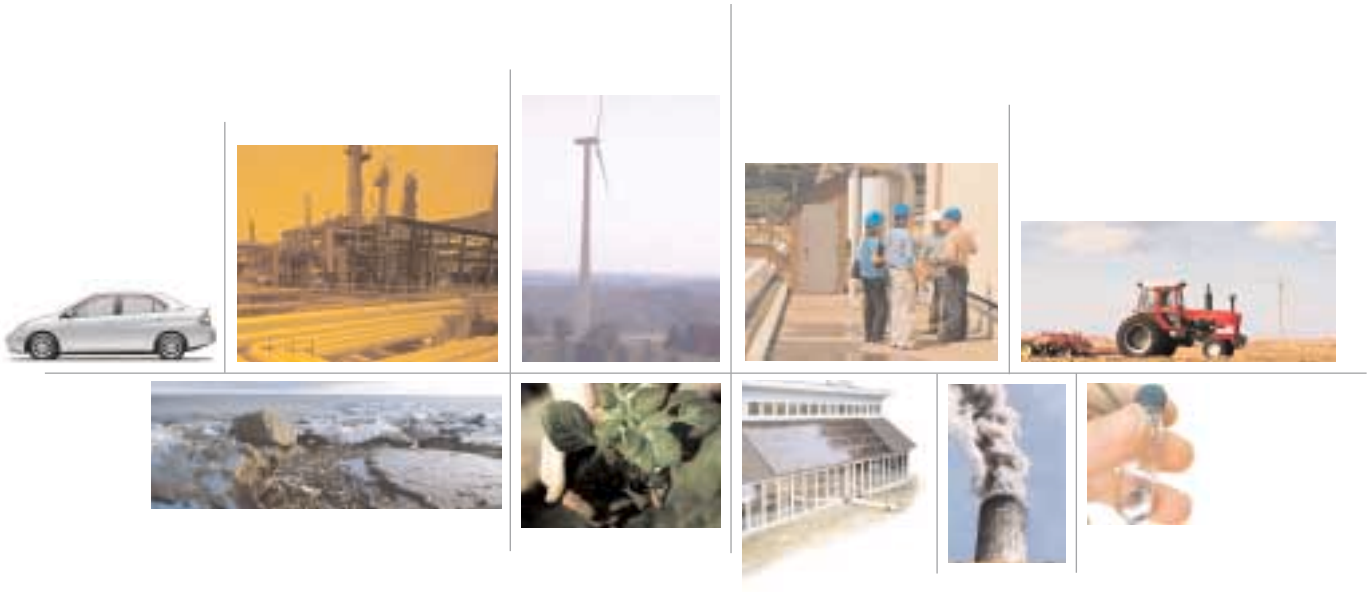

Pollution Prevention Evaluation Report

2002

MARCH 2002

Minnesota Office of **Environmental Assistance**

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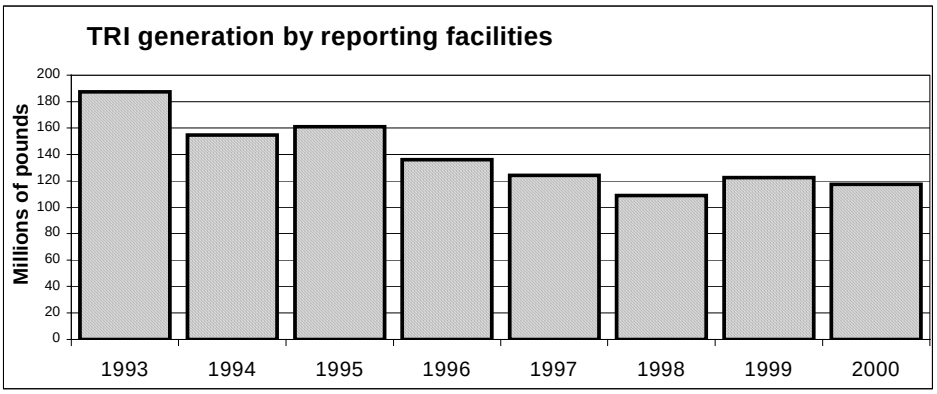
Executive Summary

Pollution prevention (P2) means eliminating or reducing at the source the use, generation, or release of toxic chemicals, hazardous substances, and hazardous waste. There are significant economic and environmental benefits when waste is reduced at its source as compared to controlling and managing it after its creation.

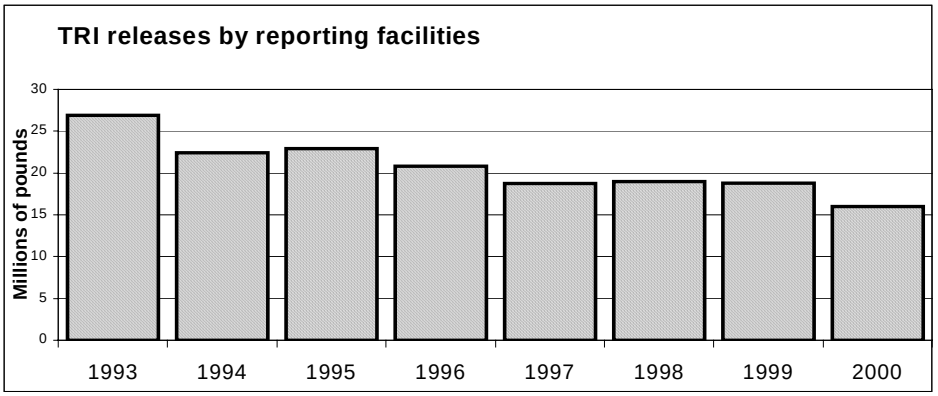
In accordance with the Pollution Prevention Act (Minn. Stat. § 115D.10), the Minnesota Office of Environmental Assistance (OEA) submits a Pollution Prevention Evaluation Report to the Legislature on progress in P2 each even-numbered year. Evaluating progress, providing technical and financial assistance, and analyzing facility P2 progress reports are part of required OEA P2 activities and are integrated into OEA's strategic plan. Highlights regarding these activities follow.

Manufacturing sectors

The number of reporting facilities within manufacturing sectors that have reported continously under Toxic Release Inventory (TRI) requirements from 1993 through 2000 has decreased from 550 to 357. In addition these sectors have decreased the amount of chemicals generated and the amount of chemicals released.



The amount of reported toxic chemicals generated has decreased by 37 percent, from 187 million to 117 million pounds.



The amount of reported toxic chemicals released has decreased by 34 percent, from 24 million to 16 million pounds.

While research shows that additional pollution prevention opportunities remain, a decrease in the number of reporters and an approximate one-third reduction in releases and generation, strongly indicates that noteworthy progress in P2 has occurred for these manufacturing sectors.

Individual facilities

Although knowing the change in the quantity of TRI chemicals generated at a facility over time does not precisely tell what caused the change in generation, it does serve as an indicator of progress in pollution prevention.

Between 1998 and 2000, out of 357 TRI reporters:

- 51 percent reduced the quantities of the total chemicals they generated.
- 32 percent reduced the quantities of total chemicals they generated by more than 10,000 pounds.
- 12 percent had a more than 50 percent *decrease* in the quantity of chemicals generated.
- 18 percent had a more than 50 percent *increase* in the quantity of chemicals they generated.

Facility P2 plans and progress reports

Minnesota's Pollution Prevention Act requires TRI reporters to write a P2 plan to reduce the generation or release of toxic chemicals. Although a facility's plan is not public, its progress in implementing the plan is. Facilities are required to state P2 objectives and submit P2 progress reports for each toxic chemical for which they report releases under TRI.

Based on the information provided in these reports, P2 objectives were met for 58 percent of the chemicals for which progress reports were filed.

PBTs

Persistent bioaccumulative toxics (PBTs) are some of the most dangerous substances ever produced or released through human activities. Bans and restrictions have been extremely effective in reducing their release to the environment, although because of their long life, consequences remain.

Due to the opportunities available, OEA's outreach has and will primarily focus on two PBTs: dioxin and mercury.

Dioxin

Dioxins are regarded as some of the most toxic substances known. They are not intentionally manufactured, but are created as a by-product of some manufacturing processes and through low-temperature burning of chlorine-containing materials. Due to a combination of P2 and pollution control devices, levels of dioxin released to the environment from industrial sources have deceased 80 percent since the 1980s. The majority of dioxin being formed in Minnesota today comes from the low temperature burning of chlorine-containing products in burn barrels. P2 reduces or eliminates the chlorine in products so that the method of their disposal is less critical.

Two industries which have made progress decreasing the amount of chlorine in their products are the paper and plastics manufacturing industries. The paper manufacturing industry changed from using elemental chlorine to chlorine dioxide for bleaching purposes resulting in 94 percent less chlorine today as compared to 10 years ago. Some 100 percent chlorine-free papers are also becoming available. The plastics industry is the single largest user of chlorine, accounting for 30 percent of chlorine consumption. The plastics industry is developing and providing increasing numbers of chlorine-free products. A lack of market demand is a primary reason for limited industry investment in these alternative products.

As a means to reduce precursors to dioxin emissions, OEA will research and promote purchase of functionally equivalent, chlorine-free products by the health care sector, by office supply stores and by units of government.

Mercury

Minnesota's coal-fired electric utilities represent the single largest source of mercury released to air, approximately 1600 pounds annually. Since mercury is a naturally occurring trace element in coal, P2 options are limited. Energy conservation is a low cost and the most readily available P2 opportunity to reduce mercury emissions from coal-fired utilities. From 1992 through 2000, Minnesota's energy conservation program saved approximately 1300 MW for an average savings of $343 per Kw. The OEA will continue to promote energy conservation through a variety of state and national energy saving programs.

Mercury-containing products have also been a historically high source of mercury pollution. Primarily due to regulatory bans, there has been an 87 percent decrease in Minnesota mercury emissions due to products. The OEA will continue to promote use of functionally equivalent products that do not contain mercury.

Pesticides

EPA estimates that about three-fourths of all conventional pesticide use in the United States is for agriculture. The amounts of crop-specific pesticides sold, contrasted with the change in the number of acres planted in corn and soybeans over time, shows that less pesticide is purchased per planted acre today than prior to 1994. There are no data available to make a similar calculation for residential/commercial turf grass. Progress in pesticide P2 has been made though the Minnesota Department of Agriculture's programs, including Integrated Pest Management, crop rotation, organic farming, multi-versus mono-crop planting, precision farming techniques and crop variety diversification projects.

The focus of OEA's P2 pesticides outreach will be through promoting use of Integrated Pest Management (IPM) at commercial and public facilities, and promoting use of native landscaping as a part of OEA's green building efforts.

Greenhouse gases and related toxic pollutants

Eighty percent of Minnesota's greenhouse gas (GHG) emissions comes from energy production from fossil fuels for electricity and transportation.

Minnesota's fossil fuel-powered electric utilities emit 37 million tons of CO_2 per year. CO_2 emissions from electric utilities are more than four times what they were 40 years ago. Electric utilities are also the state's largest TRI reported source of vanadium, hydrogen fluoride, molybdenum trioxide, mercury, nickel, barium, antimony, chromium, aerosol hydrochloric acid, and manganese released to air. They represent 37 percent of the state's lead air emissions. Energy conservation is the most readily available P2 action to reduce these emissions.

The focus of OEA's outreach will be on energy conservation and on promotion of alternative energy sources such as demonstration of educational, desktop solar/hydrogen-powered fuel cells. The OEA will continue researching P2 technologies for energy, many of which will be cost effective in ten years.

Transportation emits 45 million tons of CO_2 per year. CO_2 emissions from transportation are more than 2.5 times what they were 40 years ago. The production and use of gasoline for vehicles also represents the largest source of benzene emissions in the state. Increased use of more fuel-efficient vehicles, mass transit, and E85 fuel are the most readily available P2 opportunities to reduce these emissions.

In coordination with other state agencies, the OEA will continue to research P2 opportunities for transportation and promote them though the OEA's sustainable communities program.

Continued progress for manufacturers

Although progress has been made, research indicates that significant P2 opportunities remain.

Maintaining competitive advantage

Providing incentives and assistance for facilities to improve their environmental and economic performance has proven to be a very effective strategy for keeping Minnesota businesses competitive with those in other states and nations. To ensure that Minnesota-based facilities can continue to produce competitively priced products while in the state, additional incentives and assistance, independent of their source, will be necessary.

Technical and financial assistance

The OEA prioritizes its P2 technical and financial assistance through evaluating:

- **Opportunity.** Manufacturing sectors which have market-ready P2 technology are the best candidates for implementation.
- **Risk.** Manufacturing sectors which use large quantities of the chemicals that pose the largest potential for risk to public health and the environment receive priority.

The OEA recognizes that strong partnerships based on mutual trust are needed to turn P2 assistance into results.

Technical assistance

The OEA provides technical assistance to Minnesota businesses in a number of different ways.

Design for the Environment (DfE). Approximately 70 percent of a product's life-cycle costs are determined during the design stage. The OEA provides on-site assistance for DfE. The OEA's often cited *DfE Tool Kit* had more than 9,000 requests for downloads in 2001. A recent project documents DfE design changes that can save $4 million per year for the industrial partner.

Environmental Management Systems (EMS). Many Minnesota facilities have quality and environmental management systems such as ISO 9000 or ISO 14001 in place. OEA and MnTAP staff have been trained in these systems so that P2 can be integrated into a facility's existing programs.

Minnesota Technical Assistance Program. The OEA's Minnesota Technical Assistance Program (MnTAP) provides pollution prevention technical assistance to businesses throughout Minnesota. MnTAP provides on-site and telephone assistance, interns, an information clearinghouse, and materials exchange services. Over the last two years, facilities receiving MnTAP assistance have saved over $5.2 million, prevented 11.2 million pounds of waste, and conserved 90 million gallons of water. The documented dollars alone show that MnTAP saves businesses more than $2 for every $1 spent on the program.

The MnTAP budget has remained constant at $950,000 per year for the past several years and has not been increased to cover cost of living and rent increases. As a result, the number of staff was reduced from 15 to 14 in 2001, and additional reductions of approximately one position a year are projected to occur.

Financial assistance

The cost of P2 technologies must compete against all other needs a business has for investment. OEA's financial assistance results in new P2 products and improved efficiencies that would otherwise not have occurred. OEA grants and loans are matched dollar-for-dollar by participants.

Part 1

Introduction

Pollution prevention reduces the use and release of toxic chemicals at their source. There are significant environmental, economic and social advantages to pollution *prevention* rather than relying on pollution *control* equipment to reduce the release of toxic chemicals during their use or after becoming waste.

Chemicals in the environment are of concern. Recently, the Centers for Disease Control and Prevention (CDC) conducted a study of 3,000 people from around the country. Of the 27 chemicals (metals, including uranium; pesticides; phthalates; and tobacco by-products) tested, the CDC found traces of all of the chemicals in all of the sampled population.[1] While levels are currently below health limits, their presence indicates there are opportunities for pollution prevention. With the exception of lead and perhaps mercury, none of these chemicals would have been found in people 60 years ago. Chemicals such as polybrominated diphenyl ethers, polychlorinated biphenyls and some pesticides are routinely found in mothers' milk.[2, 3, 4] Air, water and soil sampling also documents the unintended presence of many toxic chemicals due to human activity.

Pollution prevention is a *front-end* solution to reduce the toxicity of environmental air emissions, water discharges and wastes to decrease exposure and risk to humans and ecosystems. In addition to decreasing risk to environmental and public health, pollution prevention is a benefit to public safety. Reducing the quantity and toxicity of the waste, air emissions and water discharges that is produced through making products, decreases the potential for harm in the event of an accidental or intentional release.

There are also important economic and social benefits. Minnesota's businesses have saved millions of dollars by implementing pollution prevention measures that use less toxic materials to produce goods and provide services. Businesses benefit through eliminating costly end-of-process pollution control equipment and hazardous waste management; conserving resources; improving worker safety and community relations; improving recyclability of manufacturing materials and products, and decreasing product liability and the costs of managing the product in the general waste stream at the end of its useful life.

As a tool to implement the Ventura Administration's Big Plan, pollution prevention fosters healthy, vital communities, integrates environmental and economic issues to preserve resources, and encourages service rather than systems. The Office of Environmental Assistance's (OEA) strategic plan supports the Ventura Administration's emphasis on making Minnesota a world competitor and leader. The OEA's P2 program implements one of the four goals of the OEA's strategic plan: Reduce and prevent pollution and toxicity. Key strategies to achieve this goal are in concert with statutory requirements.

Under the Toxic Pollution Prevention Act (Minn. Stat. § 115D), the OEA is responsible for providing technical, financial and educational assistance for pollution prevention (P2). Participation with OEA's P2 assistance is completely voluntary. OEA's P2 program is built upon experience which shows that positive incentives such as technical assistance, recognition awards, education, grants and loans, and P2 planning motivate organizations to implement pollution prevention. The OEA is charged to evaluate Minnesota's progress in pollution prevention and to report this progress to the public every even-numbered year.

Improved coordination among state agencies is a priority of the Ventura Administration. To leverage the benefits of P2, the OEA is working closely with:

- Minnesota Pollution Control Agency to determine if permit backlogs can be reduced through P2 activities which could reduce permit applicant chemical emissions to levels below air, water and waste permit thresholds.
- Emergency Response Commission to optimize use of TRI data and reporting facilities P2 plans.
- Department of Administration to increase the number of less toxic, functional equivalent products available through the state purchasing system.
- Department of Commerce to research P2 technologies for energy production and pilot use of fuel cells.

- State Planning Agency through loaning a staff person to coordinate public and private sustainable development activities.
- Department of Natural Resources to identify and increase use of non-toxic fishing line sinkers.
- Department of Agriculture to leverage use of Integrated Pest Management efforts for schools.
- County assistance providers to coordinate efforts to reduce waste at its source.

Assessing pollution prevention

The most significant problem when evaluating progress in pollution prevention is lack of data. Out of the more than 87,000 chemicals in commerce in the United States, 600 are included under the federal Toxic Release Inventory (TRI) Community Right-to-Know legislation. Because of their associated risk, this legislation requires facilities that manufacture, process or otherwise use above-threshold amounts of these chemicals to report the amounts they manage and release to the air, water or land. In Minnesota, the Emergency Response Commission maintains TRI data, which for the year 2000 includes 118 chemicals reported by 404 facilities.

The OEA has received comments from diverse interests regarding the limitations imposed by relying on TRI data, which only covers large, point sources of pollution, as a means to evaluate progress in pollution prevention. Mobile and area sources, as well as greenhouse gas pollution, are also known to be significant in the state. In an effort to expand beyond TRI the amount of data that could be used for an evaluation of progress in pollution prevention, the OEA also includes information necessary to evaluating progress for persistent, bioaccumulative toxics, pesticides and greenhouse gases in this report. This information provides some insight into other sources of pollution to aid an assessment of Minnesota's progress in pollution prevention.

OEA pollution prevention activities

OEA's required P2 activities include providing technical and financial assistance, recognition, collecting P2 fees, analyzing facility P2 progress reports, and evaluating progress.

Technical assistance

Providing P2 technical assistance is a proven means to achieve implementation. An independent 1999 survey of manufacturers showed that on-site P2 technical assistance ranked as one of the highest needs by Minnesota facilities. The OEA provides technical assistance to Minnesota businesses in several different ways.

Design for the Environment

Approximately 70 percent of a product's costs are determined during the design stage. Factoring in P2 during the design stage has documented benefits which include reduced costs, cycle times, regulatory concerns and liabilities; and improved products, market position and environmental performance. The OEA provides on-site assistance for Design for the Environment (DfE). The OEA's often cited *DfE Tool Kit* had more than 9,000 requests for downloads in 2001.

