Michigan**Science**

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Premier Issue!

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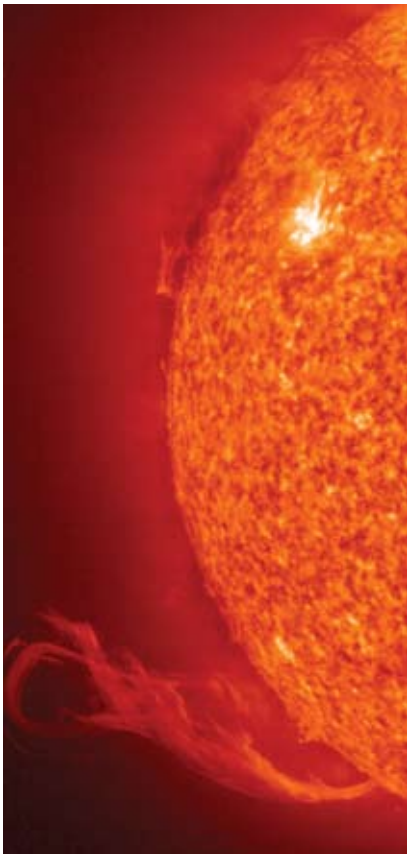
In Memoriam
Herbert D. "Ted" Doan
1922 – 2006

From childhood until his death on May 16 at age 83, Herbert D. Doan delighted in the wonders of science and inspired the same in those fortunate enough to know him. A man of many talents and unwavering principles, Mr. Doan deserves to be long remembered and appreciated for fostering the search for knowledge and understanding of our world.

Mr. Doan served as president and CEO of the Dow Chemical Co. from 1962 to 1971. His decades of public service reflected his devotion to science, including affiliations with the Michigan Molecular Institute; the National Science Board; the Office of Technology Assessment in Washington, D.C.; the University of Michigan's College of Engineering; the University of Chicago's Board of Governors for the Argonne National Laboratories; the Cornell University Engineering Council; the American Institute of Chemical Engineers; and the American Chemical Society.

In these pages, his admonition to let sound science prevail lives on.



ON THE COVER
SOHO-EIT image from September 14, 1997 showing a huge eruptive prominence on the sun.
Courtesy of SOHO/[instrument] consortium. SOHO is a project of international cooperation between the European Space Agency and NASA.

MichiganScience is published quarterly by the Mackinac Center for Public Policy, a nonpartisan, nonprofit research and educational institute devoted to promoting sound solutions to state and local policy questions. MichiganScience is received by legislators and their staff; state agency personnel; radio, television news directors and producers; print news editors and reporters; educators; libraries; and civic organizations. Please contact Bruce Edward Walker, at walker@mackinac.org or by mail at 140 West Main St., Midland, Mich. 48640. He can be reached by phone at 989-631-0900.

By The Numbers

Beyond propaganda and rhetoric, numbers tell the real story

GLOBAL WARMING is believed by some to be melting the polar ice caps, thereby increasing sea levels. But according to a 1998 study by the Society of Economic Paleontologists and Mineralologists the current sea levels are lower today than at any time in the past 30 million years. There also is evidence that elevated CO_2 levels are reversible. During the middle Cretaceous era some 90 million to 110 million years ago, large portions of all continents were submerged below shallow seas, and the atmosphere was abnormally high in carbon dioxide (CO_2). The oceans mitigated the CO_2 with an explosion of single-cell organisms (coccolithophores) that extracted the gas from the atmosphere and formed massive deposits of chalk — the White Cliffs of Dover, for example.

MICHIGAN FOURTH-GRADERS and eighth-graders scored slightly above the national average on the science portion of the 2005 National Assessment of Educational Progress. On a scale of zero to 300, Michigan fourth-graders averaged 152, compared to the national average of 149, ranking the state 22nd in the nation. Michigan eighth-graders scored 155, compared to the national average of 147, ranking the state 15th in the nation. According to the National Center for Education Statistics, only about 32 percent of U.S. fourth-graders and 35 percent of U.S. eighth-graders were "proficient" on the 2005 science test. For more information, go to http://nationsreportcard.gov/science_2005/.

ABOUT 10,000 COMPUTERS used by the federal government join the waste stream every week, according to the U.S. Environmental Protection Agency. Learn more at www.epa.gov/oamhpod1/admin_placement/0300115/fact.htm.

LAKES HURON, ONTARIO, Michigan, Erie and Superior contain about 6 quadrillion gallons of water. According to the Great Lakes Information Network, the lakes account for 20 percent of the world's fresh surface water, and if all that H_2O were spread across the continental United States, we would be 9.5 feet underwater. More numbers are available at www.great-lakes.net/lakes/ref/lakefact.html.

*Just the Facts

The Michigan League of Conservation Voters claims on its Web site that the Great Lakes and our way of life are "threatened" daily by water diversion, pollution and loss of wetlands.[1] It's a common refrain that's unsupported by the facts.

