildings and to reduce automobile use in the short and medium terms. The full cost-effective energy savings potential is not being realized in new buildings and renovations--a shortcoming that urgently needs to be corrected. The engineering consulting community is highly conservative and provides estimates of the up-front costs of new energy efficiency design features that vary by a factor of two. Only a few firms specialize in state-of-the-art practice and are able to provide such designs at lower costs. In spite of the Toronto City Council’s commendable initial steps, much work remains to be done, not only with new initiatives but also to insure that the day-to-day decisions of the council and other city departments are consistent with the goal to reduce emissions.

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THE URBAN [CO.sub.2] PROJECT

The Urban [CO.sub.2] Project is one of several projects sponsored by the International Council for Local Environmental Initiatives, which is an affiliate of the United Nations Environment Programme that was created in 1990 and has its headquarters in Toronto City Hall. The project involves 14 cities working together to develop [CO.sub.2] emission inventories and targets, strategies, and programs for [CO.sub.] emission reduction. EAch city has prepared a draft action plan, which can be obtained from the council.(1) The table at right provides information from the draft action plans on the participating cities; targets that have been adopted so far or are under consideration; and emission reduction strategies that have been implemented, are about to be implemented, or are under active consideration. Some measures included in the table, such as district heating and co-generation, have been in place in cities such as Copenhagen and Helsinki for many decades and are a significant contributor to the already low emissions of these cities. They are listed here anyway because of plans to expand the service area or improve the overall system efficiency. As experience in Toronto indicates, going from draft action plans and plan adoption by the local city council to full-scale implementation is a major and difficult step. Nevertheless, the very fact that [CO.sub.2] is on the municipal political agenda in many cities is significant and encouraging. (1.) International Council for Local Environmental Initiatives, "Draft Local Action Plans of the Municipalities in the Urban [CO.sub.2] Reduction Project" (Toronto City Hall, M5H 2N2, Canada, March 1993, available for $50 Canadian).

TWO APPROACHES TO ESTIMATING THE POTENTIAL FOR REDUCING CARBON DIOXIDE EMISSIONS

Two fundamentally different methtodologies have been used to assess the potential for and costs of reducing [CO.sub.2] emissions. The first is a top-down or macroeconomic approach, which uses data from past relationships between energy use, income, and prices, usually combined with a non-price-induced gradual improvement in the efficiency of energy use, to estimate future energy use and [CO.sub.2] emissions. Emission reduction occurs in macroeconomic models by imposing a tax on carbon-containing fuels, usually with no increase in the rate of energy efficiency improvement or decrease in the price of nonfossil energy supplies (which would occur in reality through accelerated research and development in response to higher fossil fuel prices). The macroeconomic approach also assumes the existence of a perfect marketplace today, such that any reduction of [CO.sub.2] emissions imposes an economic cost.

The second approach is a bottom-up, or engineering-based, approach, such as was used in the studies commissioned by the city of Toronto. This approach comprehensively examines every energy end use and compares the efficiency and capital and operating costs of the equipment stock in use with the best available equipment or that which is expected to become available within the time frame under consideration. The savings potential identified by this approach is that which would be obtained if every energy user selected energy-using equipment that minimized life-cycle capital and operating costs and therefore represents an upper limit to the savings that can be economically achieved in practice.

Economists generally reject engineering-based analyses for two reasons. First, they argue that there are transaction costs associated with acquiring energy-efficient equipment that, if included in the cost analysis, would result in no economically attractive energy savings potential. This is an extreme position and is not justified. The municipal government programs described here have been designed to reduce the transaction costs significantly. And although there are real and significant transactional costs associated with many energy efficiency improvements, there are a number of other barriers to improved energy efficiency that could be largely eliminated.(1) Examples of such barriers include situations in which a landlord chooses cheaper, energy-using equipment while the tenant pays the higher energy costs or in which energy consumers are not billed for energy in direct proportion to their use of it; codification of existing, inefficient practices in building codes or through "rule-of-thumb" designs; and lack of up-front capital for small energy users or its availability only at higher interest rates than are used to finance expansion of energy supply.