Recently the OEA and Medtronic Corporation worked together to integrate DfE into the design of medical products. A coating process project shows a potential annual savings of $3.8 million and a 75 to 85 percent reduction in chemical usage. A DfE battery manufacturing project shows a potential savings of $200,000, a 30 to 35 percent reduction in materials used, and avoidance of 1,000 pounds of solid waste per year.

Environmental Management Systems

According to environmental managers, one of the most significant barriers they face acquiring funds to implement P2 in their facilities is a lack of management support. Environmental projects are often seen as an addition rather than as a complement to existing programs. Many Minnesota facilities have environmental

management systems such as ISO 9000 or ISO 14000 in place. OEA and MnTAP staff have been trained in ISO systems so that P2 can be integrated into their existing programs.

Minnesota Technical Assistance Program

The OEA's Minnesota Technical Assistance Program (MnTAP) provides pollution prevention technical assistance to businesses throughout Minnesota. MnTAP provides on-site and telephone assistance, interns, an information clearinghouse, and materials exchange services all designed to help businesses prevent pollution. Over the last two years, facilities receiving MnTAP assistance have saved over $5.2 million dollars, prevented 11.2 million pounds of waste, and conserved 90 million gallons of water.

Recent examples include:

- A two-year project with Minnesota Publicly-Owned Treatment Works facilities resulted in savings of $2.8 million as well as saving 66 million gallons of water and preventing the generation of 3 million pounds of phosphorus, total suspended solids and chemicals that contribute to biological oxygen demand in water bodies.
- In 2000, approximate savings for companies participating in MnTAP's intern program were $1 million and a total of 3.6 million gallons of water, collectively. In addition, these projects identified opportunities to prevent the generation of a potential 4.7 million pounds of waste.
- A two-year project with the Minnesota Pollution Control Agency's Small Business Assistance Program assisting the fiber-reinforced plastics (FRP) industry resulted in savings of $119,150 and prevented the generation of 108,400 pounds of styrene waste and 17.7 tons of scrap resin.
- In 2001, companies participating in the intern program projected savings of $1.3 million and 25.4 million gallons of water, collectively. The projects identified opportunities to prevent the generation of a total of 0.7 million pounds of waste.

The documented dollars alone show that MnTAP saves businesses more than $2 for every $1 spent on the program. Medium- and small-sized businesses, which cannot afford their own P2 staff, receive much of the assistance. Although total cost savings may not be large, individual businesses often save what is a significant amount of money to them.

The MnTAP budget has remained constant at $950,000 per year for the past several years and has not increased to cover cost of living and rent increases. Due to these cost increases, the number of staff was reduced from 15 to 14 in 2001, and additional reductions of approximately one position a year are projected to occur.

Financial assistance

The cost of demonstration and implementation of P2 technologies must compete against all other needs and opportunities a business or community has for investment. OEA grants and loans, which are matched dollar-for-dollar by the recipient, have resulted in new P2 products and improved efficiencies that would otherwise not have been possible. P2 financial assistance accelerates development and adoption of technologies that make Minnesota a more competitive and environmentally attractive state.

Grants

Each year, the OEA awards grants for projects that focus on environmental projects, including pollution prevention. Grants for pollution prevention support innovation by demonstrating "real world" use of an emerging technology, leveraging local efforts, and by developing educational resources. Current grant projects include the following activities:

- develop curriculum that integrates DfE into University of Minnesota engineering course work.
- evaluate and demonstrate P2 technologies for the metal finishing industry.
- pilot use of retired engineers to perform commercial sector on-site P2 evaluations.
- pilot use of a reusable bottle, automatic refill system for nonhazardous cleaning products for retail customers.

Using U.S. Department of Energy grant funding, the OEA partnered with an industrial leader to develop a demonstration facility for product testing of a new technology to cure metal castings that uses 80 percent less energy and has no toxic chemical releases.

Loans

In the 2001 session, the Legislature authorized the OEA to set up a revolving account for pollution prevention loans. Such loans are being used with success in five other states to accelerate new investments in "off-the-shelf" P2 technology to improve the performance of the states' manufacturing sectors. OEA allocated up to $200,000 of its fiscal year 2002 grant budget for use as the new financial assistance tool. The reduced-rate loans are matched dollar-for-dollar by lending institutions that administer the loans.

A number of states have successful pollution prevention loan programs. Examples include:

- Michigan's program was initiated in 2000 and has made 13 loans for a total of $469,032. Benefits of the program to date include the reduction in use of 27 tons per year of perchloroethylene, a combined 21 million gallons of water saved per year, and a total reduction of 42 tons of solid waste.
- Ohio's program has awarded 28 loans for a total of $5,150,000 since 1994. To date, over 4.2 million tons of solid waste have been eliminated, 79,000 tons of hazardous waste prevented, 113 million gallons of water saved, and 1.5 million tons of air emissions prevented.
- Pennsylvania initiated a $2 million revolving loan fund in 1999. In one early success story, a $50,000 loan to a company to aid in equipment purchases has resulted in annual savings of 593,333 gallons of water and has prevented 7 tons of volatile organic compound (VOC) emissions yearly.

Governor's Awards for Excellence in Pollution Prevention

The annual Governor's Awards recognize facilities which have demonstrated leadership and the economic and environmental benefits of implementing P2. The awards are an important tool for inspiring others. The OEA has documented results of award winners each year from 1992 though the present. The recipients of the 2001 awards represent examples of recent leaders in pollution prevention.

Haubenschild Farms in Princeton, Minnesota is a pioneer in using anaerobic manure digestion to produce methane for generating electricity. The 800-cow family farm produces enough power to run the entire farm, plus 78 homes in the Princeton area. Alternative energy isn't the only benefit. Other benefits include greenhouse gas reduction, reduced use of petroleum-based fertilizers, and pathogen reduction. The farm has produced about $130,000 worth of electricity, and saves between $60,000 and $80,000 in fertilizer each year.

Honeywell-Solid State Electronics Center in Minneapolis saves $457,000 per year from a variety of pollution prevention actions. Water needed to produce semiconductors is now purified with UV light rather than chlorine, and deionized with an electrodeionization system rather than a corrosive chemical. Variable frequency drive motors run at the speed needed, reducing energy use. The facility eliminated the use of R11 refrigerant, an ozone-depleting gas, in favor of a high efficiency chiller. Use of an energy-saving heat exchanger to transfer energy between cooling water and well water conserves electricity, and the wastewater is clean enough to fill a wildlife pond rather than being discharged to the city sewer.

IBM Rochester now manufactures computer disks from glass instead of aluminum which resulted in:

- 76 percent reduction (799,500 pounds) of total TRI releases and off-site transfers.
- 74 percent reduction of reported discharges to the sanitary sewer, including nitrate (620,000 pound reduction) and aqueous ammonia (3,100 pound reduction).
- 94 percent reduction (97,700 pounds) in reported releases, which consist primarily of nickel, zinc and aqueous ammonia.
- 74 percent reduction (254 pounds) of air emissions.

- $2 million annual savings from reduced chemical handling, on-site general water treatment, on- and off-site nickel wastewater treatment, and waste disposal costs.
- $1 million annual savings from reduced charges for electricity, natural gas, water and sewer.
- More than $10 million annual savings for nickel-plating chemicals and operating costs.

Minneapolis Park and Recreation Board used an innovative combination of P2 education, filtering vegetation, and catch basins to reduce Cedar Lake and Lake Calhoun phosphorus and other contaminate levels by more than 66 percent in 1999. As a result, water clarity increased from 5.7 feet to 14 feet of depth clarity in the last three years.

Pollution prevention fees

The OEA is responsible for collecting P2 fees which are based upon the quantity and number of chemicals released to the environment from TRI facilities and from facilities which generate more than 1,000 kilograms of hazardous waste per month, also called large quantity generators (LQGs). More than 90 percent of the fees come from TRI reporters and the remainder comes from LQGs.[5] The revenue raised is allocated to the Environmental Fund, a portion of which funds OEA P2 programs.

Released: *TRI chemicals emitted to air, discharged to water, or disposed of in a landfill or by landspreading.*

The table below shows the total amounts of fees collected from 1996 to 2001. The total amount has increased because the number of chemicals and types of facilities which must report has increased over time. When only the amount of fees collected from manufacturing sectors that have reported each year from 1996 through 2001 are considered, the amount of fees collected has dropped. This decrease indicates progress in P2 by these reporters.

Figure 1-1. Total fees collected from TRI reporters and LQGs

Fiscal year	Total fees collected
1996	$973,378.20
1997*	$1,020,446.98
1998	$886,573.62
1999	$901,329.36
2000**	$1,156,320.64
2001	$1,252,276.64

*Increase in the number of chemicals required to be reported by U.S. EPA.

**Increase in the number of industries required to report to TRI by U.S. EPA, majority of increased fee collections from electricity-generating plants.

Pollution prevention plans

Minnesota's Toxic Pollution Prevention Act[6] requires facilities that report under TRI to develop non-public P2 plans as a means to integrate P2 into facility operations. By requiring reporting facilities to develop P2 plans, managers have the opportunity to become more aware of "front-end" P2 solutions to waste, and the company is better able to realize the significant economic and environmental savings which can occur due to this approach. Although a facility's plan is not public, progress in implementing its plans is reported to the Minnesota Emergency Response Commission each year. The OEA is responsible for reviewing progress reports for content and for performing analysis.

As with TRI, reporting facilities submit progress reports for individual chemicals. Chemicals that are reported under TRI but do not have releases are exempt from pollution prevention planning and progress report requirements. Progress reports must contain objectives, which may be numeric or non-numeric. Examples of numeric objectives might be to reduce releases of a chemical by a certain number of pounds or to reduce use of a toxic chemical by a certain percentage. Non-numeric objectives are intended to serve as intermediate objectives in situations where it may not yet be feasible to set a numeric objective. However, the Toxic

Pollution Prevention Act states that in the case where a numeric objective is not yet feasible, non-numeric objectives should be designed so as to lead to the establishment of numeric goals as soon as practicable. There is no penalty if reporters decide to set low P2 objectives or no objectives at all.

In 2000, 118 TRI chemicals were reported. If the chemical is released to the environment, each facility must file a progress report form for each TRI chemical they generate in above-threshold quantities. Minnesota facilities filed 955 chemical report forms. Numeric objectives were listed for 44 percent of the chemicals and non-numeric objectives were listed for the remaining chemicals. The data show that 58 percent of these numeric and non-numeric P2 objectives were met.

Of those reported, the manufacturing processes that generated the most waste include:

- paper manufacturing
- applying coatings such as paint, varnish or adhesives
- sterilizing
- cleaning and degreasing
- chemical transferring and packaging

The most common solutions used to reduce waste and prevent pollution include:

- improving maintenance scheduling, record keeping and procedures
- modifying equipment, piping and layouts
- improving procedures for loading, unloading or transferring a chemical
- changing production schedules to minimize equipment or feedstock changeovers
- substituting raw materials

Major barriers to meeting pollution prevention objectives include:

- technical limitations of the production process
- concerns that product quality may decline as a result of source reduction
- additional reduction does not appear technically feasible due to previous implementation of pollution prevention solutions

Prioritizing assistance to accomplish OEA strategic goals

The technical, financial and educational P2 assistance required of OEA must be prioritized to assure that assistance results in maximum pollution prevention. Rapid improvements in technology provide continued opportunities to reduce use of toxic chemicals by facilities and in products. The OEA considers three primary factors for prioritizing P2 assistance: opportunity, risk and strength of partnerships.

Opportunity

A given industrial sector may be responsible for use of significant amounts of toxic chemicals, but if P2 technology is not feasible for that sector, assistance would not likely result in implementation. In these cases, pollution *control* technology may be the best currently available option for these facilities. Because it is an end-of-pipe rather than a front-end solution, the OEA does not provide assistance for pollution control technology. Industries which have market-ready P2 technology available are the best candidates for implementation.

To aid targeting efforts, the OEA undertook a research project which evaluated 34 four-digit Standard Industrial Classifications (SICs) to determine which industries currently had the greatest opportunity to reduce chemical generation through P2. The P2 technologies which were included had to meet the following criteria:

- meet the definition of P2
- be technically and economically feasible based on actual applications in the industry
- currently have a less than 60 percent adoption rate in the industry
- reduce generation of a TRI chemical

A total of 175 technologies were reviewed for the study. The evaluation showed that, in Minnesota, 12 industries have the best potential to benefit from P2 at this time because of the new and available P2 technologies which could be adopted by these industries.

Figure 1-2. Industries with best P2 opportunities (listed in alphabetical order)

SIC number	Industry
3585	Air-conditioning and heating equipment
3732	Boat building and repairing
2022	Cheese, natural, processed, and imitation
3679	Electronic components, not elsewhere classified
3571/3672	Electronic computers and printed circuit boards
3471	Electroplating, plating, polishing, anodizing, and coloring
308	Fiberglass reinforced plastic composites (3082, 3088, 3089, 3792)
3411	Metal cans
3398	Metal heat treating
3632	Refrigerators and freezers
3841	Surgical and medical instruments and apparatus
2434	Wood kitchen cabinets

Risk

Risk to human health and the environment is a critical factor for prioritizing P2 assistance. Out of the approximately 87,000 chemicals registered for use in the United States, the government has some toxicity data on about 1,300 of these, and either chronic or cancer-complete data on 210. Potential for risk is established by taking the quantity of a chemical released to the environment and multiplying by its "human toxicity potentials" factor. In this way, a chemical which may be released in comparatively small quantities but has a high toxicity factor may be shown to pose a greater risk than a less toxic chemical released in large quantities.

OEA and MPCA risk assessment staff used TRI data (106 chemicals released to air and water) and Air Emissions Inventory data (87 chemicals released to air) to determine quantities of chemicals released to the environment. The State of California's CalTOX toxicity factors were modified with Minnesota values to establish state risk values for each chemical. The availability of cancer and non-cancer toxicological data for chemicals released to both air and water is the primary limiting factor for assessing risk. Such data exist for only 41 of the 169 chemicals that are reported released to Minnesota air and water.

OEA and MPCA were able to identify chemicals, for which data exist, that pose the highest potential risk for cancer and non-cancer (or chronic) ailments through air and water releases to the state as a whole. Statewide risk may be different than a particular community's risk. This is because the highest risk to a particular community may come from chemicals released within or near that community rather than as aggregated from statewide data.

Figure 1-3. Top 25 chemicals with highest potential statewide risk for cancer* and non-cancer**

Chemicals released to air

Non-cancer	Cancer
Lead	Arsenic
Mercury	2,3,7,8-tetrachloro dibenzo-p-dioxin (TCDD)
2,3,7,8-tetrachlorodi benzo-p-dioxin (TCDD)	Lead
Cadmium	Benzo(a)pyrene
Arsenic	Chromium
Chromium	Chloroform
Copper	Carbon tetrachloride
Bromomethane	Chloromethane (methyl chloride)
Manganese	Tetrachloroethylene (perc)
Di-n-octyl phthalate	Nickel
Nickel	Dichloromethane (methylene chloride)
Acrolein	Cadmium
Cobalt	Benzene
Barium compounds	Trichloroethylene
Hydrochloric acid (aerosol forms only)	Beryllium
Chloromethane (methyl chloride)	Crotonaldehyde
Tetrachloroethylene (perc)	Formaldehyde
Carbon tetrachloride	Ethylene dichloride (1,2-Dichloroethane)
Methyl chloroform (1,1,1-trichloroethane)	Ethylene oxide
Dichloromethane (methylene chloride)	1,3-butadiene
Beryllium	1,1,2,2-tetrachloroethane
Antimony compounds	1,1,2-trichloroethane
Zinc compounds	Benzo(b)fluoranthene
Ammonia	Di(2-ethylhexyl) phthalate
Formaldehyde	Benzo(k)fluoranthene

Chemicals released to water

Non-cancer	Cancer
Lead compounds	Chloroform
Copper compounds	Lead compounds
Selenium compounds	1,3-butadiene
Barium compounds	Benzene
Antimony compounds	Acetaldehyde
Chloroform	Ethyl acrylate
Chromium compounds	Formaldehyde
Zinc compounds	Chromium compounds
Manganese compounds	Nickel compounds
Nickel compounds	
Acetaldehyde	
Ammonia	
Naphthalene	
1,2,4-trimethylbenzene	
Acetonitrile	
Benzene	
N-hexane	
1,3-butadiene	
Xylene (mixed isomers)	
Toluene	
Methyl methacrylate	
Methyl ethyl ketone	
Ethylbenzene	
Ethyl acrylate	
Methanol	

*Cancer risks are defined as the probability of contracting cancer due to a unit release of the chemical.

**Non-cancer health effects may include damage to selected organs (skin, eyes, liver, kidney); systems (respiratory, immune, reproductive or blood-forming); or adverse effects to a developing fetus due to a unit release of the chemical.

Figure 1-4. Top 15 industries that release significant quantities of the chemicals which pose the highest statewide potential risk (listed in alphabetical order)

SIC	Description	Chemicals
2063	Beet sugar	2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), ammonia
2899	Chemicals and chemical preparations	Arsenic, chromium, copper, dichloromethane, ethyl acrylate, ethylbenzene, formaldehyde, lead, methy ethyl ketone, n-hexane, toluene, zinc compounds
2672	Coated and laminated paper	1,2,4,-trimethylbenzene, antimony compounds, barium compounds, ethylbenzene, formaldehyde, lead, n-hexane, toluene, xylene, zinc compounds
4911	Electric services	2,3,7,8-tetrachlorodibenzo-p-dioxin (tcdd), ammonia, antimony compounds, barium compounds, chromium, copper, lead, manganese, mercury, nickel compounds, zinc compounds
3471	Electroplating, plating, polishing, anodizing and coloring	Chromium, copper, nickel compounds, trichloroethylene, zinc compounds
3499	Fabricated metal products	Copper, dichloromethane, manganese, methyl ethyl ketone, nickel compounds, toluene, xylene, zinc compounds
3711	Motor vehicle and passenger car bodies	1,2,4,-trimethylbenzene, ethylbenzene, methyl ethyl ketone, n-hexane, nickel compounds, toluene, xylene, zinc compounds
2911	Petroleum refining	1,2,4,-trimethylbenzene, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), ammonia, barium compounds, benzene, chromium, cobalt, copper, ethylbenzene, lead, manganese, mercury, n-hexane, nickel compounds, tetrachloroethylene (perc), toluene, xylene, zinc compounds
2611	Pulp mills	2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), acetaldehyde, ammonia, barium compounds, chloroform, formaldehyde, manganese, methyl ethyl ketone, zinc compounds
2493	Reconstituted wood products	2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), acetaldehyde, acrolein, formaldehyde, zinc compounds
4953	Refuse systems	Ammonia, chromium, copper, nickel compounds, zinc compounds
2079	Shortening, table oils, margarine, and other edible fats and oils	Ammonia, n-hexane, nickel compounds
2075	Soybean oil mills	Barium compounds, mercury, n-hexane, nickel compounds
3312	Steel works, blast furnaces and rolling mills	Barium compounds, chromium, copper, lead, manganese, mercury, nickel compounds, zinc compounds
2434	Wood kitchen cabinets	1,2,4,-trimethylbenzene, ethylbenzene, methyl ethyl ketone, toluene, xylene

Strength of partnerships

Assistance must be turned into results. Experience has proven that successful P2 requires strong partnerships. Partnering with trade associations, individuals or organizations that are motivated to find P2 solutions and have technical expertise improve the likelihood of success. Participation with OEA assistance is voluntary and may involve specifics such as costs, materials and determination of payback periods. Developing strong partnerships based on mutual trust and respect is crucial for achieving P2 results.

Opportunity to eliminate confusion

A 1996 governor's reorganization order changed the agency responsible for collecting and reviewing pollution prevention progress reports. The order changed the agency which receives Pollution Prevention (P2) Progress Reports from the MPCA to the Emergency Response Commission (ERC). The ERC is also identified as the group that will do the initial compliance review; and the OEA is specifically identified as the agency which will review the reports to determine technical assistance needs. The OEA proposes to codify these changes in

statute by amending Minn. Stat. § 115D to reflect the reorganization order. This would eliminate confusion by the regulated community and others who look at the statute for guidance but are not aware of the reorganization order.