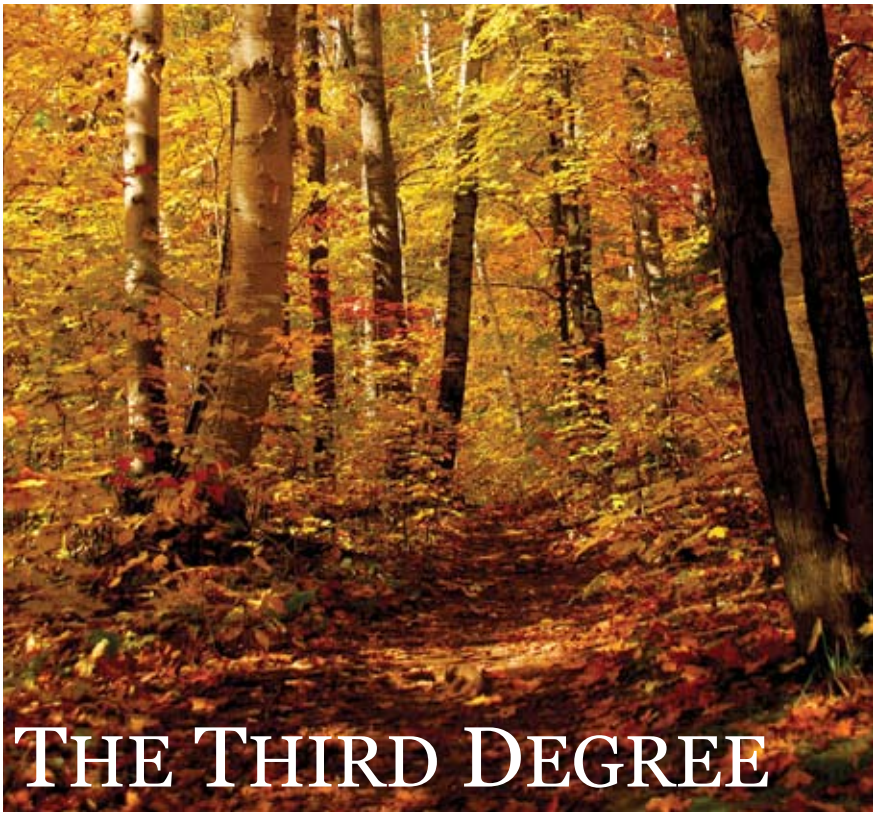
More water is diverted into the Great Lakes than is siphoned out, and groundwater supplies are regularly replenished and remain abundant. (See Michigan Department of Environmental Quality, Office of the Great Lakes, "Great Lakes Trends: Into the New Millennium," May 2000.)

Water quality has improved dramatically during the past three decades. Michigan's 2006 report "Water Quality and Pollution Control" asserts "The open waters of the Great Lakes have good to excellent water quality."

There is no current, comprehensive inventory of wetlands in the Great Lakes basin. According to the Great Lakes Commission,[2] "Current estimates of wetland area lack precision." Estimates of wetland losses following American settlement have ranged from 30 percent to 50 percent. In recent years, however, the rate of wetland loss has slowed dramatically, according to the U.S. Fish and Wildlife Service. In fact, there was a net gain in freshwater wetland area of 220,200 acres between 1998 and 2004, according to the agency's report "Status and Trends of Wetlands in the Conterminous United States 1998 to 2004."

1 The Michigan League of Conservation Voters, "Know the Issues: Protecting Water Resources of the Great Lakes Basin." Available on World Wide Web at: http://www.michiganlcv.org/issues.htm.

2 The Great Lakes Commission coordinates water conservation efforts among eight states. More information about the commission is available on the World Wide Web at: http://www.glc.org/.



The Third Degree

What do you know about Michigan's landscape?

1. What percentage of Michigan's land area is forest?*
- A. 20 percent
- B. 60 percent
- C. 10 percent
- D. 37 percent

2. What percentage of Michigan's land area is wetlands?*
- A. 18 percent
- B. 5 percent
- C. 36 percent
- D. 10 percent

3. What percentage of Michigan's land area is agricultural?*
- A. 12 percent
- B. 29 percent
- C. 20 percent
- D. 45 percent

4. What percentage of Michigan's land area is urbanized?*
- A. 6 percent
- B. 15 percent
- C. 25 percent
- D. 40 percent

5. How much did non-federal forests in Michigan increase between 1982 and 1997?
- A. 238,000 acres
- B. 750,000 acres
- C. 538,000 acres
- D. 112,000 acres

6. What was the increase in the volume of Michigan forest timber during the past 50 years?
- A. Double
- B. Triple
- C. Quadruple
- D. None of the above

*Source: "State of Michigan's Environment 2005: Third Biennial Report" *MDNR 1978 survey.*

Answers: 1. D (37 percent) 2. A (18 percent) 3. B (29 percent) 4. A (6 percent) 5. C (538,000 acres) 6. B (Triple)

Field Trips

Area science museums host special programs of interest to budding scientists and their families.

Fossils of the Michigan Basin

Live footage of crinoids crawling 1,300 feet below ground is just one of the features of this exhibit, which examines fossils that are helping paleontologists to understand Earth's history.

Through December 2006, University of Michigan Natural History Museum, 1109 Geddes Ave., Ann Arbor, 734-764-0478. Museum is open Monday through Saturday, 9 a.m.-5 p.m.; Sunday, 12 p.m.-5 p.m.

For more information, go to http://www.exhibits.lsa.umich.edu/exhibitmuseum/publicprogrms/calendar/.

When Crocodiles Ruled North Dakota

The Cranbrook Institute of Science has recreated the subtropical swamps of North Dakota as they existed 60 million years ago. After the extinction of dinosaurs, new species emerged that were just as interesting and terrifying, including 40-foot-long crocodiles, prehistoric primates and underwater predators.

Through Jan. 1, 2007, Cranbrook Institute of Science, 39221 Woodward Ave., Bloomfield Hills, 248-645-3200. Museum is open Saturday through Thursday, 10 a.m.-5 p.m.; Friday, 10 a.m.-10 p.m.

For more information, go to http://science.cranbrook.edu/common/news_detail.asp?L1=7&L2=0&newsid=257882.

