RENEWABLE ENERGY, EFFICIENCY, AND CONSERVATION

DECISION-MAKERS
FIELD CONFERENCE 2002
San Juan Basin

NEW MEXICO'S ENERGY, PRESENT AND FUTURE

Policy, Production, Economics, and the Environment

Brian S. Brister and L. Greer Price, Editors

This electronic document is part of a larger work that can be obtained from
The New Mexico Bureau of Geology

http://geoinfo.nmt.edu/publications/decisionmakers

or call: [505] 835-5410

New Mexico Bureau of Geology and Mineral Resources
A Division of New Mexico Institute of Mining and Technology
2002

Wind turbines at Altamont Pass, California

Renewable Energy in New Mexico: Current Status and Future Outlook

Chris J. Wentz, *Energy Conservation and Management Division*
New Mexico Energy, Minerals and Natural Resources Department

Renewable energy is energy produced from naturally occurring, renewable resources that are virtually inexhaustible. These resources include solar, wind, hydroelectric, biomass, and geothermal. Renewable resources share a number of common attributes that make them attractive for the production of power: reduced environmental impacts, no or low fuel costs, and sustainability of supply. Moreover, renewable energy technologies have improved significantly over the past few decades—some to the point where they are already cost-competitive in certain markets with new conventional power plants (e.g., large commercial wind farms vs. coal-fired generation). Despite these technological advances and inherent environmental benefits, the development and use of renewable energy resources in New Mexico has been minimal. This paper will look at New Mexico's renewable resource base, end-use applications for these resources, their potential as a driver for economic development, and what barriers may be impeding more widespread use.

BACKGROUND

According to the 2000 census, New Mexico currently has a population over 1.8 million. New Mexico's total electric generating capacity now stands at approximately 5,700 megawatts (MW). Of that total capacity, about 88% is from coal-fired power plants; most of the remainder (10%) is natural gas-fired electrical generation. New Mexico is a net exporter of electricity, consuming only slightly more than half of the electric power it produces. The remaining electricity (43-48% per year on average) is sold out-of-state on the wholesale power market.

The U.S. Department of Energy's National Renewable Energy Laboratory estimates that renewables presently account for 81 MW of our total commercial generating capacity—less than one-quarter of one percent of all electricity produced within the state. This total renewable electric capacity in New Mexico (81 MW) consists predominantly of hydropower (80 MW, 99% of total renewable production), with wind (0.66 MW) and solar photovoltaics (0.08 MW) providing the balance.

RENEWABLE ENERGY RESOURCES IN NEW MEXICO

New Mexico has a very large and diverse renewable energy resource base. This resource base, which includes solar, wind, hydroelectric, biomass, and geothermal, extends throughout the state and to every county. Much of the following information on our renewable resources was compiled from nationally recognized sources and adopted by consensus among participants in the New Mexico Sustainable Energy Collaborative, a recently formed (2001) renewable-energy advocacy group of diverse organizations and individuals representing private industry, government, electric utilities, national laboratories, trade associations, environmental/public interest groups, and universities.

- *Solar* New Mexico experiences more than 3,200 hours of sunshine per year—substantially more than most other states in the Southwest. Nationally, we rank among the top three states in solar resource potential. As an example of this potential, a photovoltaic (PV) array with a collector area equal to the size of a football field, strategically situated, would be sufficient to power over 122 average homes. Thus, energy from the sun represents a potentially enormous energy resource readily available for both thermal and electrical generation applications within the state.
- *Wind* According to the U.S. Department of Energy, New Mexico ranks 12th in the nation—the upper echelon—in wind energy resources. Ongoing wind monitoring studies by the Energy, Minerals and Natural Resources Department confirm that a number of sites in eastern New Mexico have very good wind speeds (15-20 miles per hour) capable of utility-scale electricity production. Significantly, if New Mexico's total wind potential were developed with large, state-of-the-art wind turbines, the power produced each year would equal approximately 25 times the entire state's electricity consumption. Other states, such as Texas, with comparable potential are currently

adding hundreds of megawatts of wind electric generating capacity. At present, however, total installed commercial wind capacity in New Mexico amounts to less than 1 megawatt from a single wind turbine near Clovis operated by Southwestern Public Service Company/Xcel Energy.