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[1] U.S. Centers for Disease Control, "National Report on Human Exposure to Environmental Chemicals." Report provides information on the exposure of the U.S. population to these 27 chemicals: Metals: lead, mercury, cadmium, cobalt, antimony, barium, beryllium, cesium, molybdenum, platinum, thallium, tungsten, and uranium. Tobacco smoke: cotinine—a metabolite of nicotine. Organophosphate pesticides (six metabolite measurements representing exposure to 28 pesticides): dimethylphosphate, dimethylthiophosphate, dimethyldithiophosphate, diethylphosphate, diethylthiophosphate, and diethyldithiophosphate. These metabolites are generally formed by the breakdown of 28 pesticides, including chlorpyrifos, diazinon, fenthion, malathion, parathion, disulfoton, phosmet, phorate, temephos, and methyl parathion. Phthalate metabolites (from cosmetics and plastic softeners); mono-ethyl phthalate, mono-butyl phthalate, mono-2-ethylhexyl phthalate, mono-cyclohexyl phthalate, mono-n-octyl phthalate, mono-isononyl phthalate, and mono-benzyl phthalate. http://www.cdc.gov/nceh/dls/report/default.htm.

[2] Walkowiak, J., J. Wiener, A. Fastabend, B. Heinzow, U. Krämer, E. Schmidt, H. Steingrüber, S. Wundram, and G. Winneke, 2001. "Environmental exposure to polychlorinated biphenyls and quality of the home environment: effects on psychodevelopment in early childhood." *Lancet* 358: 1602–07.

[3] U.S. National Institutes of Health, Environment Health Perspectives, March 2001. Air borne contaminants most commonly found in breast milk were three pesticides (dieldrin, mirex and DDE) and two industrial chemicals (polychlorinated biphenyls and hexachlorobenzene).

[4] *Environmental Science and Technology, Science News*, "Rapidly rising PBDE levels in North America," December 2001. Although due to the limited number of samples the data can indicate, not demonstrate, a trend: the levels of polybrominated diphenyl ethers (PBDEs) in breast milk of North American women appear to be doubling every two to five years. PBDE is used as a flame retardant in North American consumer goods. PBDE is banned from products in the European Union.

[5] All facilities required to report under TRI pay $150 per chemical released; facilities that release less than 25,000 pounds pay an additional $500; facilities that release more than 25,000 pounds pay two cents per pound per chemical released.

[6] Minnesota Toxic Pollution Prevention Act, 1990, Minn. Stat §§ 115D.07 and 115D.08.

Part 2

Statewide Trends

The data provided by Toxic Release Inventory (TRI) reporters to the Emergency Response Commission shows that facilities within the industries that have reported each year from 1993 through 2000 have made progress in pollution prevention. Although the total reported quantities of releases of toxic chemicals to air, water or land increased by 9 percent, from 27 million pounds in 1993 to just over 29 million pounds in 2000, the increase is due to an increase in the number of chemicals and industries subject to reporting, rather than from the on-going reporters. Expanded reporting captures information from additional industry sectors and evaluation of these added sectors will be possible as trend data become available. This will be explained in more detail later in this section.

New reporting requirements for 2000

The U.S. Environmental Protection Agency (U.S. EPA) lowered the reporting threshold for 18 TRI chemicals that are classified as persistent, bioaccumulative, toxic (PBT) chemicals. In addition, EPA designated vanadium compounds as TRI-reportable.

These changes resulted in the additional reporting of nearly half a million pounds of chemical releases and over 560,000 pounds of total chemicals generated by Minnesota TRI reporters. There were 109 additional TRI Form R submittals by 56 facilities. Ten of these facilities were first-time reporters in 2000 because of the expanded requirements. TRI data from Minnesota reporters is now available for vanadium compounds and eight PBT chemicals. Vanadium compounds made up the bulk of the new release, totaling 470,700 pounds. The large majority of them are from electric utilities due to the natural presence of vanadium in coal.

Figure 2-1. Most commonly reported PBT chemicals

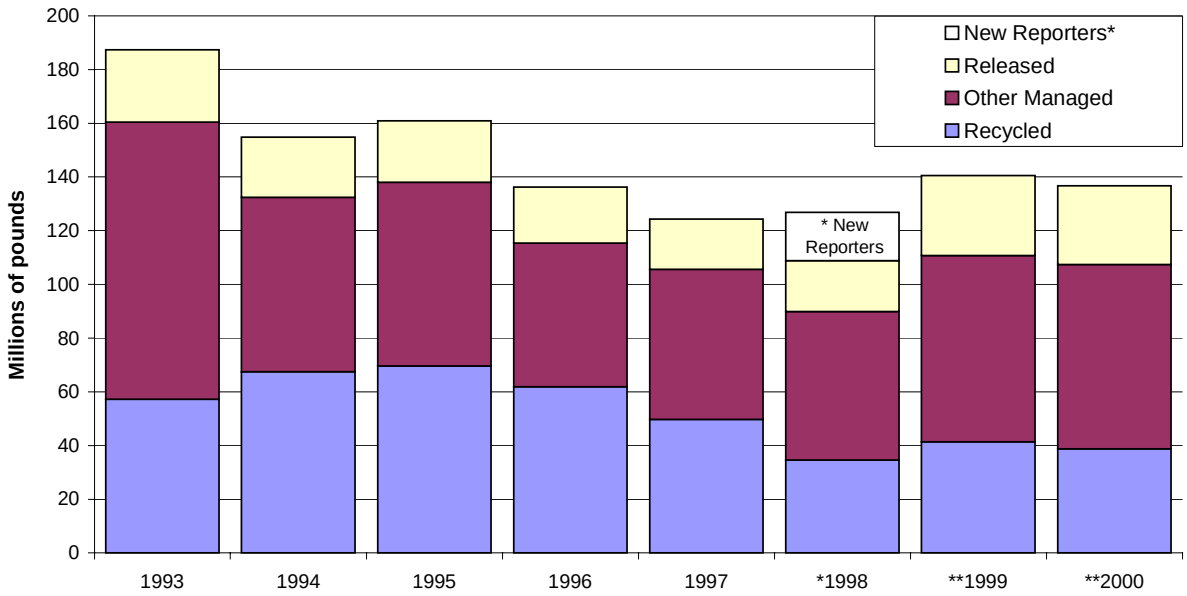
	Number of facilities	Total amount generated	Total amount released
Polycyclic aromatic compounds	35 facilities	89,614 pounds	23,844 pounds
Mercury and mercury compounds	21 facilities	3,398 pounds	2,977 pounds
Dioxins	19 facilities	3.7 pounds	2.95 pounds

Industry trends

Manufacturing sectors that have reported each year since 1993 have *decreased* the amount of reported toxic chemicals released to air, water or land by 34 percent, from 24 million pounds in 1993 to 16 million pounds in 2000. In addition, total reported toxic chemical generation has decreased 27 percent, from 187 million to 137 million pounds for the same years. During the same time period, of the nearly 550 reporting industrial facilities in 1993, only 400 needed to report in 2000, meaning that many facilities have dropped below reporting thresholds. This may be due to successful P2, although in some cases manufacturing processes moved out-of-state. While additional pollution prevention opportunities do remain, an approximate one-third reduction in releases and generation strongly indicates that noteworthy progress in P2 has occurred by these reporters.

When assessing P2 progress, it is important to differentiate between those reporters that *manufacture* products from those that *recycle* another manufacturer's waste and disposed products. While the primary goal is to reduce toxic chemical generation, recycling facilities offer a means for reusing TRI chemicals that would otherwise be disposed of as waste, providing a benefit to both the environment and the economy. Figure 2-2 excludes these recyclers and shows the trend in quantities of toxic chemicals generated, released and managed by manufacturers only.

Figure 2-2. Statewide trend for reported TRI chemicals (excluding recyclers) from 1993 to 2000 in millions of pounds



	1993	1994	1995	1996	1997	*1998	**1999	**2000
Number of reporters	549	532	465	432	406	428 (25)	399	404
Released	26.9	22.4	22.9	20.8	18.7	30.6 (11.6)	29.8	29.3
Other managed	103.3	65.0	68.4	53.5	55.9	56.6 (1.3)	69.3	68.7
Recycled	57.2	67.5	69.6	61.9	49.7	39.7 (5.1)	41.4	38.7
Total chemicals generated	187.4	154.9	160.9	136.2	124.3	126.9 (18.0)	140.5	136.7

*In 1998, U.S. EPA expanded TRI reporting requirements; parentheses (x) show growth due to that expansion.

**Values reflect expanded 1998 reporting requirements.

Although manufacturers may recycle part of the waste they generate into their manufacturing process, recycling facilities recycle waste they receive from others. They provide recycled-content feedstocks for use by manufacturers. Figure 2-3 shows the trend in the amounts of toxic chemicals generated, released or managed through other methods by the state's largest recyclers: Gopher Resources Corporation which recycles lead batteries; North Star Recycling, a scrap steel processor; and U.S. Filter Recovery Services, a metals and chemicals recycler. The portion of TRI chemicals managed by these recyclers has increased from 28 percent of chemicals generated in 1993 to 56 percent in 2000. The cost of recycling products decreases as the quantity of toxic material in them decreases.

Figure 2-3. Trend for reported TRI chemicals of major recyclers from 1993 to 2000 in millions of pounds

	1993	1994	1995	1996	1997	1998	1999	2000
Released	2.1	1.6	1.5	1.2	1.6	1.6	1.8	3.7*
Recycled	68.4	82.0	104.1	104.5	134.9	169.2	190.6	168.8
Other managed	2.5	2.0	0.1	0.1	0.1	0.1	0.1	0.1
Total generated	73.0	85.6	105.7	105.8	136.6	170.9	192.5	172.6

* The majority of the shift in pounds from Recycled to Released between 1999 and 2000 was a result of a regulatory issue that forced one recycler to discontinue metals recovery of their wastewater treatment sludge. An alternative sludge recycling system is expected to reduce releases in the near future.

Facility trends

Pollution prevention is most effectively evaluated by documenting a facility's change in the amount of waste generated per product, over time. A decrease in the number of products produced may cause a decline in the quantity of reported chemicals, but if the quantity of toxic chemicals used and generated remains the same for each product, there has been no reduction in toxic materials related to the product.

Generation. *The sum of all TRI chemicals released, recycled, treated to reduce quantity or toxicity prior to disposal, or burned for energy recovery.*

Although production ratios are reported under TRI, this data does not have the statistical validity needed to determine a change in toxic material produced per product. Data on the quantity of TRI chemicals *used* per unit of production would be needed to evaluate the change in toxic material related to the product. Use data reporting is required in New Jersey and Massachusetts; however, use data reporting is not required from Minnesota reporters.

A decrease in toxic chemical generation may be caused by P2. However, an increase or decrease in toxic chemical generation can be caused by an increase or decrease in production, or a transfer of production to or from another facility. Although uncertainty is present, the OEA uses TRI chemical generation data as a means to evaluate progress in P2 for facilities. This data indicates that some individual facilities have recently made significant progress in pollution prevention while others have not.

Largest quantity reduction in chemicals generated

In 2000, 51 percent of TRI reporters reduced the quantities of total chemicals generated (TCG), compared to 1998 levels. Out of 357 total reporters, 114 facilities reduced their TCG by more than 10,000 pounds. The following table (Figure 2-4) identifies the top 15 facilities that achieved the greatest decreases in pounds of TRI chemical generation. Based on this data, successful P2 is indicated.

Figure 2-4. Facilities with the largest reported decrease *in pounds* of chemicals generated

	1998 TCG (in pounds)	2000 TCG (in pounds)	Quantity change (in pounds)
3M Cottage Grove Center	19,571,477	12,861,749	-6,709,728
IBM Corporation	1,603,147	394,584	-1,208,563
Minnesota Mining & Mfg.-Hutchinson	25,818,826	24,877,130	-941,696
Melrose Dairy Proteins, LLC	1,489,591	806,880	-682,711
Koch Petroleum Group	4,897,487	4,383,263	-514,224
Crystal Cabinet Works, Inc.	678,435	226,460	-451,975
Sheldahl, Inc.-East Facility	2,351,135	1,910,826	-440,309
3M Company	3,169,376	2,818,228	-351,148
Georgia-Pacific Corporation	685,840	369,831	-316,009
Ford-Twin Cities Assembly Plant	2,185,275	1,890,744	-294,531
Pioneer Metal Finishing	1,143,728	851,743	-291,985
Dairy Farmers of America, Inc.	480,726	221,200	-259,526
Cenex Harvest States	763,800	512,200	-251,600
American Crystal Sugar Company	418,009	173,001	-245,008
Interplastic Corp.	395,762	164,207	-231,555

Largest percentage reduction in chemicals generated

Although large facilities may reduce the largest number of pounds of waste generated, smaller facilities may reduce a larger *percentage* of chemicals. In 2000, 12 percent of TRI reporters (44 reporters) reduced the percentage of chemicals they generated by 50 percent or more compared to 1998 levels. The following table identifies the top 15 facilities that achieved the greatest percentage reductions in TRI generated. Based on this data, successful P2 is indicated.

Figure 2-5. Facilities with largest reported decrease *by percentage* of chemicals generated

	1998 TCG (in pounds)	2000 TCG (in pounds)	Percentage change
Loes Enterprises, Inc.	1,000	0	-100%
Kraft Foods	28,886	<1	-100%
Bo-Decor Metal Finishing Inc.	3,630	23	-99%
Aacron, Inc.	65,842	4,917	-93%
M. E. International-Duluth	135,030	15,470	-89%
Professional Plating	89,100	12,200	-86%
Dayco PTI, Inc.	8,394	1,297	-85%
Atofina Chemical, Inc.	13,652	2,198	-84%
Pechiney Plastic Packaging, Inc.	248,000	40,200	-84%
Applied Coating Technology, Inc.	92,042	15,000	-84%
Vision Ease Lens, Inc.	94,004	16,883	-82%
Minncast, Inc.	5,120	920	-82%
Le Sueur Incorporated	238,622	48,580	-80%
Salo Manufacturing Inc.	29,608	6,240	-79%
Cypress Semiconductor	88,694	18,843	-79%

Largest quantity increase in chemicals generated

The following table shows the top 15 facilities that reported the largest increases in pounds of TRI chemicals generated. Based on this data, P2 is not indicated.

Figure 2-6. Facilities with the largest reported increase *in pounds* of chemicals generated (excluding recyclers)

	1998 TCG (in pounds)	2000 TCG (in pounds)	Quantity change (in pounds)
Potlatch Corp.-Cloquet*	5,918,926	12,713,926	6,795,000
Boise Cascade Corp.*	8,300,410	11,378,330	3,077,920
Filmtec Corp.	1,340,968	2,349,392	1,008,424
3M-Electrical Products Division	298,240	830,509	532,269
Davisco Le Sueur Cheese Division	778,207	1,275,442	497,235
North Star Steel-Manufacturing*	4,508,355	4,984,835	476,480
Xcel Energy-A. S. King Generating Plant*	718,300	1,157,895	439,595
ADC Telecommunications, Inc.-Shakopee	712,416	1,104,897	392,481
Polarfab, LLC	72,469	421,785	349,316
Intermet	331,255	603,482	272,227
The Bergquist Company	582,310	817,580	235,270
Electrolux Home Products	450,535	684,450	233,915
Northwood Panelboard Co.	74,160	295,217	221,057
Federal Cartridge Company	234,000	450,355	216,355
Grede-St. Cloud	223,919	433,340	209,421

*Increases due in part to expansion of TRI reporting requirments.

Largest percentage increase in chemicals generated

In 2000, 63 reporting facilities out of 357 showed a greater than 50 percent increase in TRI chemical generation, compared to 1998. The following table shows the top 15 facilities that reported the largest percentage increase in TRI chemical generation. Based on this data, P2 is not indicated.

Figure 2-7. Facilities with the largest reported increase *by percentage* of chemicals generated

Facility	1998 TCG (in pounds)	2000 TCG (in pounds)	Percentage change
Fox Lake Plant	260	20,790	7896%
Tandem Products, Inc.	1,038	11,897	1046%
BP Amoco Oil-Twin Cities Terminal	2,010	18,180	804%
Gorecki Mfg., Inc.	800	6,044	656%
Polarfab, LLC	72,469	421,785	482%
Degussa Construction Chem. Op., Inc.	10,200	54,861	438%
Quality Circuits Inc.	45,303	213,938	372%
Plasti Dip International	2,937	12,171	314%
Northwood Panelboard Co.	74,160	295,217	298%
Westin Automotive Products, Inc.	5,151	19,088	271%
Zalk Steel & Supply Co.	663	1,910	188%
Honeywell Advanced Circuits, Inc.	81,529	234,314	187%
Badger Equipment Co.	102,839	289,380	181%
3M-Electrical Products Division	298,240	830,509	178%
Wastequip/Rayfo	19,138	48,998	156%

Part 3

Persistent Bioaccumulative Toxics Pollution Prevention

The Office of Environmental Assistance (OEA) is responsible for pollution prevention (P2) technical, financial and educational assistance and for evaluating state progress in P2. As data allows, this chapter of the *2002 Pollution Prevention Evaluation Report* evaluates progress and opportunities to reduce persistent bioaccumulative toxics through using P2.

Persistent, bioaccumulative toxic (PBT) chemicals are some of the most dangerous substances ever produced or released as a result of human activities. PBTs are long-lasting pollutants that are notable for their ability to be transported long distances by air or water, remain static for long periods of time in soil until disturbed, to move and partition among environmental media, and to bioaccumulate in aquatic and/or terrestrial organisms. They are particularly troublesome due to their high toxicity and persistence in the environment. PBTs may interfere with human endocrine systems, cause reproductive and developmental problems, impair the immune system, and cause cancer. Fetuses and children are at particularly high risk from PBT exposure because their rapidly developing systems can be affected by very small amounts of these substances. The symptoms of impaired development or toxicity may not be immediate; and dramatic health effects may show up in subsequent generations.

The EPA's Office of Pollution Prevention and Toxic Substances "Priority PBTs List" includes selected pesticides (aldrin/dieldrin, chlordane, DDT, DDE, DDP, mirex and toxaphene), and dioxins and furans, mercury and its compounds, benzo(a)pyrene, PCBs, hexachlorobenzene, alkyl-lead, and octachlorostyrene. The EPA has developed a national strategy to reduce these PBTs.[1] Chemicals and materials discussed in this background paper are on EPA's Priority PBTs List.

Due to the opportunities available through alternative products, P2 technologies and strong partnerships, the majority of the OEA's P2 activities to reduce PBTs are targeted for dioxins and mercury.

Dioxins

Dioxins are regarded as some of the most toxic substances known. They are not intentionally manufactured, but are created as a by-product of some manufacturing processes and through the incomplete burning of chlorine-containing materials. Once formed, dioxin molecules can persist for decades, and continuously move through air, water, soil and sediment, plants and animals alike. Due to uptake of dioxin in the environment, even burning today's wood or crop waste releases dioxin. The amounts of dioxin found in current samples of plant, soil or human tissue is many times greater than the amounts found in historical samples.[2, 3, 4]

Due to a combination of pollution prevention efforts and pollution control devices, levels of dioxin released to the environment from industrial sources have decreased 80 percent since the1980s. Although burn barrels are currently the second highest source of dioxin emissions, they will soon become the primary source as pollution control technology on incinerators improves. [5] Due to low burning temperatures, dioxin emissions from burning approximately 50-900 pounds of household waste in a burn barrel are equivalent to burning 400,000 pounds of household waste in a modern, well-controlled incinerator.[6] Assuming emission control devices are operating correctly to meet 2002 emission control limits, the majority of dioxin being formed in Minnesota will come from the incomplete burning of chlorine-containing products, principally through residential use of burn barrels and fire-pits.