Don't Make Me Sick!

Develop a better understanding of how the body defends itself against the bacteria and viruses that make us sick. Explore the human immune system with several types of microscopes as well as interactive models.

Opens Nov. 9, Impression 5 Museum, 200 Museum Drive, Lansing, 517-485-8116. Museum is open Monday through Saturday, 10 a.m.-5 p.m.; Sunday, 1 p.m.-5 p.m.

For more information, go to http://www.impression5.org/germs.htm.

2006 Girls in Science Day: Making Dreams a Reality

Girls in grades 7-12 can learn about careers in science, math and technology while participating in hands-on workshops featuring women who work in the fields of research, science, engineering and technology.

Dec. 2, 9 a.m.-4 p.m., Toledo Center for Science and Industry, 1 Discovery Way, Toledo, 419-244-2674. Museum is open Tuesday through Saturday, 10 a.m.-5 p.m.; Sunday, 12 p.m.-5 p.m.; closed Mondays.

For more information, go to http://www.cositoledo.org/calendar/index.htm.

By Diane S. Katz

Toward a Scientifically Literate Republic

"The value of science to a republican people, the security it gives to liberty by enlightening the minds of its citizens, the protection it affords against foreign power, the virtue it inculcates, the just emulation of the distinction it confers on nations foremost in it; in short, its identification with power, morals, order and happiness (which merits to it premiums of encouragement rather than repressive taxes), are considerations [that should] always [be] present and [bear] with their just weight." — Thomas Jefferson

Writing these words in 1821, Thomas Jefferson could not have foreseen the remarkable advancements in science that were to occur in the future. It's equally fair to say that were he somehow to witness the ignorance of science among average Americans today, he might despair for the republic.

Somewhere along the way, it became acceptable to admit — even boast of — one's inaptitude for all things scientific. In its annual survey of science and engineering indicators, researchers with the National Science Foundation found that less than one-fifth of the U.S. population meets a minimal standard of scientific literacy.

One reason may be that a majority of Americans say they glean most of what they know about science from the popular press. Unfortunately, a survey of the public by the National Health Council, a health policy organization, found that 68 percent of respondents agreed with the statement, "When reporting medical and health news, the media often contradict themselves, so I don't know what to believe."

This bodes ill in a democracy in which scientific and technological issues are growing increasingly complex. Citizens can't make informed policy choices if they don't comprehend the questions before them.

Herewith, then, is a beginner's guide to interpreting science news.

1. Science is a journey, not a destination. As wisely noted by former Harvard Provost Harvey V. Fineberg, the latest recent scientific study does not set the standard for truth, nor does it demolish all earlier findings.
2. What's left out of a story can be as important as what's kept in. Always assume that any single article doesn't tell the whole story. Reporters often face confined space in the newspaper or limited time in a broadcast, and they frequently write under deadline pressure.
3. Journalistic "balance" is not the same as "accuracy." The mere existence of conflicting opinions in a single story does not ensure that the conclusions are factual.
4. Not all research is scientific. Special interest groups have been known to commission not just research, but research findings to advance a cause.
5. Science can become politicized. Universities and researchers sometimes compete for public funding. The politicians holding the purse strings aren't necessarily expert in knowing what research most "deserves" support from a scientific standpoint.
6. Not all correlations are causes. Just because two events occur together does not mean there is a causal link. The strength of scientific findings largely rests on how carefully researchers have controlled for other possible causes.
7. Answers to the following questions must be obtained to evaluate the validity of any research:

- What was the precise research question?
- When did the research start and end?
- Did researchers stick to the scientific method?
- Has the research been peer reviewed?
- How was the study performed? Was there a control group?
- What was the sample size? Was it large enough to be statistically significant?
- What does other research say about the subject?

If guided by time-tested principles, you don't need a Ph.D. to distinguish between most junk science and sound science. This concern isn't intellectual elitism: Scientific reasoning is an important underpinning of much law and regulation, particularly as it relates to public health and the environment. As Jefferson noted: "If a nation expects to be ignorant and free, in a state of civilization, it expects what never was and never will be." ■

Michigan's Environment

Getting Better All the Time

By Bruce Edward Walker

Michiganians are justifiably proud of their natural surroundings. They prize the recreational opportunities available throughout the Great Lakes, and many residents depend on the state's unique geography and abundant resources for their livelihoods. Not surprisingly, concerns about pollution, non-native species and land use run strong.

Despite these concerns, however, there is plenty of good news about Michigan's environment. Consider the following summary of findings from the Michigan Department of Natural Resources' third biennial report on the state of Michigan's air, water and forests.[1]

Forests

Conventional wisdom holds that forestland is disappearing fast. In fact, stands of maple, birch and beech trees increased by 1 million acres between 1980 and 1993, and overall, the state netted 538,000 acres of forest (on non-federal lands) between 1982 and 1997. Moreover, the volume of standing timber increased from 18 million to 30 million cubic feet between 1980 and 2003.

According to the report, "(M)ore growth has been continuously added to the forest than what has been removed or died through natural causes. Annual growth has steadily increased over the past 50 years."

Birds

The bald eagle population is soaring in Michigan. In 1961, when the Department of Natural Resources launched its annual census of eagles, the number of nests was just 50. In 2004, the figure reached 427. During the same period, the number of bald eagle fledglings per nest increased 50 percent, from 0.42 to 0.63. Also noteworthy is the dramatic decline in levels of polychlorinated biphenyl — PCB — in eagles' blood during the past decade.