- *Hydroelectric* Hydropower facilities take advantage of the kinetic energy of flowing or falling water to generate electricity. At present, nine commercial hydroelectric plants are in operation in New Mexico, including Navajo Dam on the San Juan River near Aztec (30 MW), Elephant Butte Dam on the Rio Grande near Truth or Consequences (24.3 MW), Abiquiu Dam on the Rio Chama near Los Alamos (15 MW), El Vado Dam on the Rio Chama near Tierra Amarilla (8 MW), and other smaller facilities less than 1 megawatt in size. Although no new large hydropower plants are scheduled for construction in New Mexico, past studies by the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers concluded that 18 of the largest undeveloped sites in the state have the potential to generate over 3.5 billion kilowatt-hours of electricity per year. However, numerous constraints limit New Mexico from realizing its full hydropower potential. These constraints include financing, multi-use issues, regulatory barriers, environmental considerations, and economic factors.
- *Geothermal* Geothermal resources exist in at least 20 of New Mexico's 33 counties, with more than 300 thermal springs and wells identified to date. According to the U.S. Geological Survey, our geothermal resource base contains the thermal energy equivalent of more than 100 billion barrels of oil. These geothermal resources have to date not been used for commercial electrical generation but have been tapped for direct-use applications. At present, approximately 50 acres of greenhouse space and an aquaculture facility in southern New Mexico are heated with geothermal energy, as is part of the New Mexico State University (NMSU) campus in Las Cruces; however, no commercial geothermal electric generation is under development or in operation.
- *Biomass/Biofuels* This renewable energy resource is derived from plants or animal waste. New Mexico also has an abundant diversity of biomass resources, including wood or wood waste, agricultural residues, livestock/dairy manure, sewage sludges, and municipal solid wastes (e.g., in landfills). Energy is derived from these sources by direct combustion or conversion to methane or alcohol. A 1990 study conducted by the Southwest Technology Development Institute at NMSU indicates that the biomass waste generated in 1988 alone had a potential energy content of 35 trillion BTUs—many times greater than our state's total daily energy consumption. At present, municipal sewage plants in Albuquerque, Carlsbad, Las Cruces, Los Alamos and Roswell produce biogas (methane) for generating heat and electricity for their internal consumption. With much forest thinning scheduled over the next few years, coupled with the continuing rapid expansion of our dairy industry, biomass resources have great potential to supply an increasing amount of New Mexico's future energy.

In general, at least one or more of our abundant renewable resources are available to residents and businesses of every county in New Mexico.

RENEWABLE ENERGY TECHNOLOGIES AND END-USE APPLICATIONS

Renewable resources in New Mexico can be used to generate electricity, thermal energy (heat), or both.

- *Solar* ***Passive solar*** systems take advantage of building design and natural physical properties to store and transfer heat. Most new home and office construction in New Mexico could use passive solar energy to some extent to reduce heating and lighting costs. ***Solar photovoltaic*** (PV) technologies, which convert sunlight directly into electricity, are commercially available and in use nationwide for such applications as powering residential and commercial buildings, running irrigation pumps, and lighting billboards and mobile highway construction signs. International demand and new building-integrated PV systems hold much promise in the near term for increasing the market penetration of solar photovoltaics. PV power generation costs have decreased substantially to between 15 and 30 cents per kilowatt-hour (kWh) over a typical 25-year system life, but this is still more expensive than the price of electricity paid by most New Mexicans. ***Solar thermal*** technologies—specifically solar air and water heaters, are well-established, reliable technologies whose use could be much more widespread. ***Solar thermal electric*** systems, which use parabolic troughs, central receiver stations ("power towers") or parabolic dish/stirling engines to concentrate sunlight to produce heat that is then converted into electricity, are in the early stages of commercialization; yet these technologies are particularly suitable for deployment in New Mexico due to our many cloudless days of sunshine.