P2 options for dioxins

It is expensive to purchase and maintain pollution control equipment on incinerators and difficult to control the waste disposal behavior of individual citizens. With regard to reducing precursors to dioxin, pollution prevention focuses on reducing or eliminating chlorinated compounds at the source. By using chlorine-free feedstocks and purchasing chlorine-free products, manufacturers can reduce or eliminate the chlorinated compounds, which can in turn form chlorinated organic compounds. For example, because dioxins are created as a by-product of the manufacturing process, the pesticide 2,4-D, is contaminated with dioxins.[7,8]

Progress in industry

Although the following two industries are historically high users of chlorine, in recent years they have made significant progress in reducing the amount of chlorine in their products.

P2 in the pulp and paper industry

The pulp and paper industry has made very significant progress toward reducing the potential for their manufacturing processes and products to form dioxin. In the United States, this was done through a change from the use of elemental chlorine to chlorine dioxide for bleaching purposes. As a result, the white paper products produced today by Minnesota facilities contain only 6 percent of the chlorine as compared to ten years ago. Chloroform emissions have also been reduced substantially. One hundred percent chlorine-free paper bleaching processes are available and were adopted by the majority of European paper manufacturers. However, these processes are reported to be cost-prohibitive for Minnesota facilities, given current market incentives.

P2 in the plastics manufacturing industry

The use of chlorinated compounds is particularly important for the polyvinyl chloride (PVC) industry. This industry is the largest single user of chlorine in the world, accounting for 30 percent of chlorine consumption.[9] The plastics industry is developing and providing alternatives to products customarily made with PVC, such as polypropylene pipe, wire coating and food wrap; and polyethylene containers and tubing. Baxter International, one of the two largest volume makers of medical IV bags, announced it will cost effectively move to PVC-free bags in 5 to 10 years.[10] According to Environment Canada, when economies of scale are reached with current product alternatives, approximately 89 percent of current PVC resin uses could cost effectively be replaced with non-chlorine resins.[11, 12] A lack of market demand is a primary reason for limited industry investment in alternative products.

OEA P2 actions and opportunities to reduce dioxin precursors

Due to the working partnership between the OEA and Department of Administration process chlorine-free (PCF) paper is now available to purchasers that use the state contract. One hundred percent post-consumer recycled content, PCF paper is available for 12 percent above the price of 30 percent post-consumer paper. OEA will continue to promote the availability and use of PCF paper to other state agencies, and to educate consumers on the importance of purchasing PCF products and non-bleached tissue and paperboard containers.

As part of its continuing efforts to reduce dioxin precursors, the OEA will:

- research opportunities to educate office supply stores to stock and customers to ask for process chlorine-free paper.
- continue to partner with the Department of Administration to increase availability and purchase of functionally equivalent, non-chlorinated product alternatives by state agencies.
- continue to educate consumers about the availability of non-chlorinated products.
- continue to educate health care professionals about the availability of chlorine-free supplies and equipment.
- evaluate feasibility of an educational campaign, similar to what was achieved with mercury, as a means to inform the public on issues related to dioxin.

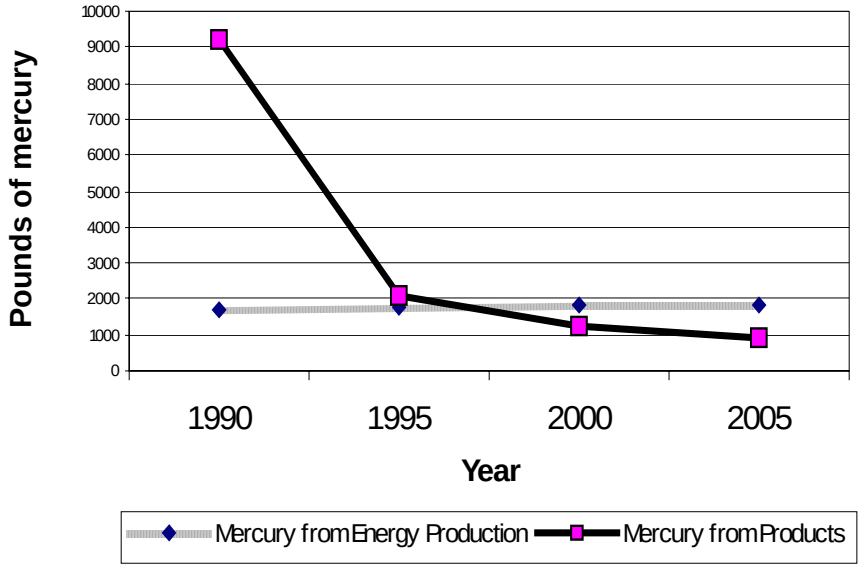
Mercury

For centuries it has been known that mercury has toxic effects on humans and wildlife. Mercury is a PBT that affects the nervous system. Children who are exposed to mercury through their mothers' consumption of fish are particularly at risk.

Coal-fired electric power plant emissions represent the single largest source of mercury released to the air.[13] Combustion of coal, which commonly has a mercury content averaging about 0.1 ppm, releases approximately 1,600 pounds in Minnesota annually.[14] Mercury is also used in a wide range of products. The highest priority of any pollution prevention program is to eliminate the use of mercury in the first place.

The following graph shows the trend of mercury emissions from primary sources in Minnesota. The large decrease in amounts of mercury released to the environment from products between 1990 and 1995 was primarily due to a ban of mercury in paint products, the elimination of mercury from most batteries, and to improvements in management and recycling. Due to an estimated 87 percent reduction in mercury from products between 1990 and 2000, emissions from energy production are now the largest sources of mercury releases in the state.

Figure 3-1. Estimated mercury emissions in Minnesota and projections for 2005

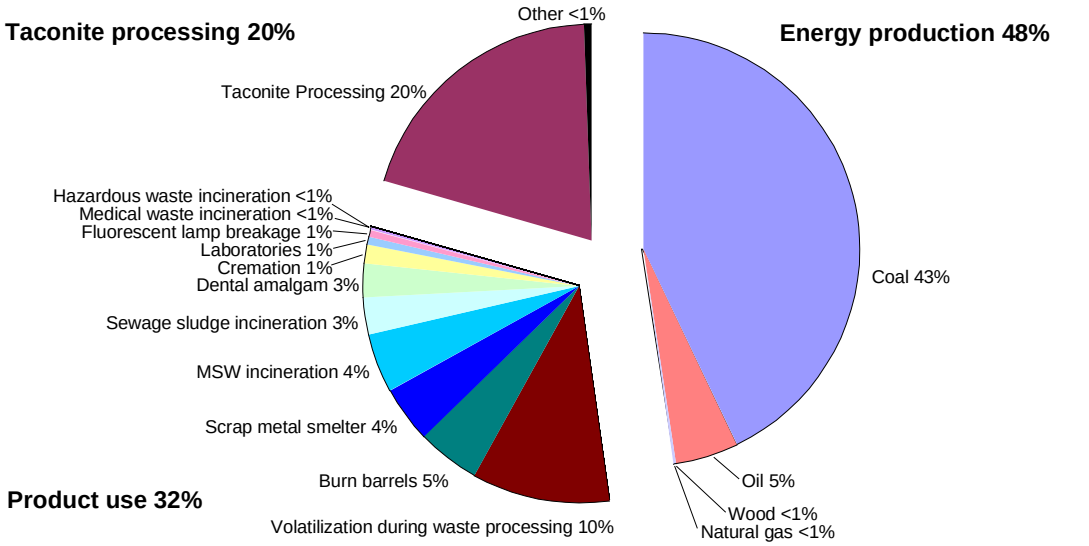


Source: MPCA, December 2001

Mercury from utilities

Fossil fuel-fired power plants currently produce 75 percent of the electricity consumed in Minnesota and are substantial contributors to mercury, lead, ozone, NOx, SOx, particulate matter and greenhouse gas pollution. Although research is underway, current technology is not available to remove the concentration of mercury found in electric utility stock gases. In 2000, Minnesota coal-fired utilities released approximately 1,600 pounds, or almost 48 percent of the total mercury emitted from primary sources. The following chart shows estimated mercury emissions from primary sources in Minnesota in 2000.

Figure 3-2. Primary sources of estimated mercury emissions in Minnesota, 2000



Source: MPCA, December 2001

Please refer to the description of P2 technologies that reduce mercury emissions due to energy production which is included in Part 5, the Greenhouse Gas and Related Toxic Chemical Pollution Prevention section of this report. This information is intentionally not duplicated here.

OEA P2 actions and opportunities regarding electric utility mercury emissions

The following activities outline OEA activities to reduce mercury emissions due to generation of electricity.

Energy conservation

Because energy conservation can reduce the amount of coal burned for electricity, the OEA will promote energy conservation as a part of its Green Building Program. The OEA will provide Internet resources to:

- promote Energy Star labeled products, which now include buildings, homes, heating and cooling equipment, high efficiency motors and air compressors, major appliances, office equipment, lighting and consumer electronics.
- promote the use of energy efficiency auditors who examine existing and recommissioned buildings to eliminate energy waste.
- promote use of energy efficiency building design assistance offered through such efforts as Xcel Energy's Energy Assets program and Energy Star Target Finder to improve architectural plans.
- promote use of the state's sales tax exemption for purchase of Energy Star lighting, photovoltaic devices, and high efficiency heat pumps, water heaters, and furnaces.
- promote use of Xcel Energy's Renewable Energy Development Fund.

The OEA's Green Building web site will also link to Minnesota Department of Commerce web site resources that promote use of energy audits for residences and the construction of super-insulated homes with air-to-air heat exchangers to assure air quality.

OEA P2 actions and opportunities regarding mercury in products

Mercury is also used in a wide range of products, including thermostats and other tilt switches, thermometers, barometers and sphygmomanometers, fluorescent and HID lamps, dental amalgam, and chemicals.

Reducing mercury in health care products

OEA will continue to work with representatives from the Minnesota health care community to promote pollution prevention within the health care sector. The Healthcare Environmental Awareness and Resource Reduction Team (HEARRT) meets quarterly. OEA and Minnesota Technical Assistance Program (MnTAP) staff, with additional help from health care professionals and Health Care Without Harm, conducted training programs in three Minnesota locations for hospital staff during June of 2001 to address the goals of the Hospitals for a Healthy Environment (H2E) project. H2E's goals include eliminating mercury in health care facilities by 2005, reducing the generation of PBTs, and reducing overall waste by 33 percent by 2005 and 50 percent by 2010. The training staff plan to reach additional hospitals and clinics throughout Minnesota during 2002 through technical assistance, training and product demonstrations.

HealthSystems Minnesota mercury reduction intern

The Minnesota Technical Assistance Program funded a summer 2000 intern project at HealthSystems Minnesota to identify all mercury-containing materials and develop a Mercury Elimination Plan. The final intern project report is an excellent model for other health care facilities and organizations.

Health Care Environmental Purchasing Tool

Under a grant awarded to the OEA by the Great Lakes Protection Fund, a "Health Care Environmental Purchasing Tool" has been developed for health care facilities. The tool, developed under a collaborative project of four Great Lakes states and the American Hospital Association, facilitates purchasing medical supplies that do not contain persistent bioaccumulative toxics, including mercury. [15]

Mercury in vehicles

OEA, MPCA and the nonprofit group INFORM partnered with the Department of Administration–Materials Management Division to include a mercury component disclosure requirement in the 2002 Vehicle Request for Bids. The state intends to require vehicles to be mercury-free in future model years and will use this year's information disclosure to develop future bid specifications.

Travel Management Division (TMD), OEA and MPCA are cooperating on a pilot project to change out mercury switches in TMD vehicles that are being withdrawn from state service. TMD intends to make this a permanent program, with switch changeout occurring when vehicles are serviced at the St. Paul TMD facility. Mercury convenience lighting switches, containing about 0.8 gram of mercury, were phased out by Ford, GM and Chrysler between the 1999 and 2002 model years. Foreign manufacturers phased out the use of mercury switches in the early 1990s. Use of mercury-containing four wheel drive ABS sensors, used only by Ford and DaimlerChrysler, will be fully discontinued for the 2003 model year.

Use of mercury-containing HID headlights, navigational displays, and entertainment units is increasing in both domestic and foreign vehicles. An estimated 150 to 200 tons of mercury remain in vehicles currently in use nationwide.

Mercury thermometer sales ban

The Office of Environmental Assistance developed a 2001 session legislative proposal to prohibit the sale of most mercury thermometers in Minnesota. Two legislators also introduced mercury thermometer sales prohibitions. The Legislature passed the most comprehensive language from these proposals. With a few narrow exemptions to cover legally required uses, products with no available alternative, and primary calibration standards, the sales prohibition became effective January 1, 2002. There are no reliable estimates of the total amount of mercury contained in thermometers sold annually in Minnesota. Fever thermometers contain slightly less than a gram of mercury; typical school laboratory thermometers contain 1 to 3 grams of mercury.

Mercury detecting dog and Mercury-free Zone

The OEA has provided a grant to the Institute for a Sustainable Future to provide project management support for this project, matching Xcel Energy's contribution. The project was kicked off statewide on October 19, 2001, with the introduction of a mercury sniffing dog at the Minnesota Science Teachers' Association Fall Conference at North St. Paul High School. The goal of the Mercury-free Zone Project is to eliminate mercury use in K-12 schools, find any remaining hidden and spilled mercury, and educate students and teachers about mercury. To date, an average of three pounds of mercury has been found and removed from each participating school.

Binational Toxics Reduction Strategy

The OEA represents Minnesota in the Binational Toxics Reduction Strategy (BNS) Mercury Workgroup, and works with the MPCA to coordinate mercury management and reduction activities with governments, businesses, institutions, nongovernmental organizations, and citizens within Minnesota and on a national basis. The OEA has been actively involved in BNS Mercury Workgroup activities and has developed and implemented programs in Minnesota addressing, for example, mercury in schools, mercury in health care, motor vehicle mercury switches (management and government procurement), and mercury thermometer education and phaseouts.

Long-term storage/retirement of surplus mercury

As demand for mercury drops and mercury recovery increases, the United States will generate a mercury surplus, which must be managed in some manner. The OEA and MPCA have been active since 1993 in the national and international discussions about how to manage surplus mercury to prevent its release to the environment. OEA led an effort to raise awareness about possible stockpile sales in 1995 to 1996 and its efforts resulted in 30 to 40 letters from governments and nongovernment organizations, and passage of an Environmental Council of States resolution opposing mercury stockpile sales. Department of Defense initiated an Environmental Impact Statement on stockpile disposition in early 1999; and OEA is monitoring that process. OEA is representing the state on the steering committee for an EPA conference on long-term management of mercury that will be held in Boston in May 2002.

Other PBTs

Other than research, the OEA currently has no P2 projects for the following PBTs.

Banned pesticides (DDT, DDD, DDE, chlordane, mirex, aldrin/dieldrin, toxaphene)

These pesticides are classified as PBTs and are banned from use in the United States, although some may still be manufactured here for sale to other countries. Although pollution prevention opportunities exist for pesticides that are approved for use, P2 opportunities for PBT pesticides consist of using alternative pesticides or banning all of these PBTs from manufacture.

Benzo(a)pyrene [B(a)P]

B(a)P is a probable human carcinogen. With long-term exposure, B(a)P may cause developmental and reproductive problems. Short-term health effects may include red blood cell damage, suppression of the immune system and anemia. B(a)P is a member of a class of compounds known as polycyclic aromatic hydrocarbons (PAHs) which generally occur as complex mixtures and not as single compounds.

PAHs are primarily by-products of incomplete combustion. These combustion sources are numerous, including fuels used in transportation, fuel production, industrial processes, food preparation, smoking tobacco, disposal activities such as open trash burning and natural sources such as wildfires. In a collaborative project with the nonprofit group INFORM and E4, the Minnesota Department of Natural Resources is piloting use of bio-based two-cycle engine oils and other lubricants in chainsaws and outboard motors as a means to reduce PAHs.

Data collected from the Great Lakes states, including Minnesota, indicate that about 90 percent of B(a)P emissions in the Great Lakes Basin come from two sources: residential wood combustion (46%) and petroleum

refining (42%). The airborne emissions of B(a)P to the Great Lakes Basin are estimated to be about 122,000 pounds annually.

Polychlorinated biphenyls (PCBs)

PCBs were originally used in insulation for electrical cables and wires, as an additive for lubricants, in epoxy, caulk, plasticizers, and in electrical condensers and transformers. PCBs have been shown to inhibit postnatal and infant mental and motor development.[16] PCBs have been banned from production and use in the United States since 1975.

In May 2001, the United States signed the international Persistent Organic Pollutants (POPs) treaty that will allow countries to work together to restrict or ban the production of PCBs.[17] This is significant because even though this material is banned for use and production in the United States, like other PBTs, it is readily transported long distances by air and water, resulting in contaminated areas throughout the globe.

Hexachlorobenzene (HCB)

HCB is a highly persistent environmental toxin that until the late 1970s was manufactured for use as a fungicide on grain seeds such as wheat. The last registered use as a pesticide was voluntarily canceled in 1984. However, HCB is currently formed as an inadvertent by-product in the production of silicone products, metal cans, pesticides, chlorine, and other chlorination processes. It is also released from water treatment plants, commercial refuse systems, and petroleum refineries. A significant source of HCB is the application of surface coatings to metal cans.

Alkyl-lead

Alkyl-lead compounds are man-made compounds in which a carbon atom of one or more organic molecules is bound to a lead atom. Tetraethyllead (TEL) and tetramethyllead (TML) compounds are the most common alkyl-lead compounds. Alkyl-lead compounds are used as a fuel additive. Although the alkyl-lead problem in the United States has largely been solved, there are still some limited uses of alkyl-lead containing fuels that can lead to direct human exposure, including piston driven aircraft gasoline, auto racing gasoline, and recreational marine gasoline.

In the human body, alkyl-lead compounds are distributed through the blood to soft tissues, particularly the liver, kidneys, muscles and brain. Alkyl-lead is a dominant type of organic lead compound, and is much more bioavailable and toxic than inorganic lead. Exposures to humans can result in lead poisoning. Lead poisoning can also result from the ingestion or inhalation of inorganic lead compounds emitted as exhaust through the combustion process as a direct result of the use of alkyl-lead in gasoline.

Octachlorostyrene

Octachlorostyrene (OCS) has never been deliberately produced as a commercial product and its release is essentially unmonitored.[18] OCS has been reported in Great Lakes fish, birds, and sediments. Potential sources of OCS are chlorinated solvent production, production of graphite electrodes, semiconductor manufacturing, production of aluminum, magnesium, and synthetic graphite. Flame retardant and waste incineration are also potential sources. Because a number of processes create OCS as a by-product, the EPA recommends that "the four-step analytic process for OCS set forth under the Binational Toxics Strategy (be used to locate the sources)...continued assessment of potential sources, consideration of reduction methods if current sources are identified, and evaluation of environmental progress."[18] OEA will continue to monitor the EPA's findings and work towards OCS reduction once sources are more clearly identified.