Forest maturation and the alteration of habitat have contributed to a decline in the numbers of grassland bird species, including the eastern meadowlark, bobolink and vesper sparrow. But population increases have occurred among "generalist" species, such as the house finch, northern cardinal, house wren and eastern bluebird.

Fish

Mercury and PCB levels in Michigan fish have declined significantly, according to extensive tissue testing by the Michigan Department of Environmental Quality.[2] PCB levels peaked at nearly 24 parts per million in 1975, but declined to just 1 part per million in 2000. Mercury levels also have plummeted, from a high of 0.45 parts per million in 1993 to less than 0.25 parts per million in 2000.

The number of walleye in Michigan has fluctuated during the past three decades. The walleye population was small in the 1970s and early 1980s; peaked in 1989; declined between 2000 and 2003; and rebounded in 2004 to its highest level in a decade.

The number of lake trout in Michigan has increased dramatically. Restrictions on commercial fishing, stocking from trout hatcheries and efforts to control sea lampreys have helped the population rebound. According to the report, "By the mid-1990s, wild lake trout abundance increased to a point where stocking of hatchery-produced fish was discontinued in all areas of Michigan's waters of Lake Superior, except in Keweenaw Bay and Whitefish Bay."[3]

Brook trout and brown trout populations in the Au Sable River also have expanded significantly since the early 1990s, signaling habitat improvements.

Other Wildlife

Wolves, bears and deer are plentiful in Michigan, according to the report. In particular, the steady increase in the number of gray wolves indicates that declines in wildlife populations are reversible, despite alarmist claims to the contrary.

The bald eagle population is soaring in Michigan

Air

The state routinely monitors six pollutants designated as hazardous to human health under the federal Clean Air Act: carbon monoxide, lead, nitrogen dioxide, ozone, sulfur dioxide and particulate matter. As the findings below suggest, state monitoring indicates that Michigan's air quality has improved steadily in the past three decades.

Carbon Monoxide

Carbon monoxide levels in Michigan register far below the concentrations deemed unsafe by the U.S. Environmental Protection Agency — two-thirds less, in fact. Carbon monoxide levels in the state have fallen by 20 percent since 1990.

Lead

All metropolitan areas in Michigan have met the air quality standard for lead since 1985. According to the report, current levels of lead throughout Michigan are "50 times less" than the level deemed unsafe by the U.S. Environmental Protection Agency. Much of this reduction is attributed to the removal of alkylated lead from gasoline.

Nitrogen Dioxide

Nitrogen dioxide levels in Michigan hover near 0.01 and 0.02 parts per million, which is less than half of the amount deemed unsafe by the federal government.

Ozone

All Michigan counties were in attainment for the federal ozone[4] standard. In July 2005, the EPA designated 25 Michigan counties as in "nonattainment" for a new, more stringent 8-hour ozone standard.[5] However, in 2006, all but one of the state's 27 monitoring sites were meeting this more restrictive standard. When data for Michigan's ozone monitoring sites is averaged for the period from 2003 to 2005, 24 of the state's 27 sites met the newly imposed more restrictive federal standard.

Sulfur Dioxide

According to the report, sulfur dioxide levels in Michigan have decreased to less than one-fourth of the maximum amount deemed unsafe by the federal government.

Particulate Matter

Particulate matter is comprised of solid particles, fine liquid droplets or condensed liquids absorbed into solid particles. Across Michigan, levels of particulate matter less than 10 micrometers in diameter have remained well below the maximum amount permitted by the federal government. State data also indicate that only Wayne County is not meeting federal standards for particulate matter measuring 2.5 micrometers or less.

In summary, the data suggests a significant and widespread rebound in Michigan's environmental quality since the 1950s and 1960s. Even as Michigan confronts ongoing environmental challenges, state residents can know that the natural surroundings in which they take pride are not just beautiful, but much cleaner, too. ■

1 Harrison, K.G. (ed.). 2006. "State of Michigan's Environment 2005, Third Biennial Report," January 20006. Prepared by KGH Environmental PLC for the Michigan Departments of Environmental Quality and Natural Resources, Lansing, 100p. The full report can be found at http://www.deq.state.mi.us/documents/deq-osep-ftp-deqdnrei05.pdf.