The second reason some economists reject engineering-based analyses is that they believe that macroeconomic feedbacks will cancel the energy savings achieved at the microeconomic level. These feedbacks arise from the fall in the real price of energy as demand falls because of more efficient energy us from the fall in the effective price of energy because it can be used more efficiently; and from the effect on total energy demand of the purchasing power released when energy cost savings accrue. However, available evidence indicates that these feedbacks are small, at least in industrialized countries.(2) (1.) See E. Jochem and E. Gruber, "Obstacles to Rational Electricity Use and Measures to Alleviate Them," Energy Policy 18 (1990):340-50; and A. K. N. Reddy, "Barriers to Improvements in Energy Efficiency," Energy Policy 19 (1990):953 61. (2.) See M. Grubb, "Energy Efficiency and Economic Fallacies," Energy Policy 18 (1990): 783-85; and L. G. Brookes and M. Grubb, "Energy Efficiency and Economic Fallacies: A Reply," Energy Policy 20 (1992): 390-93.

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NOTES

(1.) See A. Duarne and E. Plater-Zyberg, Towns and Town-Making Principles (Cambridge, Mass.: Harvard Graduate School of Design, 1990), for a perceptive comparison of post-World War II North American cities with traditional urban forms and for commentary on the environmental, social, and economic problems posed by the former. (2.) The report is available from the author at the University of Toronto Department of Geography, 100 St. George Street, Toronto, Canada, M5S 1A1. A summary of the report may be found in L. D. D. Harvey, "Implementation of Mitigation at the Local Level: The Role of Municipalities," in S. K. Majumdar. L. S. Kalkstein, B. Yarnal, E. W. Miller, and L. M. Rosenfeld, eds., Global Climate Change: Implications, Challenges, and Mitigation Measures (Easton, Pa.: Pennsylvania Academy of Sciences, 1992), 423-38. (3.) World Meteorological Organization, Conference Proceedings: The Changing Atmosphere: Implications for Global Security, Report 710 (Geneva: WMO, 1989). (4.) See Marbek Resource Consultants, "City of Toronto, Study 1: Potential for Electricity Conservation" (Prepared for the city of Toronto, Ottawa, March 1992); and Harvey, note 2 above. Other data are from the SACE report and the Energy, Efficiency Office of Toronto. (5.) Marbek Resource Consultants, note 4 above. (6.) This estimate of economic potential is based on a comparison of discounted life-cycle costs of alternative energy-using equipment, including current capital, maintenance, and energy costs. For existing building envelopes and heating or cooling equipment, normal rates of renovation and building turnover are assumed. In other cases, here total stock turnover will occur by 2005 or where it is cost-effective to replace existing equipment, irrespective of its age, full replacement of the existing stock is assumed. If environmental externalities exclusive of global warming concerns are included in the analysis, the economically attractive electricity savings in 2005 amounts to 57 percent of the projected 2005 demand, or 49 percent of the 1988 demand. This estimate assumes a damage cost for coal-fired electricity, which is on the margin in Toronto, of 5 cents per kilowatt-hour. (7.) See P. L. Joskow and D. B. Marron, "What Does a Negawatt Really Cost? Evidence from Utility Conservation Programmes," Energy Journal 13 (1992): 41-74. (8.) See L. D. D. Harvey and M. J. Wiggen, "Simultaneous Reduction of [CO.sub.2], [CH4.sub.4], and Chlorocarbon Emissions Through District Heating and Cooling" (in preparation). (9.) S. Solomon and D. L. Albritton, "Time-Dependent Ozone Depletion Potentials for Short- and Long-Term Forecasts," Nature 357 (1992): 33 37. (10.) D. A. Fisher et al., "Model Calculations of the Relative Effects of CFCs and Their Replacements on Global Warming," Nature 344 (1990): 513 16. (11.) This figure assumes that electricity and steam would be produced in a 2-to-1 ratio; that the absorption chiller COP (coefficient of performance, or ratio energy input to cooling provided) is 0.7; and that the average COP of the electric chillers that would be displaced is 3.55. (12.) D. M. Nowlan and G. Stewart, "Downtown) Population Growth and Commuting Trips: Recent Experience in Toronto," Journal of the American Planning Association 57, no. 2 (1991): 165-82. (13.) See W. Cline, The Economics of Global Warming (Washington, D.C.: Institute for International Economics, 1992), for a review of some of these models. (14.) See J. B. Robinson, "The Proof of the Pudding: Making Energy Efficiency Work," Energy, Policy 19 (1991):631-45.

L.D. DANNY HARVEY is an associate professor in the Department of Geography at the University of Toronto; cochair of the city of Toronto's Special Advisory Committe on the Environment; and a member of the Board of Directors of the Toronto District Heating Corporation and the Toronto Atmospheric Fund.

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