Other pollution prevention projects for persistent toxics

Toxics in products/listed metals

In 1991, the Minnesota Legislature passed a law (Minn. Stat. §115A.9651) requiring the reduction of four heavy metals (mercury, lead, cadmium, and hexavalent chromium) in specified products. This statute was amended several times and in 1997 became known as "Listed Metals in Specified Products." As a result of that legislation, the MPCA facilitated the Listed Metals Advisory Group which reviewed 229 products,[19] of which 22 products containing lead and hexavalent chromium are now banned from use and production in Minnesota. Activities under the program ceased in 2000. A component of this program was to have manufacturers report to the MPCA amounts of these toxic chemicals in their products. Annually 65,882 pounds of lead and 15,899 pounds of hexavalent chromium will no longer be put into the environment due to a permanent ban of these products by a State of Minnesota rule.[19]

The OEA is presently engaged in several product stewardship activities designed to collect and recycle products that are difficult to manage and/or contain hazardous and toxic components. The OEA product stewardship policy statement places a priority on reducing or eliminating the toxic and hazardous constituents of products and product components and reducing the toxicity and amount of waste that results from the manufacture, use and disposal of products. The OEA has worked for many years to prevent pollution in the manufacture of products. One successful element of P2 has been the public disclosure of chemical release and generation data submitted by manufacturers and then published in documents such as the *P2 Evaluation Report* or in an annual summary of TRI data published by the Emergency Response Commission.

Over the next two years, the OEA will consider developing incentives to encourage manufacturers to remove toxic constituents from their products in the design and redesign stages. It is much more efficient in the long term to eliminate hazardous and toxic materials before they are placed into a product rather than managing hazardous and toxic materials at end of the product's useful life.

Toxics in packaging

Since 1991, Minnesota has had statutory restrictions on the level of certain toxic metals in packaging. The Toxics in Packaging legislation (Minn. Stat. §115A.965) is based upon model legislation developed by the Coalition of Northeast Governors (CONEG) which is currently in place in 18 states. The law states that the toxic metals lead, cadmium, mercury and hexavalent chromium must not exceed 100 ppm in total by weight in packaging. Manufacturers and distributors must provide a Certificate of Compliance to the MPCA certifying that they have either met the requirements of the law or are claiming an exemption allowed in the statute.

As part of implementing this statute, Minnesota has been participating in the multi-state Toxics in Packaging clearinghouse, formerly based in CONEG and currently based in the Council of State Governments. This clearinghouse allows member states to exchange ideas on toxics in packaging issues and to coordinate laws and regulations to ensure uniformity. The clearinghouse meets a few times a year and maintains contact by monthly conference calls.

This legislation has its roots in pollution prevention: Reduce the toxic chemicals that are in a product and you reduce the environmental impacts throughout the product's life cycle. The potential exists for further pollution prevention and toxicity reduction in packaging and other nondurable products. The OEA plans to assist the MPCA in this program by participating in clearinghouse activities. The MPCA will retain its statutory authority in this area.

Over the next year, the OEA and MPCA will examine how the statute and this program could be modified to have a greater emphasis on pollution prevention and toxicity reduction. The OEA is currently highlighting PBT chemicals in its toxicity reduction activities.

[1] U.S. EPA, Strategy to Reduce Persistent, Bioaccumulative Toxics. http://epa.gov/pbt/pbtstrat.htm.

[2] EPA's dioxin source inventory estimated that more than 99% of all dioxin in the U.S. comes from industrial sources. *The Inventory of Sources of Dioxin in the United States.* U.S. EPA Office of Research and Development EPA/600/P-98-002a, 1998a. Part I and II, http://www.epa.gov/ncea/pdfs/dioxin/part1and2.htm. "Temporal Trends," Part III, http://www.epa.gov/ncea/pdfs/dioxin/dioxreass.htm. Due to federal regulation and industry efforts, known industrial sources of dioxin are down 90% from 1980 levels.

[3] *Biological Basis for Risk Assessment of Dioxins and Related Compounds.* Banbury Report 35:169-214, 1991. Dioxin levels in ancient human tissues were no more than 1 to 2% of the amount in today's humans.

[4] *Estimating Exposures to Dioxin-like Compounds, Volumes 1-3.* U.S. EPA Office of Research and Development, EPA/600/6-88-005, 1994b. The theory that much of today's body burden of dioxin could be due to natural sources has been largely discounted by the testing of ancient human tissues.

[5] In 1999, about 20% of dioxin was from burn barrels. EPA burn barrel emissions data http://www.epa.gov/ttn/catc/dir1/barlbrn1.pdf.

[6] "Burn Barrels" *New York State Solid Waste Examiner,* Spring Edition 2001. Joint U.S. EPA and NY State Dept. of Health and Environmental Conservation study reports that dioxin emissions from burning 50 to 900 pounds of household waste in burn barrels are equivalent to those from burning 400,000 pounds in a modern incinerator.

[7] "Pesticides and You," Vol. 6, No. 4, October 1986. *ChemicalWATCH Factsheet: 2,4-D*. National Coalition Against Misuse of Pesticides, Washington, DC.

"2,4-D: Toxicology, Part 2." *Journal of Pesticide Reform,* V. 19, No. 2, Summer 1999. pp 17-18. Northwest Coalition for Alternatives to Pesticides, Eugene, Oregon.

[9] Leder A., E. Linak, R. Holmes, and T. Sasano. *CEH Marketing Research Report: Chlorine/Sodium Hydroxide*, Palo Alto: SRI International, 1994.

[10] Toloken, Steve. "Baxter Advances Toward PVC-free Bags," *Plastic News,* December 2001.

[11] Hickling Corporation. "Economic Instruments for the Virtual Elimination of Persistent Toxic Substance in the Great Lakes Basin." Windsor, Ontario: International Joint Commission, 1993, presentation text. 82nd Annual Meeting of the Air and Waste Management Association, Anaheim, California, June 1989. Cost-effective substitutes are available for 26% of PVC products, based on current market price for alternatives and does not include installation costs, capital costs to produce larger quantities of the alternatives, or cost reduction of alternatives due to economy of scale.

[12] CHEMinfo Services for Environment Canada. *A Technical and Socio-economic Comparison of Options to Products derived from the Chlor-alkali Industry.* November 1997. The article notes that 65% of the alternatives are slightly or moderately more expensive, 9% of current PVC products are quite expensive to phase out, 89% of PVC could be replaced for a total of $13 million at a net savings of 2 cents per kilogram. Current cost increase is 0.04% for a non-PVC home. Environment Canada estimates that phase out of PVC would create 87% more jobs per dollar per sales than does PVC and would create over 200,000 new jobs. http://www.on.ec.gc.ca/glimr/data/chlor-alkali/.

[13] EPA's PBT Initiative: Strategy and Action Plans–Mercury. www.epa.gov/pbt/hgaction.htm.

[14] Minnesota Pollution Control Agency, *2001 Air Quality Report,* Appendix G; Reported 1999 mercury emissions from non-exempt electrical production facilities in Minnesota. Updated with 2000 data. December 2001. http://www.pca.state.mn.us/hot/legislature/reports/2001/airquality.html.

[15] *The "Health Care Environmental Purchasing" tool is located on the American Hospital web page at http://www.ahrmm.org/HCEPT/index.html.*

[16] Walkowiak, J., J. Wiener, A. Fastabend, B. Heinzow, U. Krämer, E. Schmidt, H. Steingrüber, S. Wundram, and G. Winneke. "Environmental exposure to polychlorinated biphenyls and quality of the home environment: effects on psychodevelopment in early childhood." *Lancet* 358: 1602–07. 2001.

[17] U.S. signs POPs Treaty, http://www.state.gov/g/oes/env/rls/index.cfm?docid=3015.

[18] U.S. EPA information on Octachlorostyrene, http://www.epa.gov/glnpo/bnsdocs/98summ/ocsresp.html.

[19] MPCA's Listed Metals web site, http://www.pca.state.mn.us/waste/listedmetals.html.

Part 4

Pesticides Pollution Prevention

Pesticides are agents used to control unwanted insects, plants, rodents, fungi or bacteria. The focus of pollution prevention (P2) in regard to pesticides involves practices that eliminate, or where this is not feasible, use the least amount and the least toxic alternatives possible, to accomplish the needed control. Although progress has been made, research shows that many opportunities remain for pesticide pollution prevention.

The Office of Environmental Assistance (OEA) is responsible for pollution prevention (P2) technical, financial and educational assistance and for evaluating state progress in P2. *Pollution Prevention Evaluation Report* evaluates progress and opportunities to reduce pesticides through using P2.

Environmental monitoring data

Due to the risk pesticides present to public health, a number of government agencies monitor environmental concentrations of commonly used herbicides and insecticides. Although pesticides have been detected in the state's rain, surface and ground water, their concentrations are, for the most part, within the Minnesota Health Risk Limits (HRL) and federal drinking water Health Advisories standards.

A 1995-98 United States Geological Survey (USGS) study of commonly detected pesticides in streams and shallow ground water showed that most concentrations were within drinking water standards and aquatic life guidelines. However, not all of the pesticides detected currently have standards and guidelines.[1] One part of the study showed the Little Cobb River, an agricultural stream near Beauford, Minnesota, contained degradation products of four commonly used herbicides (acetochlor, alachlor, atrazine and metolachlor). The study concluded that total concentrations of the pesticides' degradation products were always greater than the summed parent compound concentrations. The effects of these degradation products on aquatic and human health are not known, but their persistence and relatively high concentrations are cause for concern.[1] Recent research by the University of California documented disruptions in the sexual development of frogs at concentrations of atrazine frequently found in the environment.[2] In contrast, earlier research indicated that the herbicide does not pose a risk to the aquatic environment.[3]

The Minnesota Department of Agriculture (MDA) is performing ground water testing in the sand plains of central Minnesota, and in the exposed limestone (karst) areas of southeastern Minnesota.[4] Monitoring results for the year 2000 show that atrazine, a corn herbicide, and its degradation products were most frequently detected, being found in 76 percent of the wells and 68 percent of the samples collected. Metolachlor and metribuzin and their degradation products have also been detected multiple times in multiple wells. The MDA *2001 Common Detection Report*, which provides information to the public on environmental concentrations of pesticides, states that a recommendation should be made regarding these pesticides (atrazine, metolachlor and metibuzin) and their possible candidacy for placement in "Common Detection Status," a designation for pesticides frequently found in the environment. The levels of atrazine, metolachlor, and metribuzin detected are within the current state HRL levels established by the Minnesota Department of Health (MDH), although atrazine has been frequently placed in Common Detection Status.[5]

A 1998 joint investigation by MDA, U.S. Geological Survey, University of Minnesota, and Minneapolis Park and Recreation Board found pesticides (alachlor, atrazine, cyanazine and metolaclor) in rainwater falling in the Lake Harriet watershed of Minneapolis.[8] Since these pesticides are commonly used in agriculture and are *not* approved for urban use in Minnesota, the report concludes that the chemicals were volatilized after application on crop land, transported through the atmosphere and subsequently deposited by rain.[6, 7] Because these same pesticides were detected in much lower concentrations in storm water runoff, the indication is that they tend to accumulate in the urban watershed. Concentrations of pesticides in storm water routinely exceed Minnesota Department of Health HRLs.[7, 8] In Europe, over 80 pesticides in current use have been detected in rainwater. The most commonly detected are the organochlorine insecticide lindane and triazine herbicides.[9]

The Minnesota Department of Health conducted a pilot study in 1997 to test methods of measuring children's exposure to pesticides. Researchers collected tap water, food, beverage, soil, dust, blood, urine and hair samples from 102 homes in urban and rural Minnesota that reported past use of pesticides. The most common pesticide found was chlorpyrifos, which was found in 95 percent of personal air samples, 67 percent of food samples and 62 percent of dust samples. The chlordanes, dieldrin, DDD, DDE and DDT were fairly common in both air and food. Two-thirds of the homes had measurable concentrations of the herbicides 2,4 D, MCPA and/or MCPP. Over 90 percent of the children in the study had measurable levels of TCPY, a metabolite of chlorpyrifos, in their urine. The MDH study concluded that, "Among the sampled households, no child's exposure reached a level of concern."[10] In June 2000, EPA announced an agreement with registrants to phase out nearly all household uses and most food uses of chlorpyrifos, also known by the trade names Dursban and Lorsban. This action was taken primarily for the purpose of protecting children's health.[11]

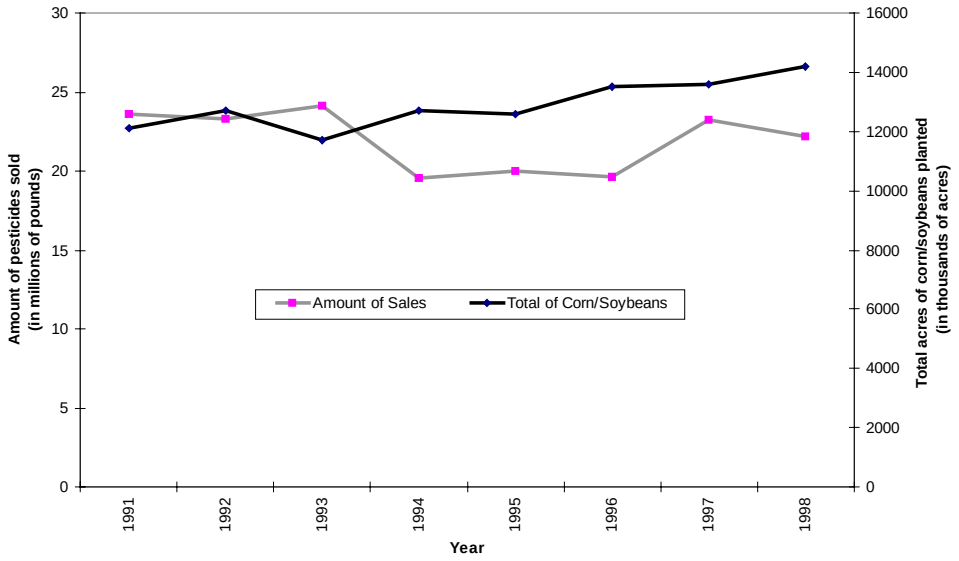
Progress in pesticide pollution prevention

Pollution prevention reduces the toxicity or the amount of a substance used to accomplish a task. The fact that pesticides move in measurable amounts from points of application means there are opportunities to reduce waste through pollution prevention. Recognizing this opportunity, a number of successful pollution prevention activities have occurred.

Agriculture

EPA estimates that about three-fourths of all conventional pesticide use in the United States is for agriculture.[12] Pollution prevention is most accurately determined by documenting the change in the amount of chemicals used to produce a product over time. Little data is available to make this determination in regard to pesticides. The following graph uses available data on the amounts of pesticides most commonly sold for use on soybeans and corn (Minnesota's largest crops) and the numbers of acres planted with them, so as to provide a general indication of progress in pollution prevention.[13, 14] The amounts of crop-specific pesticides sold, contrasted with the change in the number of acres planted in corn and soybeans over time shows that less pesticide is purchased per planted acre today than prior to 1994. This may indicate that pollution prevention has occurred.

Figure 4-1. Amounts of crop-specific pesticides sold compared to acres of corn and soybeans planted in Minnesota



Additional data are needed before a more statistically valid conclusion regarding progress in P2 can be made. Sales data does not mean the chemicals were actually used when purchased, or in fact, used in Minnesota. In addition, pesticides may have been purchased in adjacent states but used in Minnesota. Relative persistence, bioaccumulation and toxicity data are also not available. If more pounds of a less persistent, bioaccumulative and toxic pesticide are used versus fewer pounds of a more hazardous one, pollution prevention may have in fact occurred although more pounds of the less hazardous pesticide may have been sold.

P2 options to reduce pesticides

P2 options include practices that eliminate, or where this is not feasible, use the least amount and the least toxic alternatives possible, to accomplish the needed control.

Integrated pest management

One of the most inclusive methods of decreasing pesticide pollution is Integrated Pest Management (IPM). As defined in state statute (Chapter 17.114 Sustainable Agriculture Subd. 4), "Integrated Pest Management means use of a combination of approaches, incorporating the judicious application of ecological principles, management techniques, cultural and biological controls, and chemical methods, to keep pests below levels where they do economic damage."[15] IPM includes planning and setting action thresholds, monitoring sites for early detection and accurate assessment of pests, proper identification of pests, then deciding what actions to take after considering all the information.[15] Essays about a number of sustainable agriculture practices can be found in the *Greenbook*, published by the MDA.[16]

At five apple orchards in various locations throughout the state, IPM was implemented by using an insect pheromone or mating scent to attract male spotted tentiform leafminer insects to traps. This three-year MDA project showed that use of traps is a viable alternative in terms of effectiveness and economics to the application of insecticides.[17] In a University of Minnesota research project, scientists plan to release a parasitoid of the alfalfa blotch leafminer into alfalfa fields as a natural control for these insects.[18] The goal of this project is to alleviate the need for growers to apply pesticides to alfalfa fields. Many other promising IPM research projects such as timing cultivation to reduce herbicide use in ridge-till soybeans and experimenting with bio-based weed control using materials such as sheep wool or canola mulch to control weeds in strawberry beds are being conducted.

Organic farming

One method of decreasing pesticide use is to farm organically. In 1997 Minnesota ranked seventh overall in certified organic acreage in the United States, with 64,000 acres in production. Organic food is the fastest growing segment in the U.S. food industry, with sales in 2001 expected to reach $9.5 billion and a continuing overall annual growth of 20 percent.[19]

Crop rotation

Seasonal rotation of two or more crops on the same farmland can reduce pesticide use. Since pests are commonly crop specific, crop rotation serves to decrease breeding and break the multi-year cycle of plant disease, weeds and insect pests. Use of cover crops, perennial crops and weed competitive crops will help diversify crop rotations and minimize weed control problems.

Multi- versus mono-crop planting

Large tracts of the same crop are more susceptible to disease than those interspersed with different crops. Using multi- versus mono-crop planting can decrease the need for pesticide. Strip cropping can be used on an annual or rotational basis to reduce weed and insect pest problems.

Diversified varieties

Approximately 10 percent of common crop varieties remain as compared to the number of varieties available in 1700. The fewer varieties, the less genetic diversity available to resist changes in climate, insects and disease. Planting different varieties of the same crop can reduce the need for pesticides.

Precision farming techniques

Precision farming techniques, using computers to adjust the inputs of fertilizer and pesticides within a field, is being tested on a pilot farm by the MDA.[20] Precision farming uses satellite information through a global information system, which allows farmers to apply fertilizer and pesticides only in the areas where they are needed.

Use of less persistent, bioaccumulative and toxic pesticides

There is also progress with the types of pesticides being used. Due to their persistent, bioaccumulative and toxic nature, the insecticides aldrin, chlordane, DDT, dieldrin, mirex and toxaphene have been banned or voluntarily withdrawn from use in the United States. Efforts have been made to replace them with less persistent and less bioaccumulative insecticides. For the past several years, the U.S. EPA has been in the process of phasing out most registered uses of organophospate pesticides (such as chlorpyrifos, mentioned above), which substituted for the organochlorine pesticides mentioned here.

Due to the complexity of pesticides, it may take time to recognize unintended effects. The pesticide clopyralid has been detected in compost made from grass clippings and livestock bedding.[21] A recent study indicates that when two agricultural fungicides, paraquat and maneb, are used together they could have a synergistic effect triggering Parkinson's disease.[22, 23] Constant research takes place to develop less hazardous, newer generations of insecticides. Recent entries to the market are the pyrethroids (deltamethrin, permithrin).

Genetically modified crops

Research is taking place to increase use of food and fiber crops of genetically modified organisms (GMO) that are engineered, in part, to decrease the need for pesticides. The use of GMO soybeans in the United States increased to 68 percent in 2001. One quarter of the country's corn crop is genetically modified. Although use of pesticides with GMO crops was projected to decrease 30 percent, a recent study calculates that actual reductions may only be 0 to 10 percent.[24] A second study by Cornell and Iowa State University found that use of GMO corn is not being used as a replacement for insecticides but in addition to them.[25] Since the modified genetics have not occurred previously in nature, there is concern that introducing them into the environment could result in unforeseen consequences. Since monitored pesticide levels are commonly below human health risk standards, the relative risk between the technologies is a factor.

Residential, public and commercial sectors

There are programmatic examples of pollution prevention in these sectors, which indicates that progress in P2 is occurring, but a more quantified evaluation is not possible. A quantified evaluation would require data such as the number of acres of turf grass cultivated with the number of pounds of turf grass pesticides used, or the quantity of pesticide used in the same schools over time, or the changes in the quantity of pesticides used in the same homes over time. Programmatic examples of P2 follow.