2 The DEQ has collected and analyzed more than 17,000 fish tissue samples from more than 800 locations since 1980.

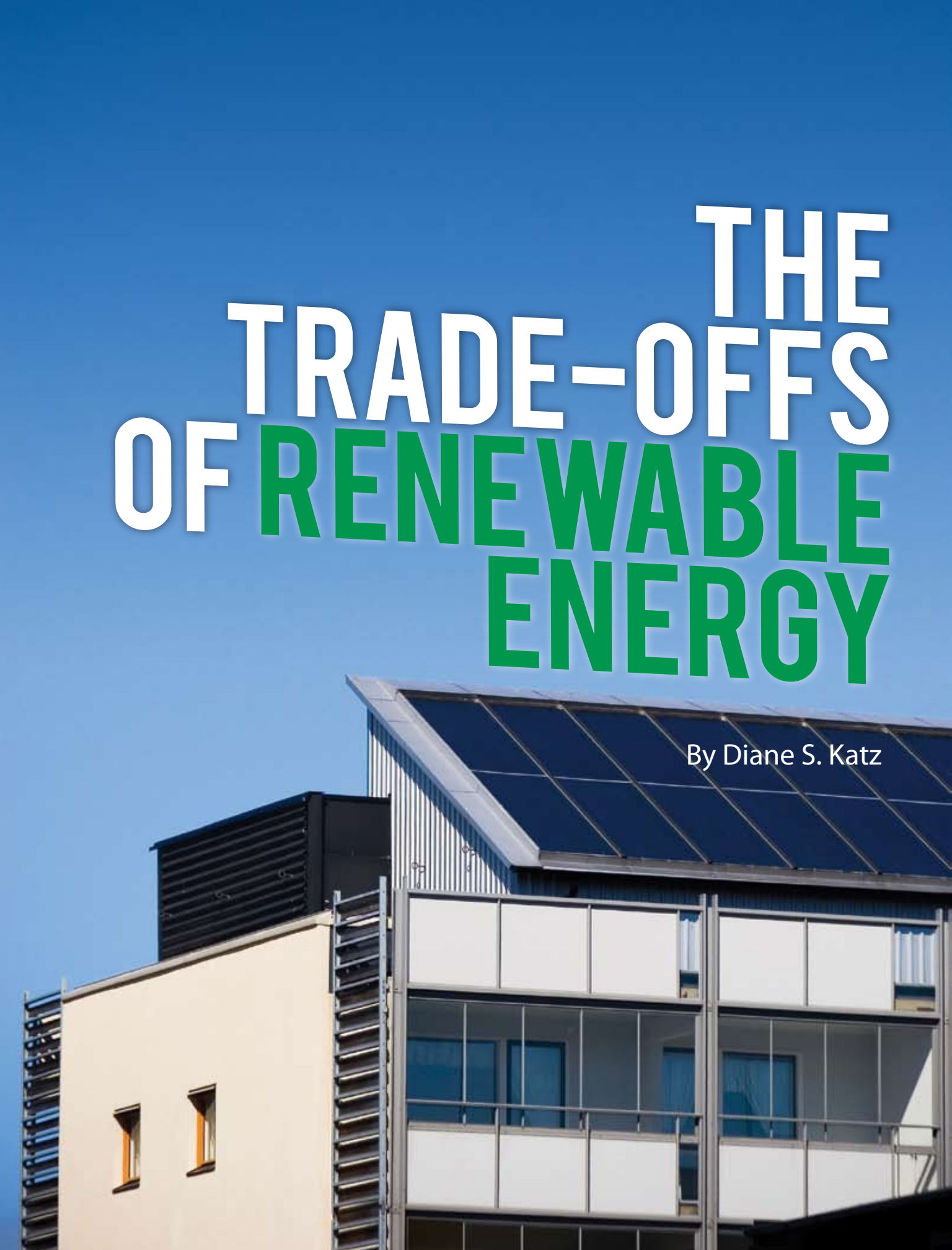
3 Most lake trout in Whitefish Bay originated from hatcheries, according to the DEQ.

4 Ozone is formed when nitrogen oxides react in the presence of sunlight with volatile organic compounds, such as paint solvents, vehicle exhaust and degreasing agents.

5 The original standard was based on concentrations exceeding 0.12 parts per million in the course of one hour; the stricter standard is based on concentrations exceeding 0.08 ppm over eight hours.

THE TRADE-OFFS OF RENEWABLE ENERGY

By Diane S. Katz



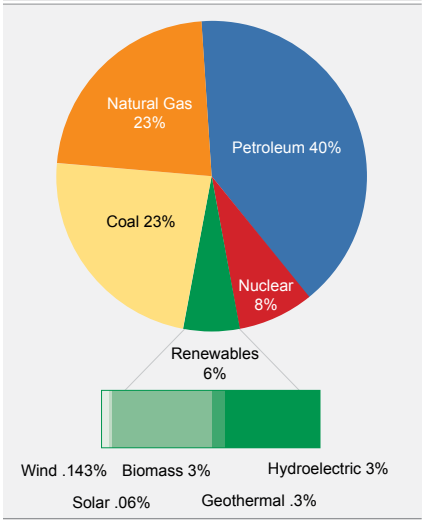
FROM THE OVAL OFFICE to state legislatures, politicians are talking up "renewable" energy as the cure for America's "addiction to oil"[1] and the best hope for independence from OPEC.

Gov. Jennifer Granholm suggests we can reverse Michigan's moribund economy by making the state the "epicenter" of alternative fuel research and development, while U.S. Rep. Joe Knollenberg, R-Bloomfield Hills, recently informed voters in a campaign letter that he stands for "Innovative Renewable Solutions."

Time will tell whether energy derived from sunlight, wind and corn can fulfill these ambitious objectives. But as in all matters related to natural resources, a basic foundation of scientific knowledge is necessary to craft intelligent policy.

[1] President George W. Bush, State of the Union, Jan. 31, 2006. Available on the World Wide Web at http://www.whitehouse.gov/stateoftheunion/2006/

U.S. Energy Consumption by Type



Source: Energy Information Administration (U.S. Department of Energy)

Energy derived from so-called renewable sources now comprises about 6 percent of the more than 100 quadrillion Btu[2] that Americans use annually.[3] As the chart above illustrates, the largest shares of renewable energy currently consumed are hydroelectric[4] and biomass.[5]

Should present trends continue, the share of energy generated from renewable sources is projected to grow slightly in the next two decades.[6] Congress and state legislatures, however, are considering enactment of "renewable portfolio standards" that would require power companies to generate a quota of electricity from renewable sources.

2 A British thermal unit is a measurement of energy content. One Btu is equal to the amount of heat required to raise the temperature of one pound of water by 1 degree Fahrenheit at water's maximum density, which occurs at a temperature of 39.1 degrees Fahrenheit.
3 Energy Information Administration, U.S. Department of Energy, "Renewable Energy Trends 2004." Available on the World Wide Web at http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/rentrends04.html.
4 Electricity produced by turbines that are driven by falling water.
5 Electricity produced by processing plant and animal waste — for example, burning wood to create steam for turbines, capturing methane from landfills or producing combustible alcohols from crops.
6 Energy Information Administration, U.S. Department of Energy, op. cit.

Such standards are in effect in 20 states and the District of Columbia, and at least two bills to establish a similar standard in Michigan are pending in the Legislature. House Bill 4608 would require electricity suppliers to generate or acquire from renewable sources not less than 4 percent of the electricity sold to retail customers, with at least 1 percent of the required renewable energy being solar. The renewable energy quota would increase to 7 percent of the power sold by 2013. Similarly, House Bill 4154 would require that no less than 7 percent of retail electricity be generated from renewable sources, with the standard increasing to 15 percent by 2015. The bill also mandates that at least 5 percent of the required renewable energy be solar. In both measures, utilities would be permitted to increase retail rates to offset the higher costs of renewable energy.

Also pending is House Bill 4584, which would authorize a sales tax break of up to $60 on the purchase of equipment that uses renewable energy sources to heat, cool or supply electricity to residential and commercial buildings. Earlier this year, the Legislature approved creation of 10 "renaissance zones" in which tax breaks will be offered to lure renewable energy facilities.

In 2004, the most recent year for which total energy production data are available, Michigan ranked 12th nationwide in the amount of electricity generated annually — more than 118.5 million megawatt-hours.[7] Coal was the most common fuel source, generating 58 percent of the electricity in the state, followed by nuclear power (26 percent) and natural gas (13 percent).[8]

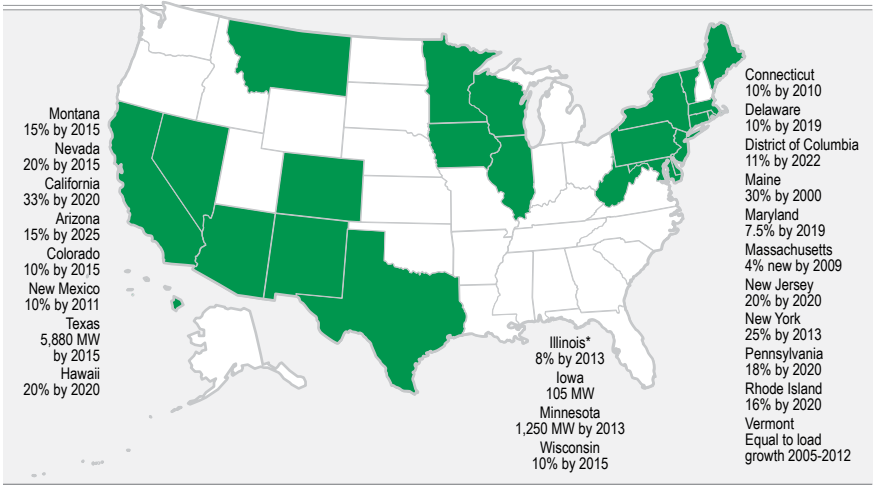
In 2003, the most recent year for which detailed renewable energy data are available, hydroelectric power was the single biggest source of renewable energy in Michigan, with a net generation[9] of about 1.31 million MWh.[10] Ranking second as a net generator of renewable energy is a combination of wood and wood products, at about 1.02 million MWh. Ranking third, fourth and fifth respectively are a combination of landfill gas and municipal solid waste, at 658,861 MWh; other biomass, such as agricultural byproducts, at about 124,751 MWh; and wind, at about 2,660 MWh.[11]

Whether government should drive further development of alternative energy is a policy issue, not a scientific one. Secretary of Energy Samuel Bodman has named former Exxon-Mobil Chief Executive Officer Lee Raymond to head a federally funded study charged with issuing recommendations for U.S. energy policy through 2025. In Michigan Gov. Granholm has requested an energy plan by year's end from Peter Lark, chairman of the state Public Service Commission. Likewise, state Sen. Bruce Patterson, R-Canton, chair of the Energy and Technology Committee, has assembled a bipartisan working group to develop a long-range energy plan for the state.

Opinions vary widely about the reliability of oil imports, the environmental impacts of fossil fuels and the economics of energy subsidies[12] and regulatory

7 One megawatt-hour (abbreviated as "1 MWh") is equivalent to 1 million watt-hours. The average household uses about 10.7 MWh of electricity per year, according to the U.S. Environmental Protection Agency.
8 Energy Information Administration, U.S. Department of Energy, "State Electricity Profiles 2004: Michigan." Available on the World Wide Web at http://www.eia.doe.gov/cneaf/electricity/st_profiles/michigan.pdf.
9 The figures provided for renewable energy sources in this paragraph involve net production, not gross production, and therefore should not be compared to the figures in the preceding paragraph.
10 Although hydroelectric power traditionally has been characterized as a renewable energy source, some environmentalists object to that characterization because dams and reservoirs can harm fish and waterways.
11 "Energy Information Administration, U.S. Department of Energy, "Renewable Energy Trends 2004." Available on the World Wide Web at http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table18.pdf. According to the Energy Information Administration, the state of Michigan did not provide data for commercial generation of power from solar or geothermal energy sources.
12 Government support of renewable energy exceeds $1 billion annually, according to estimates by the U.S. Department of Energy.

The Expanding Role of U.S. Statewide Renewable Portfolio Standards



*Source: Pew Center on Global Climate Change *Illinois implements its RPS through voluntary utility commitments.*

mandates. But even if consensus were achieved tomorrow, a host of scientific and technological challenges would still need to be overcome before renewable energy could replace fossil fuels to any measurable degree.