Residential

During the best management practices study for the Lake Harriet and Lake Alimagnet watershed of South Minneapolis, a water-monitoring site was established at the point where storm water runs off from 700 households into the lake. Extensive education campaigns were conducted throughout the watershed. Master Gardener volunteers surveyed homeowners on a periodic basis, and the storm water was monitored to learn the effectiveness of the campaigns. As a result of the P2 education efforts, runoff from the Lake Harriet watershed showed decreases of 56 to 86 percent in the amounts of four commonly used lawn herbicides.[26] The educational materials developed in this project sponsored by the MDA and the Minneapolis Park Board have been used in other watersheds.

Public schools

The Parents' Right to Know Act of 2000 (Minn. Stat. §123B.575) requires all K-12 schools to issue notices to parents and school employees if the school plans to apply the pesticides specified in the law to prevent pest problems. The notice must provide that an application schedule is available at the school and offer that the parent may request to be notified by the school before application. It further must state that health effects on children from the application of such pesticides may not be fully understood. Although schools are not required to adopt Integrated Pest Management (IPM) plans, the MDH encourages schools to use IPM plans, which will reduce pesticide use.[27] Training of school personnel on IPM will be conducted by the Minnesota Department of Agriculture throughout Minnesota beginning in the spring of 2002.

A multi-agency work group coordinated by the Department of Agriculture has been formed to exchange information and plan and develop curriculum for the IPM in the Schools training. The group includes representatives from MDA, MDH, the Department of Children, Families, and Learning, the University Extension, school districts, the OEA, the St. Paul Neighborhood Energy Consortium, and pesticide service companies.

The St. Paul Neighborhood Energy Consortium in partnership with Advocates for Better Health and Environment received a grant from the OEA to conduct a pilot study for Integrated Pest Management in four Minnesota schools. The purpose of this project was to determine whether an effective IPM program is feasible in Minnesota schools. Project staff surveyed pesticide use and practices in four Minnesota schools, both before (baseline) and after (study year) IPM implementation. An IPM work team at each school identified and implemented the least toxic methods to manage pests in school buildings and on school grounds. The IPM teams received IPM training from national experts. Each school developed an IPM plan, which included both building practices and a guide for turf maintenance. In the second year, each school implemented its plan, beginning with an inspection of the building and grounds to identify issues that needed to be worked on.

After IPM implementation, the study schools appeared to be more conscious of sanitation, preventive maintenance practices and preventive food policies. The follow-up survey showed that team members were much more knowledgeable about IPM than they were at baseline. The project clearly succeeded in heightening awareness and concern about pesticide use and the importance of IPM in these schools. Furthermore, these schools showed that it was feasible to implement IPM without incurring additional costs. This project proved that any school could have a successful IPM program, with a little bit of technical assistance and the commitment to make changes.

Commercial

A number of Minnesota businesses are incorporating native landscaping at their facilities. Established native systems do not need the fertilizers, pesticides, and watering required to maintain imported species. Damon Farber, a Twin Cities commercial landscaping firm, estimates that of the 80 landscaping projects they do each year, 25 percent incorporates native plantings. Examples of facilities in the state that use native landscaping include State Farm Insurance regional facility building in Woodbury and the ADC Telecommunications manufacturing building in Shakopee. In addition to the complete elimination of pesticide use, there are also significant cost savings; 70 percent less installation costs and 80 percent less maintenance costs per acre are reported when natural landscaping is used.[28] Because native landscaping can take up to three years to establish, both employees and clients must be educated in process of native landscaping as it develops. Some companies have removed native landscaping due to this delay.

OEA P2 actions and opportunities to reduce pesticides

Consultants

Crop consultants have become key advisors to farmers in the area of crop management. An important aspect of P2 with regards to pesticides is to continually supply consultants with information regarding the most recent advances in alternatives to chemical pesticides for agriculture. The OEA will determine if a grant to develop educational resources is warranted.

Native landscaping

Residents, businesses, builders and architects need to be educated on the natural beauty and benefits of using native landscaping. The OEA will provide educational resource links to native landscaping web sites through the Green Building portion of its Internet site.

Integrated Pest Management (IPM)

Continued research and education in the area of Integrated Pest Management should be supported. The wide array of IPM projects currently being implemented by the Minnesota Department of Agriculture demonstrates successful use of IPM on a number of types of crops. The OEA will continue to be involved in the multi-agency work group on IPM in the Schools, which is coordinated by the Department of Agriculture. The OEA will put the results of the IPM in the Schools pilot study on its web site and look for ways to use the materials throughout Minnesota.

Interagency cooperation

As the relationships between the health of the environment and the health of the public continue to be explored, new studies with regard to human pesticide exposure are yielding new findings. The OEA will participate with efforts to improve communication between OEA, MDH, MDA and County Extension to increase distribution of information relating to pesticide use.

Dissemination and availability of public information on pesticides

The OEA participates in the Minnesota Pesticide Resource Center board and has provided grant support to develop a web site for MPRC. This web site, hosted by the Institute for Agriculture and Trade Policy, will serve as a central access point, with links, for example, to state and federal agency web sites on pesticide use, environmental monitoring data, and information on health effects.

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Part 5

Greenhouse Gas and Related Toxic Chemical Pollution Prevention

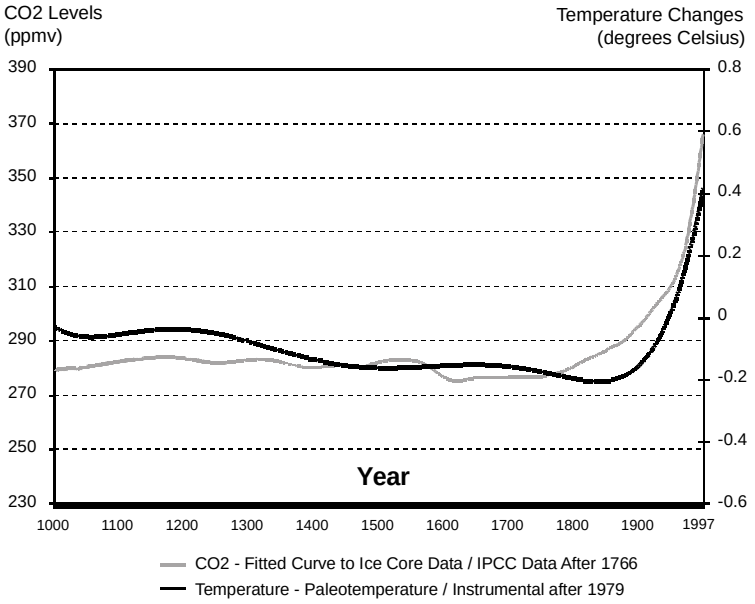
The Office of Environmental Assistance (OEA) is responsible for pollution prevention (P2) technical, financial and educational assistance and for evaluating state progress in P2. As data allow, this chapter of the *2002 Pollution Prevention Evaluation Report* evaluates progress and opportunities to reduce greenhouse gas and related toxic chemical emissions from Minnesota's largest sources through using P2. The Minnesota Department of Commerce (MDC) is responsible for state energy planning and policy. The information presented here is supportive of the MDC State Energy Planning Report.[1]

There is significant concern that human activities that produce greenhouse gases (GHG) are affecting climate. The surface temperature of the earth is rapidly rising. Documented changes, such as the Arctic icepack losing 40 percent of its thickness in the last forty years, have occurred.[9] As sea temperatures and human-related activities have increased, more coral reefs have died in the past 20 years than in the previous 5,000.[2] The National Climatic Data Center reports that the eight hottest years on record have occurred since 1990.[3]

Most scientists working to understand this temperature change have concluded that it is being caused in part or largely by the human production of greenhouse gases. A two-mile-deep ice core in East Antarctica has revealed that there are now more greenhouse gases in Earth's atmosphere than at any time in the past 420,000 years.[4] Based on continuation of current trends in emissions, the amount of warming forecast for the next century will be larger than anything found in the paleotemperature record (see figure) for an equivalent period of time. This warming will cause large geographical shifts of current climates, as well as changes in associated vegetation and sea level.

Figure 5-1 shows the observed changes in temperature and global atmospheric carbon dioxide (CO_2) levels over time.

Figure 5-1. Global CO_2 and mean temperature changes[5]



Global climate change initiatives

As a result of concern about the impact of GHG, the United Nations Framework Convention on Climate Change (UNFCCC) was developed in the early 1990s. The stated goal of the convention is to avoid dangerous interference in the world's climate. As a party to the convention, the United States and 186 other nations pledged to implement policies to return their GHG emissions to 1990 levels by 2000. As of 2000, U.S. emissions exceeded their 1990s levels by 14 percent.[9]

In 1997, the Kyoto Protocol to the UNFCC was developed. If ratified, it would require developed countries to reduce their greenhouse gas emissions by an aggregate of 5 percent from 1990 levels by 2010. President Clinton signed the agreement in 1999. In 2001 in Germany, the European Union, Japan, Russia and other developed nations signaled their intent to adhere to this Protocol. If they carry through on their commitments, this will be sufficient to bring the Protocol into effect. The current U.S. Administration has announced its intention not to participate further in the development of the Protocol, will not submit it to the Senate for ratification, and will not support U.S. participation in the Protocol. Costs are cited as one reason not to participate. According to the U.S. Department of Energy's Energy Information Agency, with business as usual conditions, the United States will increase GHG emissions by an additional 30 percent by 2020 from 2000 levels.[6] Recently, concern has been expressed that U.S. non-participation might subject U.S. business to discriminatory trade practices and technological disadvantages.[7]

Many individual companies have voluntarily adopted their own GHG reduction targets for a variety of reasons, although common ones cited include the need for long-range investment strategies, economic competitiveness and integration of environmental concerns into corporate operations.[8] The chart below lists of some of those companies and their GHG reduction targets.

Figure 5-2. Voluntary GHG reduction targets as identified by company

Company	Reduction target
ABB	Reduce GHG emissions by 1% each year from 1998 through 2005.
Alcoa	Reduce GHG emissions by 25% from 1990 levels by 2001.
Baxter International	Reduce energy use and associated GHG emissions by 30% per unit of product value from 1996 by 2005.
BP	Reduce GHG emissions by 10% from 1990 levels by 2010.
Dupont	Reduce GHG emissions by 65% from 1990 levels by 2010.
Entergy	Stabilize CO_2 emissions from U.S. power generating facilities at 2000 levels by 2005.
IBM	Reduce CO_2 emissions due to fuel and electricity use by an average of 4% from 1998 levels by 2004.
Intel	Reduce perfluorcarbon emissions by 10% from 1995 levels by 2010.
Ontario Power Generation	Stabilize CO_2 emissions at 1990 levels by 2000.
Rohm and Hass	Reduce energy consumption by 5% per pound of production from mid-1999 levels by year-end 2000.
Shell	Reduce GHG emissions by 10% from 1990 levels by 2002.
Toyota	Reduce energy consumption per unit of production by 15% from 2000 levels by 2005.

Largest sources of Minnesota GHG emissions

Energy production from fossil fuels for electricity and transportation are by far the largest sources of greenhouse gas emissions today. Eighty percent of Minnesota's GHG emissions come from fossil fuel combustion in electric utilities (37 million tons/yr.CO_2 equivalent) and in transportation (45 million tons/yr. CO_2 equivalent).[9] CO_2 emissions from Minnesota electric utilities are more than 4 times, and CO_2 emissions from transportation are more than 2.5 times, what they were 40 years ago. Total Minnesota GHG emissions are increasing at a rate of approximately 1.8 percent a year.[9]

Utilities

Opportunities for pollution prevention are available for current generation and new generation capacity.

Current generation

Approximately 95 percent of the electricity consumed in Minnesota is generated from coal and nuclear fuel.

Coal

Power plants utilizing coal as fuel currently produce 75 percent of the electricity consumed in Minnesota and are substantial contributors to ozone, nitrogen oxides (NOx), sulfur dioxide (SO_2), particulate matter and GHG pollution. 2000 Toxic Release Inventory (TRI) data show that among reporting manufacturers, (excluding the Gopher Resources Corporation's battery recycling facility) electric utilities are responsible for the following total reported TRI air emissions.

Figure 5-3. Total TRI releases to air

Chemical	Pounds	Percent
Vanadium	8,871	100%
Hydrogen fluoride	226,035	98%
Molybdenum trioxide	300	95%
Mercury	1,484	85%
Nickel	12,628	79%
Barium	62,061	76%
Antimony	90	74%
Chromium	1,885	74%
Hydrochloric acid (aerosols only)	462,035	71%
Manganese	8,670	56%
Lead	1,110	37%
Ammonia	116,533	10%
Sulfuric acid (aerosols only)	183,975	10%
Zinc	6,461	10%
Dioxin	0.0065	0.5%

A common pulverized coal plant (with a 500 MW base load) generates 16,204 tons of SO_2, 12,150 tons of NOx and 3.4 million tons of CO_2 per year.[12] Costs to supply electricity from Minnesota's current pulverized coal-fired plants will increase with plant retrofits or new construction. The table below compares the relative costs and reduction in emissions from primary pollution prevention alternatives.[12]

Figure 5-4. Comparison of P2 alternatives for a pulverized coal plant generating a 500 MW base load[(b)]

Pollution prevention option	Capital cost per KW	Percent reduction SO_2	NOx	CO_2
Improve existing plant efficiency	low or no cost	5%	5%	5%
Convert to natural gas	$400-600	99%	99%	70%
Convert to 90% coal/10% natural gas co-firing	small[(a)]	10%	small	5%
Convert to 80% coal/20% wood/bio co-firing	$100-700	10%	small	20%
Convert to circulating fluidized coal bed	$900-1,300	88%	93%	29%

[(a)] At 90% coal/10% n-gas, operating costs will increase 15% due to higher cost of natural gas.

[(b)] At 65% capacity factor, 30% thermal efficiency.

P2 options to reduce GHG and related toxic emissions due to energy generation

Improve existing plant efficiency

Based on experience at U.S. electric utilities, it appears possible to increase the efficiency of existing plants about 5 percent at low or no cost. If realized, a 5 percent improvement in plant efficiency would, at current rate of generation, result in a 5 percent reduction in CO_2 and other emissions.[54] Coal power plants operate under the air quality standards that were in place at the time of their construction. If gains in efficiency are obtained through improvements rather than repairs, the facility may be subject to the same air emission standards as a new facility. Meeting these standards may not be cost effective for the facility.

Natural gas

Today's natural gas turbines are about 55 percent efficient[10] as compared to about 32 percent for pulverized coal facilities. When compared to coal, natural gas has very little mercury or sulfur and emits 30 times less SO_2, 15 times less NOx and 3 times less CO_2 for the same amount of electricity generated. Price and supply are limiting factors for the use of natural gas.

Natural gas is an attractive fuel for power generation, and currently provides 1 percent of Minnesota's electrical generation capacity. The natural gas used in Minnesota is piped in from gas fields in the southern United States or in Ontario. Supply is dependent upon demand all along the pipelines and is limited in winter months. The cost of any needed increased security for gas pipelines is unknown at this time.[11]

Coal/natural gas co-firing

Since natural gas contains only trace amounts of mercury and SO_2, co-firing coal with 20 percent natural gas can reduce mercury and SO_2 emissions by up to 20 percent. Due to improved combustion efficiencies, CO_2 emissions are reduced by approximately 10 percent. Since natural gas historically costs more than twice the amount of coal, on a per million Btu basis, co-firing at a ratio of 80 percent coal and 20 percent natural gas would increase operating costs by approximately 20 percent.

Coal/wood/fiber co-firing

Co-firing coal with up to 20 percent wood can reduce CO_2 emissions by 15 to 20 percent. If specifically grown wood or fiber rather than waste matter is used, care must be taken to assure that the net CO_2 produced through its production process is less than if pure coal were used.

Refuse-derived fuel (RDF) may also be burned with coal. Due to the amount of mercury contained in disposed products, incinerators which burn 100 percent RDF release two times more mercury per kilowatt hour than coal.[12] Reusing or recycling material is environmentally more beneficial than burning it as fuel. For example, twice the amount of CO_2 emissions is released producing virgin newspaper as compared to producing recycled newspaper.[13] Paper's use as a fuel, rather than to replace production of virgin paper, causes a significant net gain in greenhouse gases. Retrofitting existing coal-fired facilities to utilize biomass is expected to cost $100 to $700 per KW of biomass capacity.[54]

Fluidized coal bed

There is no commercial experience with retrofitting pulverized coal to circulating fluidized bed. All retrofits thus far have been pilot-scale retrofits done under the DOE Clean Coal Technology Program with substantial federal subsidies. Initial evidence suggests that retrofit costs could be on the order of $400 to $500 per KW.

If commercialized costs are in this range, Minnesota's coal power plants could be converted from existing pulverized coal to circulating fluidized bed technology for approximately $2 billion, twice that amount to convert to gasification technology.[14] Given that today's fluidized bed units are approximately 38 to 40 percent efficient as compared to 32 percent for pulverized coal, if conversion of all plants occurs, CO_2 emissions would decrease from approximately 37 million to 29 million tons a year, provided the quantity of coal burned remained constant.[9] Emissions of toxic metals such as mercury, barium, lead and chromium contained in coal are also an issue that must be considered. Electric utilities that exclusively burn coal as fuel are the largest source of mercury emissions in Minnesota, releasing approximately 1,500 pounds into the air in 2000.[15] National releases of mercury from all

coal-fired power plants are more than 40 tons per year.[16] Although research is underway, current technology is not available to remove the concentration of mercury found in electric utility stock gases.

Nuclear

Nuclear fuel is currently Minnesota's second largest source of energy and provides approximately 20 percent of the electricity consumed in the state.[12] Minnesota's three nuclear power reactors (one in the city of Monticello and the other two on Prairie Island near Red Wing, Minnesota) have a total generation capacity of 1582 MW.[17] Although the facilities do not produce greenhouse gases, they do produce high and low-level nuclear waste. High-level nuclear waste must be safeguarded for 250,000 years. [18]

The wisdom of increasing the amount of nuclear waste in order to decrease greenhouse gases is controversial. Due to issues regarding security of nuclear reactors and their waste, public safety is of heightened concern.[19] The costs of increased safeguards, or how they will be paid for, have not yet been determined.[20] Due to a lack of a permanent storage facility for nuclear waste, the approximate $2,200 per kilowatt cost for a new nuclear plant and the difficulty of siting new facilities, it is unlikely dependence upon nuclear power will increase in the foreseeable future.[12]

Opportunities for other fuels and new generation

The remaining 5 percent of electricity consumed in Minnesota comes from hydro, wind, bioenergy and solar. Increase in their use represents the greatest pollution prevention potential to decrease greenhouse gases due to power generation. The 2001 Minnesota Energy Security and Reliability Act states that 10 percent of electricity generated in the state should be derived from renewable sources by 2015.

Hydro

Hydro energy currently produces about 2.5 percent of the electricity consumed in Minnesota.[21] Xcel Energy annually imports about 5 million MWh of electricity from Manitoba Hydro. Manitoba Hydro has plans to build several more large hydroelectric facilities in Canada to serve Minnesota and other customers. The dams used to create the depth of water needed to drive high capacity water turbines result in flooding of adjacent land, produce a small amount of methane, disrupt aquatic environments, and decrease water quality.

Other than plans by Crown Hydro to build a 3.2 MW plant at St. Anthony Falls in Minneapolis,[22] no hydro projects are under permit review in Minnesota at this time. There are opportunities to install more efficient turbines in at least two existing hydro facilities in the state. Improvements have also been made to the design of mini-turbines for use in small, rapidly flowing, natural currents for site-specific generation.[23] New, low-flow turbines are also in development for commercial use. The Massachusetts Department of Environmental Protection successfully piloted the use of a Gorlov Helical turbine, which generates electricity from dam-free rivers and streams.[24]

Wind

Wind turbines are used singularly or at large-scale wind-farms where wind energy is available. In Minnesota, wind power capacity has increased more than 200 percent since 1997[25] to 380 MW and provides for 1 percent of total electric use.[12] Wind power creates no GHG or toxic chemicals, does not deplete natural resources, and does not require mining. Hence, it is a preferred option for pollution prevention. Modern wind turbines can produce electricity for 4 to 6 cents a KWh, a cost comparable to new, modern coal-fired plants.[26, 27] Although wind alone cannot fill the need for all electricity consumed in the state, cost-effective opportunities currently exist to increase its contribution from the 1 percent presently in use to 10 percent.[12, 28]

Bioenergy: biogas, biomass and biodiesel

Bioenergy produces electricity from the decomposition or combustion of organic material.

Biogas, or methane, is produced from the decomposition of most organic materials. Methane is a greenhouse gas; however, when burned as a fuel to create electricity, it causes no net gain in greenhouse gas emissions.

Haubenschild Farms in Princeton, Minnesota uses an anaerobic digester to turn dairy farm manure waste into methane fuel to generate electricity to power the farm and 78 local homes.[29] Organic material such as manure is an ideal fuel source for anaerobic digesters due to its capacity to produce methane and low-odor, quality compost. It appears possible that Minnesota could create as much as 10 MW of power generating capacity by using farm-based anaerobic digestion.[30] Opportunities exist to increase the use of methane from animal waste and food waste as a means to generate electricity.[22] If specifically grown organic material rather than waste is used to create methane, care must be taken to assure that the net CO_2 produced through its production is less than if pure coal was used for fuel.

Cost-effective landfill sites in Minnesota have been developed to use methane to produce electricity. The Burnsville landfill uses internal combustion engine generators to produce about 25,000 MWh per year. The Pine Bend landfill in Inver Grove Heights uses gas turbines to generate 70,000 MWh per year.[31] Due to the corrosive properties of landfill gas, turbines may be more expensive to maintain than engines. The opportunities to increase generation from landfills are limited by their capacity to produce methane. Methane comprises approximately 50 percent of landfill gas.[32] Landfills are not nearly as efficient as anaerobic digesters when converting organic material to captured methane. Given this difference in efficiency, and due to the fact that landfill methane also includes impurities such as VOCs and, potentially, dimethyl mercury, organic material should not be intentionally landfilled for the primary purpose of producing methane. However, landfill gas should be recovered for energy where it already exists.

Biomass is wood, plants, or the organic component of municipal or industrial solid waste that is burned to produce energy. It may be co-fired with natural gas, oil or coal to generate electricity. Because it is made from vegetation, rather than a mined source of hydrocarbon, it is possible for biomass to cause no net increase in GHG. If specifically grown organic material rather than waste is used as fuel, care must be taken to assure that the net CO_2 produced through its use does not exceed emissions associated with the production and combustion of an energy equivalent amount of coal. This can be a problem if significant amounts of fuel are used in production and transport.

Minnesota currently burns about one-quarter of its municipal solid waste in high temperature combustors. There is about 128 MW of capacity in place. Due to the amount of mercury contained in products which wind up in the waste stream, incinerators which burn 100 percent refuse-derived fuel (RDF) or unprocessed MSW release two times more mercury than coal per kilowatt hour.[12] Due to the current economics of the solid waste industry, increased incineration of solid waste is not anticipated.

Wood and plant waste is currently co-fired with coal, natural gas and waste oil in some Minnesota industrial boilers, in the Hibbard facility in Duluth and in the Xcel Energy Allen King coal plant. Xcel Energy will contract for electricity from three biomass facilities (burning turkey litter waste, wood waste and whole trees) as a means to fulfill part of Prairie Island nuclear storage legislation.

Biodiesel is a renewable fuel produced from agricultural oil seed crops or made from waste cooking oil commonly used to fry food. Although nitrogen oxide emissions increase slightly, combustion of biodiesel made from waste or surplus material causes no net gain in CO_2, and none of the carbon monoxide, sulfur or small particles created from petroleum-based diesel.[33] Although emissions' testing has largely occurred with automotive engines, emissions should be similar with diesel generators.[12] The question as to whether crops can be grown and processed to produce biodiesel, yet create no net gain in GHG, is unanswered at this time. Opportunities currently exist to increase use of biodiesel as a means to produce electricity, particularly for on-site generation.

Solar. In Minnesota, when compared to current pulverized coal plants, each KWh per year of photovoltaic (PV) electricity offsets up to 48 pounds of NOx, 52 pounds of SO_2, and 19,900 pounds of CO_2.[34] Although it produces energy from sunlight any time of year, solar energy is best suited to provide electricity during periods of highest demand—hot summer days. A recent study by the Department of Commerce shows that, for summer months, Minneapolis has a greater solar resource than Jacksonville, Florida.[35] Although used to power remote homes and buildings in Minnesota, there is presently less than 100 KW of grid-connected photovoltaic panels in the state. Xcel Energy's Solar Advantage Program estimates installed costs of $8,500 per KW which equates to about 30 cents per KW when amortized over the 20-year life of the panels.[12] Xcel Energy awarded $1.25

million from its Renewable Development Energy Fund to reduce installation costs of rooftop PV in Minnesota.[22] Given the funding opportunities currently enjoyed by other states, there is opportunity for Minnesota to add a significant amount of solar to its energy generation system.

Solar energy represents a technology with widespread potential applications and a growing niche market. Solar energy has great potential for decreased costs and increased efficiency, partly because of large photovoltaic initiatives by the federal government.[36] Funding through energy tariffs and state and federal grants helped develop 3.6 MW of solar energy capacity in the United States.[37] The Department of Energy (DOE) has a goal to facilitate installation of one million PV rooftops across the United States by 2010.[38] According to DOE, solar generating systems will contribute 10 percent of U.S. peak power generation by 2020—more if additional incentives are put in place.[39]

Payback periods for photovoltaic panels are decreasing steadily but are still too long for widespread use. With current funding and incentives, solar electricity is projected to become competitive for peak power on a per KWh cost basis by 2010.[41] Modern solar PV systems currently supply electricity for 15 to 25 cents per KWh.[39] In 2000, PV power grew by 30 percent in the United States and by 40 percent elsewhere in the world.

In response to the new efficiencies, increasing numbers of utilities are investing in PV solar distributed power generation.[40] SRP public power utility serving Phoenix made a commitment to spend $29 million on solar and renewable energy without increasing costs to consumers.[41] Watts on Schools in Abilene, Texas, is a solar schools program with installations completed at 19 schools, generating an average of 6,266 KWh for each school and 119,045 KWh total.[40]

In California, on-site solar PV panels at the bus depot are being used to produce hydrogen for fuel cell zero-emission buses of SunLine Transit Agency, which provides mass transit service to the Palm Springs area.[42] The Sacramento Municipal Utility District is investing heavily in solar PV systems on private home and commercial roofs to meet peak energy demand.[43] In 2001, the citizens of San Francisco overwhelmingly passed a $100 million bond issue to produce 70 MW of electricity from PV panels mounted on rooftops of public buildings within three years, almost doubling the solar power supply in the nation.[44]

Research and development drives high-tech industries; and in recent years, U.S. government funding of solar energy has not kept pace with that of other nations—particularly Germany and Japan. The U.S. share of world PV shipments has dropped dramatically, from approximately 50 percent to 30 percent, over the last three years.[37] Germany is scheduled to have 350 MW of solar power on-line in 2003. Japan currently has 192 MW of solar power generation, with an additional 3.4 MW to be on-line from a Sanyo Electric plant in 2004.[45]

Fuels cells use the physical properties of hydrogen and oxygen to produce electricity and pure water, and were originally developed to supply power needs of spacecraft. Fuel cells are well suited for distributed power generation. Units are available today for commercial use, but are still too expensive for widespread use. When hydrogen is produced from the electrolysis of water with power supplied by hydro, wind or solar, this technology provides pollution-free, renewable electricity. The nation's first pollution-free, self-standing and renewable (solar) energy fuel cell system was installed to provide electricity to Kahanu Garden, Maui, Hawaii in 2001. The $150,000 cost of the system is substantially less expensive than the estimated $200,000 to $400,000 cost to connect to the Maui Electric Company grid. Long Island Power Authority is purchasing 28 pre-commercial natural gas fuel cell units to test and demonstrate efficacy of fuel cells for residential specific, distributed power generation.[46] The price for commercial residential units is expected to be $3,000 in 2006.[47] Coleman's $8,000 AirGen Fuel Cell is currently available for use as a readily portable, safe indoor, secondary power source, and is particularly useful for critical equipment power needs.[48]

Storing electricity

A problem with intermittent sources of power such as wind and solar is that although they produce pollution-free energy when sufficient wind or sunlight is present, they produce none when it is not. However, solar PV systems would work well just about anywhere in Minnesota.[35] For wind, the limitation to significantly increasing its use in the state is a lack of transmission lines, not the resource.[12] An efficient way to store energy would mitigate the issues caused by intermittent and concentrated sources of solar and wind energy.

Once electrons are produced, they cannot be stored. Energy storage systems, such as using periods of surplus electricity to pump water up a hill or compress air so that their energy can be stored and used to regenerate electricity when needed, are being used. However, there are significant inefficiencies involved due to their need to move significant mass. Because it only involves moving electrons, using surplus electricity to produce hydrogen from water through electrolysis, and storing the hydrogen for later use in a fuel cell to produce electricity, is currently the most energy efficient way to store and utilize surplus electricity.[49]

The components are available in which rooftop solar panels or wind turbines could be used for electrolysis of water to produce hydrogen and oxygen. The hydrogen, in turn, would power a fuel cell to supply a constant source of electricity to a home and excess power to the grid.[50] Research and development of this technology is proceeding rapidly. When commercially cost-effective, which is estimated to be within 10 years, the technology will remedy major problems we currently face with traditional power generation.[36]

Funding

Federal energy subsidies, some of which have been for pollution prevention, have played a major role in bringing particular electricity generation technologies to maturity. Using 1999 dollars, the historical total of ongoing subsidies are:[51]

- Hydro: Most significantly subsidized in the 1930s and 40s, with estimates ranging from $1.6 to $62 billion.
- Nuclear: Most significantly subsidized in the 1950s and 60s, with estimates ranging from $61 to $140 billion (does not include long-term nuclear waste storage costs).
- Coal, oil and natural gas: Estimated ongoing subsidies range from $300 to $410 billion.
- Wind and solar: Beginning in the 1970s, with estimates ranging from $10 to $23 billion.

Pollution prevention funding for coal has increased. Initiatives from the U.S. Department of Energy (DOE) and the coal industry are underway to increase the efficiency of coal-fired plants. The administration's budget requests $2 billion over the next 10 years to supplement the approximately $5 billion that has been spent developing more efficient ways to burn coal as a part of DOE's Clean Coal Technology Program.[52]

In 1999, out of a $6 billion annual budget, the Department of Energy's outlays were approximately 50 percent for fossil fuels, 13 percent for ethanol, 11 percent for generation technology research, 10 percent for nuclear, 5 percent for geothermal, 5 percent for solar and wind, and 5 percent for energy conservation, with the balance going to end use.[53]

Energy conservation and energy efficiency

Energy conservation is low cost and the most readily available pollution prevention action to reduce GHG from coal-fired utilities, because with more efficient use of electricity less coal need be burned.

The Minnesota Department of Commerce has identified the potential for about 1,000 MW equivalent of energy conservation that, by 2010, could be realized at costs of $350 per KW or less.[12] From 1992 through 2000, Minnesota's Conservation Improvement Program saved approximately 1,300 MW for an average savings of $343 per KW.[12] Recent national energy bottom-up engineering studies have concluded that 10 percent or more of all our GHG emissions could be avoided at zero costs through energy efficiency improvements.[54] Current conservation technologies, such as geothermal heat pumps that heat and cool buildings with 70 percent less energy than standard heating and cooling equipment, are underutilized.[55]

In 2001, the Minnesota Legislature passed the Energy Security and Reliability Act, which, in part, provides for public building energy conservation and sustainable building guidelines that will significantly improve the energy efficiency of state buildings. As a part of Minnesota's energy conservation program, utilities are also required to invest a percentage of their state revenue on conservation programs and have achieved significant results.[56] Power companies have achieved significant P2 through their participation in energy conservation programs.

Other states are increasing their use of energy conservation as a pollution prevention tool. The city of Seattle has one of the strongest green building policies in the country. All city buildings have to meet the U.S. Green Building Council's Silver LEED rating; and the city is committed to a 20 percent increase in the Seattle Energy Code, which goes beyond the National Energy Code Standard.[57]

Summary

When the public sees OEA's working tabletop model of a solar-powered, hydrogen fuel cell running a fan motor, the feedback is consistent: "When can I get one for my house?" The public's desire to have a local, pollution-free energy source is strong. However, due to costs, such energy systems for buildings are currently very rare. Today, more than three-quarters of Minnesota's electricity is generated from combustion of fossil fuels. The contrast between the pollution-free vision of the future and the current need to release 37 million tons of CO_2 and related toxic chemicals per year for electricity could not be more pronounced.

Given the rapid changes occurring with power generation and storage technologies, many of which will be cost competitive in 10 years, prudent funding decisions are needed to assure that a non-disruptive transition to new pollution prevention technologies occurs in the most beneficial and timely manner. Decisions on power generation technologies made today will substantially impact the costs and environmental impacts due to them for the next 40 years, or longer.

To effectively reduce greenhouse gas and related toxic chemical emissions due to power generation, an orderly and coordinated increase in the use of P2 technologies is needed. The pace of the transition to these technologies will be determined by economic factors, commercialization of emerging technology, the support electricity generators have to make the transition to the new technologies, public will, and the policies of their elected representatives. To address environmental and long-term economic concerns, some states and nations are seriously considering their timing for a shift from a fossil fuel to a hydrogen fuel based economy.

Minnesotans should participate with such energy research and planning so that policymakers have the information they need to make the most beneficial policy and funding decisions.[12,58] Due to the long life of energy systems, the future sources of Minnesota's electricity and their resultant emissions are being formed today.

OEA P2 actions and opportunities to reduce GHG and related toxic chemicals due to energy production

The following activities outline OEA efforts to reduce GHG emissions due to generation of electricity.

Green building

As a part of OEA's Green Building Program, the OEA will provide Internet resources to:

- promote Energy Star labeled products: buildings, homes, heating and cooling equipment, high-efficiency motors and air compressors, major appliances, office equipment, lighting and consumer electronics.
- promote the use of energy efficiency auditors who examine existing and recommissioned buildings to eliminate energy waste.
- promote use of energy efficiency building design assistance offered through such efforts as Xcel Energy's Energy Assets Program and Energy Star Target Finder to improve architectural plans.
- promote use of the state's sales tax exemption for purchase of Energy Star lighting, photovoltaic devices, and high efficiency heat pumps, water heaters, and furnaces.
- link to Minnesota Department of Commerce web site resources that promote use of energy audits for residences and the construction of super-insulated homes with air-to-air heat exchangers to assure air quality.

On-site technical assistance

OEA and MnTAP will research the feasibility of integrating energy efficiency into MnTAP on-site assistance, and provide additional measurements of pollution prevention.

Design for the Environment (DfE)

As a part of the OEA's DfE activities, the OEA has joined expertise with the Energy Office of the Department of Commerce to develop a demonstration project to showcase solar panels and a small wind turbine to make hydrogen from water. Stored hydrogen will be used to power a fuel cell to produce an uninterrupted supply of

electricity. OEA will use grant funds, as available, to demonstrate this technology, provide measurable results, and educate the public on the exponential improvements that have been made to produce a local source of renewable, pollution-free electricity.

Research hydrogen-based economy

The OEA will coordinate research and information with Minnesota Planning as a part of its 2002 initiative to investigate the costs, benefits and possible pathways for a transition to a hydrogen-based economy. Minnesota Planning will seek to develop a consensus among experts and stakeholders on what, if any, investments the state should make to prepare for such a transition.

Transportation

There are many methods to reduce greenhouse gas (GHG) from transportation. These include increasing use of such things as walkways, bikeways, mass transit, high-occupancy vehicles, telecommuting, high-efficiency vehicles, reduced highway speeds, tax incentives, improved traffic flow, policies to encourage vehicle maintenance, reduced city sprawl, increased vehicle occupancy, increased fuel economy, and low or no greenhouse gas producing fuels. The following pollution prevention opportunities describe only fuel changes which are being used to reduce GHG and toxic emissions from vehicles.

Greenhouse gas emissions from Minnesota's transportation sector are approximately 45 million CO_2 equivalent tons a year.[9] From 1998 through 2000, gasoline consumption increased 8 percent. The increase in consumption was due to a 2 percent increase in the number of miles driven per person, and a decrease of about 3 percent in the average number of miles per gallon.[59] In addition to causing the single largest source of GHG emissions in the state, on-road transportation results in the annual consumption of approximately 2,500 million gallons of gasoline which caused 9 million pounds of benzene emissions.[60] Benzene is of concern because long-term exposure to high levels can cause leukemia and damage the immune, reproductive and neurological systems.[61]

- *A 20-mpg gasoline vehicle releases about 11,500 pounds of CO_2 in an average 12,000-mile year.[9]*

P2 options for vehicle fuels

There are five low or no-GHG emission fuels of primary interest for use in Minnesota vehicles: biodiesel, ethanol, natural gas, propane and hydrogen. In addition, it is possible to use these fuels more efficiently in electric-hybrid vehicles. These Ultra Low Emission Vehicles, as certified by the U.S. EPA, use some onboard fuel to generate electricity to power an electric motor which complements power from a high-efficiency internal combustion engine when additional power is needed.

Biodiesel is a renewable fuel produced from agricultural oil seed crops or made from waste cooking oil commonly used to fry food. Its use as a fuel results in substantially reduced carbon monoxide and soot (particulate) emissions created by petroleum-based diesel fuel and requires no diesel engine modifications.

Hennepin County operates four heavy-duty trucks on B20, a mix of 20 percent biodiesel and 80 percent petroleum. The University of Minnesota Diesel Research Department operates one vehicle on 100 percent biodiesel. The Department of Commerce has received Department of Energy funding for a B20 school bus demonstration project. Other biodiesel users include the Minnesota Soybean Growers Association, U.S. Forest Service (International Falls), and the Department of Agriculture. Lower blends of biodiesel (B5, or 5 percent biodiesel) are being tested in MetroTransit buses. There are about a dozen greater Minnesota Cenex Cooperative service stations selling B2, a 2 percent biodiesel mix.

- *A 20-mpg diesel vehicle using B20 releases about 17% or 2,000 pounds less CO_2 per year than a comparative vehicle using regular diesel in an average 12,000-mile year.[62]*

Ethanol (ethyl alcohol) is a renewable fuel produced principally from agriculture corn crops at 14 facilities in Minnesota. Ethanol may also be produced from cheese whey, potatoes, brewery and wood—essentially any starch

or biomass material that can be broken down into fermentable sugars. Today, virtually all Minnesota gasoline is blended with ethanol—between 7.8 and 10 percent by volume. This is in accordance with the state's oxygen requirement for gasoline (2.7 percent by weight) which is met with a 7.8 percent-by -volume ethanol fuel.