This is not to say that conventional sources of energy haven't presented problems — noxious emissions and black lung disease among them. But the political focus at present is firmly fixed on renewables, and our expectations will be realistic only if we acknowledge the trade-offs among various energy alternatives.

The section that follows provides an overview of these issues.

Solar Power

Light from the sun can be converted directly to electricity by means of a "photovoltaic cell." Most PV cells are made from wafers of silicon. When sunlight strikes a PV cell, electrons flow between the silicon layers. This current of electrons is then channeled through metal contacts attached to the cell.

At present, solar power is among the least efficient methods of generating electricity; PV cells absorb, at most, only about 25 percent of the available energy; much is lost through heat. Thus, any large-scale generation of solar power would require enormous areas of land to hold the multiple arrays of PV cells. Heating just a typical house would require a "collector area" of 200 square feet.

Solar energy produces a direct current, which must be converted to an alternating current for residential or commercial uses. This conversion consumes up to 10 percent of the electricity produced by a solar panel, further reducing the panel's low energy output.

The cost of silicon has escalated in recent years, as demand for semiconductors has increased. In response, manufacturers are attempting to produce thinner PV cells. Unfortunately, the metal strips used to connect the PV cells have a greater rate of heat expansion than silicon, and the thinner silicon wafers are more likely to break from the tension created by the cooling of the metal. The problem is intensified when the size of the metal contacts is increased to produce more power.

Also problematic is the inescapable fact that sunlight is variable, dependent on location and weather. This renders solar power somewhat unreliable. The use of rechargeable batteries can help, but many such batteries contain metals and other potential toxins, including lithium-ion (Ni), sodium-sulphur, nickel-cadmium, nickel-metal hydride, lead-acid, polysulphide-bromide, vanadium redox and zinc-bromine.[13]

Wind Power

Windmills have been a feature of rural America since the early 1900s.[14] A wind energy system transforms the kinetic energy of wind into mechanical or electrical energy.[15] In the production of electricity, the wind turns turbine blades that power a generator, and that power is then channeled to a transformer, which converts the electricity to the proper voltage for distribution along the power grid.

The power available from the wind is a function of the cube of the wind speed.[16] To operate cost-effectively, larger turbines require wind speeds of about 13 mph. The availability of sites with adequate winds has limited the widespread development of wind farms, according to Cornell University Prof. David Pimentel, who estimates that 13 percent of the land area in the contiguous United States would be serviceable.

Like solar power, wind is intermittent. It may change direction and speed by the hour. There also are nuisances to contend with. Wind power is noisy; the whirring of turbine blades can be heard more than half a mile away. A 2004 report in the London Daily Telegraph cited numerous studies linking wind turbine noise with a variety of ailments suffered by nearby residents, including headaches,

13 Carl Johan Rydh, "Environmental Assessment of Battery Systems: Critical Issues for Established and Emerging Technologies," 2003. Available on the World Wide Web at http://homepage.te.hik.se/personal/tryca/battery/rydh_thesis_abstract.htm.
14 David Pimentel et al., "Renewable Energy: Economic and Environmental Issues," BioScience, Vol. 44, No. 8, September 1994. Available on the World Wide Web at http://dieoff.org/page84.htm.
15 American Wind Energy Association. Available on the World Wide Web at www.awea.org/faq/cost.html
16 Ibid.

migraines, dizziness, palpitations and tinnitus, as well as sleep disturbance, stress, anxiety and depression.[17] "These symptoms had a knock-on effect in their daily lives, causing poor concentration, irritability, and an inability to cope," said researcher Amanda Harry.[18]

Wind farms also require large plots of open land — an estimated 2.5 acres per turbine, on average.[19] Transmission lines must be built to connect remote windfarms to the power grid. Constructing a wind farm also requires the manufacture of hundreds of tons of cement and steel.

Particularly troubling to environmentalists is the number of birds, including some endangered species, that are routinely killed by rotating blades (dubbed by the Sierra Club as "Cuisinarts of the Air").[20] For example, the sprawling wind farm at California's Altamont Pass, which features some 7,000 turbines,[21] kills thousands of birds each year, including golden eagles, red-tailed hawks and burrowing owls.

Geothermal Energy

Geothermal power harnesses steam from geysers and reservoirs to power electricity generators.

The inaccessibility of most geothermal sources is considered a major drawback. Only four states currently generate geothermal electricity: California, Nevada, Utah and Hawaii. Development of a geothermal system elsewhere would likely require deep drilling at a prohibitive cost.

Geothermal activity at Yellowstone National Park

Geothermal power is not environmentally benign. Most geothermal sources are located in remote wilderness areas, and building a geothermal plant requires the construction of roads, the installation of power lines and other industrial infrastructure.

Geothermal power also requires large amounts of water, the uptake of which can impact aquatic ecosystems and wildlife habitat. The release of wastewater from geothermal plants has the potential to contaminate surface water and groundwater. And depending on the amount of water and steam diverted, individual geothermal sites may be exhausted faster than they are naturally reheated.[22]

Biomass Energy

"Biomass" refers to organic matter, including wood, crops, animal wastes and even some household trash. Energy can be produced in a variety of ways, such as burning the biomass to create steam to run turbines or generate heat; producing alcohols from crops for combustion; and capturing gases to produce heat, steam or electricity. In most instances, generating energy from biomass entails either land-intensive agriculture or emissions-producing combustion.