E85 (85 percent ethanol and 15 percent gasoline) fuel should only be used in Flexible Fuel Vehicles (FFVs). A number of popular FFVs are available today. There are presently 1,054 E85 FFVs in the Minnesota Department of Administration Travel Management Division's fleet. Approximately 12,000 gallons of E85 fuel was pumped from the division's bulk tank last year.[63] Minnesota has met and exceeded federal requirements for state use of alternative fuel vehicles.[64] Not including the CO_2 released during crop or fuel production, each gallon of E85 produces 77 percent less CO_2 than a gallon of gasoline when burned as fuel. There are approximately 70,000 E85 FFV owners in Minnesota, which leads the nation with 65 E85 fueling sites, making this fuel as convenient as gasoline for some FFV owners.[21] E85 use in the state is rising, from 75,000 gallons in 1999, to 320,000 gallons in 2000, to 550,000 gallons in 2001.

- *A 20-mpg E85 vehicle releases about 77 percent or 8,900 pounds less CO_2 and 85 percent less benzene per year than a 20-mpg vehicle using regular gasoline in an average 12,000-mile year.*[62]

Pollution prevention issues regarding biodiesel and ethanol

Large amounts of energy are required to grow and process ethanol and biodiesel feedstocks. If crops are farmed exclusively for use as fuel feedstocks rather than using waste or surplus crops to produce these fuels, special care must be taken to assure that the total CO_2 produced does not exceed emissions associated with the production and combustion of an energy equivalent amount of petroleum-based fuel.

The production technology for ethanol has undergone progressive improvement since 1980. Life-cycle GHG emission from ethanol production and use is currently about 20 percent less than those associated with gasoline.[65] With long-term technology development, ethanol life-cycle emissions are expected ultimately to be substantially less than for gasoline, as much as 40 percent per mile driven.[66] The use of grown crops decreases dependence on foreign sources of petroleum, and given that Minnesota imports all of its fossil fuel, there are potential economic and long-term reliability advantages for increased use of agricultural-based fuels.

Natural gas is a non-renewable fossil fuel. For equivalent vehicle miles traveled, natural gas releases 25 percent less GHG as compared to gasoline. There are more than 200 compressed natural gas (CNG) vehicles operating in Minnesota, primarily operated by natural gas utilities. Schwann's Ice Cream and Leef Brothers Inc. also use CNG trucks for their deliveries. The Minnesota Valley Transit Authority has five CNG buses in service and plans to purchase six more. Pending funding approval, the Transit Authority has plans to purchase 31 additional CNG buses.[21]

In addition to reducing GHG emissions, CNG-fueled buses avoid the particulate emissions that are problematic with regular diesel buses. Particulate air pollution from regular diesel is a concern because it has been shown to significantly increase consequences of pre-existing cardiovascular or respiratory disease, pneumonia, pulmonary disease, and asthma attacks in at-risk populations.[67]

- *A 11-mpg bus fueled with natural gas releases about 5,200 pounds less CO_2 than a comparable bus using regular diesel in an average 12,000-mile year.*[62]

Propane. There are an estimated 1500 liquefied petroleum gas (LPG or propane) vehicles operating in Minnesota, mostly operated by centrally located fleet owners, such as Schwann's Ice Cream and Leef Brothers laundry service trucks.

- *A 20-mpg vehicle fueled with propane releases about 10 percent or 1,150 pounds less CO_2 than a comparable vehicle using regular gasoline in an average 12,000-mile year.*[62]

Hybrid electric vehicles (HEVs) typically have a gasoline or diesel internal combustion engine and a battery powered electric engine in the same vehicle. Unlike the all-electric vehicles, which need electricity from power utilities, have limited range, and poor cold climate operation, HEVs have similar performance and greater range than gasoline combustion vehicles. The MPCA purchased two hybrid electric vehicles in 2001, a two-passenger Honda Insight (city 61/hwy 68 mpg) and a five passenger Toyota Prius (52city/45hwy mpg),[68] and they are meeting performance expectations.

- *A 50-mpg vehicle releases 60 percent less, or about 7,000 pounds less CO_2 and 60 percent less benzene, than a 20-mpg gasoline vehicle in an average, 12,000-mile year.*[9, 60]

Hydrogen is the most abundant element in the universe, is a very effective energy storage medium, is renewable, and burns clean. Adding just 5 percent to gasoline reduces NOx emissions by 30 percent.[69] Burning pure hydrogen produces only water and a minor amount of NOx. The goal of the U.S. Department of Energy is to use hydrogen to provide 10 percent of total U.S. energy consumption by 2025, which would reduce our dependence on oil imports by half. Cost remains the single largest obstacle. Current economics provide natural gas at $3 per million Btu, gasoline at $9 per million Btu, and hydrogen at $30 per million Btu.[69]

Today, the U.S. safely uses about 3.2 trillion cubic feet of hydrogen a year, almost all of which is produced at oil refineries for use in fertilizers and petrochemicals. Hydrogen can be added to gasoline, ethanol, methanol, and natural gas to reduce pollution and increase the performance of internal combustion engines, which will probably be its initial widespread use.[69] As with natural gas or propane, internal combustion engines can be modified with existing technology to run on 100 percent hydrogen.[49]

Although existing engines can be modified to use hydrogen, substantial research is taking place on using fuel cell engines. Fuels cells use the physical properties of hydrogen and oxygen to produce electricity and pure water, and were originally developed to supply the power needs of U.S. spacecraft. They are used to power the space shuttle's electrical systems and the only by-product is pure water, which the crew uses as drinking water. Hydrogen-powered fuel cell engines are expected to reach efficiencies of 100 mpg with the same acceleration and performance as current vehicles in the long term.[49]

The automotive industry is investing heavily in the use of fuel cells for vehicles, although rather than using pure hydrogen, mainstream automotive and fuel industry thought currently favors "reforming," or extracting, hydrogen from gasoline as a next step, since a gasoline distribution network is currently in place. However, others within the industry consider methanol a better near-term choice, since it could use the same distribution network, but is more easily reformed and can be produced from natural gas, coal, or renewable biomass. Ethanol, because it is renewable and could also use the same distribution system, is advocated as another possibility. When hydrocarbon, versus pure hydrogen, fuels are used, CO_2 is released, but due to improved fuel efficiency, at levels 50 percent less than when burned in combustion engines. The first commercially available fuel cell automobiles, although expensive, will begin appearing in 2003.

The production of hydrogen from the electrolysis of water by renewable energies such as hydro, wind or solar, provides pollution-free, renewable energy. Stuart Energy produces self-standing Hydrogen Fuelers[70] to produce pure hydrogen for fuel cell vehicles. Such a system is in use by SunLine Transit in California, which is using solar electric panels to produce renewable hydrogen for a hydrogen-powered fuel cell bus.[71] The company has also established the first public hydrogen fueling station.

- *No GHG or associated pollutants are created or released during the use of hydrogen in a fuel cell engine.*

The hydrogen economy

Significant progress is being made internationally in regard to hydrogen fuel. Iceland foresees an economic advantage to making a rapid transition away from fossil fuels to independent energy systems involving fuel cells. As a result, Iceland has made a commitment to be the first nation in the world to free itself from dependence on fossil fuels.[72] It will do so in stages. Renewable geothermal and hydroelectric energy will produce electrolytically generated hydrogen fuel from water. Due to a current lack of distribution infrastructure, the pure hydrogen will initially only be used to power the capitol city's fuel cell engine bus fleet. Hydrogen bound in methanol will be used as the near-term alternative to fossil fuel for private cars and fishing vessels because it can utilize the nation's existing fuel distribution system. Methanol fuel cell demonstration vehicles are operating in Japan and Germany.[73] Though not as ideal as pure hydrogen fuel, methanol fuel cell engines will emit very few of the toxic chemicals, nitrous oxide or sulfur dioxide caused by fossil fuels and will only emit one half the CO_2 per mile. Methanol was chosen because the metal industries of Iceland emit vast amounts of CO_2 and CO. These carbon oxides, currently released to the atmosphere, will be collected and then combined with the electrolytically produced hydrogen to produce the methanol. Iceland plans a full transition to a hydrogen-based economy within 30 years.

Summary

Rapid changes are occurring with fuels and technologies for vehicles. In regard to P2 fuels, to effectively reduce greenhouse gas and toxic emissions, an orderly and coordinated decrease in the use of fossil fuels and increase in the use of low or no GHG and toxic chemical emitting fuels is needed. The pace of the U.S. transition will be determined by economic factors, the rate of commercialization of emerging technology, public will, and the policies of their elected representatives. To position the state to benefit from rapidly changing technology, Minnesotans should participate with research and funding opportunities regarding low or no emission fuels.[12, 58] This will ensure that policymakers have the information they need to make the most beneficial policy decisions.

OEA P2 activities to reduce GHG and related toxic chemical emissions from transportation

Vehicles

To reduce emissions from vehicles, the OEA will work with other state agencies to:

- Develop coordinated research that includes P2 for transportation.
- Recommend that when such vehicles meet transportation needs, state agencies lease or purchase passenger vehicles which get an equivalent of EPA city mileage rating of 45 mpg or greater; qualify as an Ultra Low Emission Vehicle; and is manufactured primarily for use on public streets, roads and highways and has at least four wheels. (There are only two now available, the Honda Insight and the Toyota Prius.)
- Coordinate with other agencies to research incentives such as state rebates, no sales tax, reduced license tab fees, or preferred parking to employees for passenger vehicles which get an equivalent of EPA city mileage rating of 45 mpg or greater, qualify as Ultra Low Emission Vehicle, and are manufactured primarily for use on public streets, roads and highways and have at least four wheels.
- Participate with community transportation planning through the OEA's sustainable communities activities.

Research hydrogen-based economy

The OEA will coordinate research and information with Minnesota Planning as a part of its 2002 initiative to investigate the costs, benefits and possible pathways for a transition to a hydrogen-based economy. Minnesota Planning will seek to develop a consensus among experts and stakeholders on what, if any, investments the state should make to prepare for such a transition.

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Interventions in Energy Markets," December 1998, ftp://ftp.eia.doe.gov/pub/pdf/multi.fuel/emeu9202.pdf. Both use federal budget, direct program on-budget data, but use different time periods, and off-budget calculations for such additional subsidies as use of the U.S. Conservation Corp., lost revenue from tax exemptions, costs of regulatory actions, mineral rights and land grants.

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[53] U.S. Dept. of Energy, Energy Information Administration, Office of Integrated Analysis and Forecasting, "Federal Financial Interventions and Subsidies in Energy Markets 1999: Energy Transformation and End Use," May 2000, SR/OIA/2000-2. http://www.eia.doe.gov/oiaf/servicerpt/subsidy1/pdf/sroiaf(2000)02.pdf.

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[56] State law requires regulated electric utilities to invest 1.5% of their state revenues in Conservation Improvement Programs, CIP, (except Xcel Energy, which must invest 2 percent). Regulated gas utilities are required to invest 0.5% of their state revenues into conservation programs. Cooperative and municipal utilities are required to invest 0.5% of their revenues in conservation programs. The cost of CIP programs is billed back to customers of these utilities. http://www.commerce.state.mn.us/pages/Energy/MainCIP.htm. Energy Assets Xcel Energy CIP Program participants are saving an estimated total of $14 million annually in energy costs. The program has reduced peak electric demand by 54 megawatts, enough electricity to power approximately 54,000 homes. http://www.commerce.state.mn.us/pages/NewsReleases/Releases2001/News011011.htm.

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[59] Minnesota Pollution Control Agency, "Automobile and Heavy Duty Vehicle VMT, Fuel Consumption and Mileage" data sheet.

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[61] U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, "Toxicological Profile for Benzene." http://www.atsdr.cdc.gov/toxfaq.html.

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[68] U.S. EPA, Fuel Economy Ratings; http://www.fueleconomy.gov.

[69] U.S. Department of Energy, Hydrogen Information Network, Hydrogen the Fuel of the Future. http://www.eren.doe.gov/hydrogen/basics.html. Other hydrogen sites: http://www.ttcorp.com/nha/h2.htm.

[70] Stuart Energy—Hydrogen Bus Fueler supplies on-site, hydrogen fuelers for such transit companies as Coast Mountain Transit, Vancouver; Montreal Urban Transit Authority; University of California, Los Angeles; Xerox Corporation, Los Angeles; and SunLine Transit, Palm Springs for their fuel cell buses. http://www.stuartenergy.com.

[71] SunLine Transit Agency web site, Hydrogen—fuel cells. www.sunline.org/education/education_middle.html.

[72] Sigfusson, T. I. and B. Arnason, Science Institute, University of Iceland, Reykjavik, "New Perspectives for Renewable Energy in Iceland," also published as "Iceland, A Future Hydrogen Economy," *Renewable Energy Focus,* July/August 2000.

[73] Mazda is public road testing "Premacy FC-EV," a methanol fuel cell vehicle based on the Mazda Premacy; http://www.mazda.com search for Premacy FC-EV. Daimler-Benz is piloting use of a similar methanol fuel cell system in its Mercedes NECAR III. Methanol was chosen over gasoline and diesel because of its higher efficiency level and potential as renewable fuel; http://www.mercedes-benz.com/e/default.htm search for NECAR III.

Pollution-free Electricity

Design for Environment (DfE)

Renewable energy sources such as wind and solar produce pollution-free power, but the flow of electricity from wind turbines or photovoltaic panels is intermittent. Energy is only provided when the wind blows or the sun shines. But how can you store energy from intermittent sources so it can be available at any time?

Renewable hydrogen power

Hydrogen can store energy efficiently. When electricity is applied to water molecules (H_2O), you can separate the hydrogen (H) from the oxygen (O) atoms so that the hydrogen can be stored for later use.

A **fuel cell** uses hydrogen as a power source to create electricity through a simple electrochemical process. The only by-products from the fuel cell are breathable oxygen, drinkable water and some heat.

a. Through a simple chemical reaction, a "proton exchange membrane" removes an electron from a hydrogen atom.
b. The freed electron travels though a wire to power any electrical device.
c. The hydrogen atom, minus one electron, is released to the air, where it combines with an oxygen atom to form pure water.

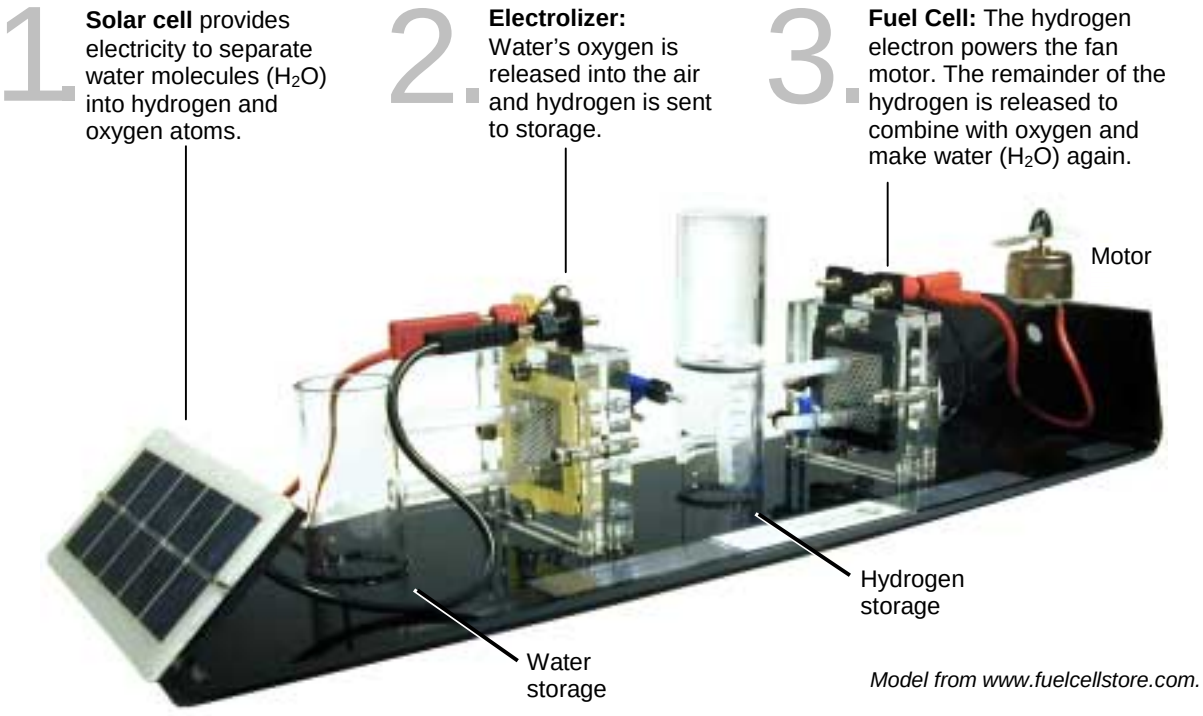
Other hydrogen sources

Fuel cells can run on any source of hydrogen, including hydrocarbons: natural gas, methanol or gasoline. These non-renewable fuels must first be run through a converter to separate the hydrogen.

This conversion process does create some air pollution. However, a hydrocarbon-powered fuel cell generates only half of the green-house gases compared to when hydrocarbons are burned in internal combustion engines.

Natural-gas-powered fuel cells that are not dependent upon power plants to generate electricity are in use today. Although economic factors have kept this technology from being widely applied, its use is increasing in powering homes and buildings.

How does a renewable, hydrogen-powered fuel cell system work?



Model from www.fuelcellstore.com.

Minnesota Office of **Environmental Assistance**

www.moea.state.mn.us

520 Lafayette Rd. N.
Second floor
St. Paul, MN
55155-4100

Ph: 651-296-3417
800-657-3843
Fax: 651-215-0246

Hydrogen-based home energy system

Although several years away from mass market, buildings similar to this one are moving from the drawing board to reality.

In this design, rooftop solar cells provide the electricity to separate water into oxygen and hydrogen. The hydrogen is stored in underground tanks for use in the fuel cell, which would provide uninterrupted electricity for the home.

Reprinted with permission from U.S. Department of Energy National Renewable Energy Laboratory.

Is hydrogen a safe fuel? Experience has shown that risks are similar to using other flammable gases such as propane or natural gas. Today, more than 3.2 trillion cubic feet of hydrogen are used safely in the U.S.

Other uses for fuel cells

In addition to power generation for homes and offices, fuel cells are being adapted for other uses.

Motorola, for instance, has a cell phone prototype that is powered by a methanol fuel cell. The methanol cartridges will last up to ten times longer than a rechargeable battery.

Electrolux Corporation is experimenting with fuel cells in common appliances such as vacuum cleaners. Other manufacturers are experimenting with putting them in electric bicycles.

In early 2002, the Bush administration announced that it was replacing a program to develop high-mileage gasoline/electric hybrid vehicles with one to develop hydrogen-powered fuel cell vehicles. Cost-competitive fuel cell vehicles are expected within ten years.

A hydrogen economy

In the United States, interest in making a transition to a hydrogen-based energy system is growing because it would free the U.S. from the costs of dependence on foreign sources of fuel. In addition to environmental benefits, the improved economic and national security offered through use of hydrogen versus fossil fuels are increasingly recognized as in the best national interest.

On the international front, Iceland declared it will be the first nation in the world to convert to a hydrogen-based economy. With no fossil fuel reserves and abundant geothermal and hydro energy, Iceland will use electricity produced from these renewable sources to separate hydrogen and oxygen from water.

Buses will use the hydrogen directly; and fuel cells in cars, trucks and ships will use liquid methanol made by combining hydrogen with existing carbon dioxide. Existing fueling stations can be used.

The government plans to make Iceland a net exporter of hydrogen with a goal of becoming a "Kuwait of the new energy economy."

For more information

Fuel Cells 2000 provides extensive information on fuel cells, from the basics to monthly technology updates: www.fuelcells.org

Plugpower is a suppler of pre-commercial, natural-gas-powered fuel cells for residential use. www.plugpower.com

Educational desktop models of solar-powered fuel cells, manufactured in Germany, are available through their U.S. distributor, The Fuel Cell Store: www.fuelcellstore.com.

Environmental benefits of fuel cells are discussed in the greenhouse gases section of the OEA's *2002 Pollution Prevention Evaluation Report:* www.moea.state.mn.us/berc/p2evaluation2002.cfm