The burning of biomass produces more emissions than the combustion of natural gas, but less than the burning of coal.[23] Burning most biomass can produce dioxins and furans. The combustion of solid biomass also produces both bottom ash and fly ash that presents disposal challenges.

Ethanol is a common form of biomass energy, and it is also the most subsidized. The majority of ethanol in the United States is made by distilling and fermenting corn, but ethanol can also be produced from wheat, grain sorghum, barley, potatoes and other starch or sugar crops.[24] There exists considerable debate about the utility of ethanol, with some researchers contending that twice as much energy is burned in the production of ethanol as is produced by ethanol. Critics also note that ethanol combustion in automobiles releases nitrogen oxides, formaldehydes and other air pollutants.[25]

Ethanol subsidies already drive intensive corn production, and increased production would impact the landscape. The Union of Concerned Scientists estimates that "to replace one-third of gasoline demand with ethanol even by 2050 … would require three times the land currently used for crops and doubling both the efficiency of making ethanol and its fuel economy."[26]

17 James M. Taylor, "Enviro Group Sues Wind Farm to Stop Bird Deaths," Environment News, The Heartland Institute, March 1, 2004. Available on the World Wide Web at http://www.heartland.org/Article.cfm?artId=14562.
18 Ibid. It is unknown whether these studies have been peer reviewed.
19 Ibid.
20 Robert L. Bradley Jr., "Renewable Energy: Not Cheap, Not "Green." Cato Institute Policy Analysis No. 280, August 1997.
21 Ibid.
22 "Geothermal Energy Resources: Principals and Recommendations," Defenders of Wildlife. Available on the World Wide Web at http://www.defenders.org/habitat/renew/geothermal.html.
23 David Pimentel et al., "Renewable Energy: Economic and Environmental Issues," BioScience, Vol. 44, No. 8, September 1994. Available on the World Wide Web at http://dieoff.org/page84.htm.
24 Ethanol.org. Available on the World Wide Web at http://www.ethanol.org/howethanol.html.
25 David Pimentel et al., "Renewable Energy: Economic and Environmental Issues," BioScience, Vol. 44, No. 8, September 1994. Available on the World Wide Web at http://dieoff.org/page84.htm.
26 Consumer Reports, "The Ethanol Myth," October 2006. Available on the World Wide Web at www.ConsumerReports.org. Although critics consider the Union of Concerned Scientists unreliable, there can be little

"I'm outta here! I'm moving to — WATCH OUT FOR THAT BLADE! — Alaska and taking my chances with the tanker spills!"

Intensive corn production may cause serious soil erosion and require the further drawdown of groundwater resources, according to Prof. Pimentel, who also notes that the fermentation process produces about 13 liters of sewage effluent for each liter of ethanol.

Hydroelectric Power

Hydroelectric power is produced by the force of falling water. This water spins turbine blades, which in turn drive electricity generators. A century ago, hydroelectric plants supplied nearly one-half of the nation's power

The environmental impacts of hydroelectric power have led some critics to challenge the conventional characterization of hydroelectricity as a renewable energy. For example, dams along the Atlantic and Pacific coasts have reduced salmon populations by preventing access to spawning grounds upstream. Turbines also are known to kill juvenile salmon on their migration to the sea.[27]

Hydroelectric dams also pose risks to humans, as they are frequently located upstream from major population centers. Major dam breaks have resulted in hundreds of fatalities. Finally, the water discharged from turbines is relatively free of suspended sediments. When released, it can "scour" downstream riverbeds and erode riverbanks.[28] Moreover, hydroelectric reservoirs in tropical regions produce substantial amounts of methane and carbon dioxide, as plant material beneath newly flooded and reflooded areas decays.

Conclusion

There's no shortage of human ingenuity to solve the myriad challenges posed by a transition to renewable energy. But policymakers and the public should not take political rhetoric at face value and assume the inherent superiority of non-fossil fuels. All forms of energy impose environmental costs. Sound policy can be crafted only by acknowledging the trade-offs inherent in the production of every type of power. ■

doubt that increased ethanol production would have an environmental impact.

27 "Hydroelectricity," Wikipedia, Oct. 27, 2006. Available on the World Wide Web: http://en.wikipedia.org/wiki/Hydroelectricity#Disadvantages.
28 Ibid.

Looking Ahead

By Russ Harding

There won't be a shortage of environmental debates in coming months, as state lawmakers and regulators turn their attention to the following issues:

Mercury. The Michigan Department of Environmental Quality has formed a working group to propose more stringent mercury regulations for coal-fired power plants. The assignment stems from Gov. Jennifer Granholm's directive of April 17, 2006, mandating a 90 percent reduction in mercury emissions from these plants instead the 70 percent reduction already required by the federal Clean Air Mercury Rule. Look for the working group's recommendations in early 2007.

Water Conservation Practices. Legislation approved last year to limit groundwater withdrawals mandates new conservation measures. The Michigan Chamber of Commerce is forming a committee to suggest appropriate water management practices. Observers expect the recommendations to be unveiled after the new legislative session opens in January.

Particulate Matter Air Standard. A stricter federal standard for the amount of particulate matter in the air will require the Michigan Department of Environmental Quality to amend the state's emissions control plan. The revised plan and subsequent rule-making must secure federal approval.

Permits for Nickel, Copper and Zinc Mining. A ruling is forthcoming in a lawsuit challenging an application by Kennecott Mining Company to mine nickel, copper and zinc in an area northwest of Marquette, Mich. Mining opponents sued to force the MDEQ to convene a "contested case hearing" on whether the company's application was complete.

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