- *Wind* Wind energy technologies are currently available for generating electricity for homeowners and businesses or at a utility scale (capacities in excess of 225 kilowatts). Unlike our solar resources, wind is very site-specific and therefore not available in every New Mexico locale. It also is an "intermittent" resource capable of generating electricity only when the wind blows. ***Wind turbines*** have improved significantly over the past two decades. Increased turbine size, research and development advances, and manufacturing enhancements have all contributed to driving down the installed (wholesale) cost of wind power generation to around 3–4 cents per kWh today for large wind farms. This cost is now on par with electricity produced from new coal-fired generating plants.
- *Geothermal* Geothermal energy can be used to generate baseload electricity and for direct application in space and water heating or other thermal processes. Like wind energy, geothermal is a site-specific resource that must generally be transformed into electricity or used directly where it is found. ***Geothermal technologies*** for electric power generation have improved considerably to the point where costs presently average 5–8 cents per kWh for existing geothermal plants. Southern New Mexico currently supports a thriving greenhouse and fish farming industry on geothermal resources, and these direct-use applications of geothermal energy are already cost-competitive with conventional resources.
- *Biomass* ***Biomass technologies*** are many and varied and have the capability of producing electricity and/or thermal energy. They include direct-combustion steam turbine technology, which is the principal process in use today for converting biomass into electricity. Biomass-generated methane can also be co-fired with conventional resources such as coal to extend fossil fuel supplies and reduce air pollution emissions.

RENEWABLES: A DRIVER FOR FUTURE ECONOMIC DEVELOPMENT

As indicated in the preceding sections, New Mexico has been blessed with significant renewable energy resources. It also has a considerable government presence at the federal, state, and local levels, which collectively represent a sizable load of electrical and thermal energy demand. Facilities in New Mexico, including our two national laboratories (Sandia and Los Alamos), Kirtland Air Force Base, and the state government's capitol complex in Santa Fe, each have sizable utility bills ultimately paid by New Mexico taxpayers on a recurring basis. In many instances, these utility costs could be lowered over the long term through the targeted, more effective use of renewables. This, in turn, would free up limited government revenues for other pressing needs—including job creation.

New Mexico also has the necessary human resources to develop and support a more vibrant renewable energy industry within its borders. Staff at both Los Alamos National Laboratory and Sandia National Laboratories-Albuquerque are already involved in many renewable research, development, and demonstration projects—activities likely to continue well into the future given the events of September 11, 2001, and the renewed focus they have placed on all forms of domestic energy production. Similarly, existing organizations such as the Southwest Technology Development Institute at NMSU (which has operated the SW Regional Solar Experiment Station in Las Cruces for over 20 years), our colleges and universities, and existing renewable energy businesses together possess a vast reservoir of expertise and experience that could be used to greatly expand the renewables industry in New Mexico.

RENEWABLE ENERGY BARRIERS AND INCENTIVES

Barriers. A number of barriers are usually cited by informed observers as impeding the development and use of New Mexico's renewable energy resources. Cost-competitiveness persists as one of the primary barriers to the increased market penetration of renewables. Transmission availability and access is another substantive impediment for bringing additional renewable electric generation capacity on-line. Embodied in the transmission issue are applicable standards and corresponding costs for connection of renewable technologies to the existing power grid. The state's tax structure is another factor identified by commercial developers in recent years as holding back

Solar Photovoltaic Power
A Native American Success Story

David S. Melton
Diversified Systems Manufacturing

The Native American Pueblo tribes of the Southwest have long realized the power of the sun. Respect for that power was clearly evident in the design and execution of the solar carport located on the premises of the Indian Pueblo Cultural Center (IPCC) in Albuquerque, New Mexico. One of the important purposes of the solar project was to inform the public of the benefits of renewable energy: economic development, cost reduction of the IPCC energy bill, conservation of natural resources including coal and water, and greenhouse gas reduction.

The solar carport goes beyond meeting the need for shaded parking for the 400,000 visitors the center receives each year. It integrates solar cells that use visible light and other natural electromagnetic radiation from the sun to generate voltage. The carport not only supplies power to the IPCC building, it is also tied to the commercial grid through the process of net metering (see article by Pat Scharff, this volume). It produces 25.5 megawatts of power annually and provides more than three thousand dollars in savings to the IPCC. This renewable energy generator saves an estimated 44 tons of coal and 1 million gallons of water, and it eliminates air emissions that would otherwise be produced in generating that energy through conventional power sources.

Diversified Systems Manufacturing, a Native American-owned and operated firm located at the IPCC, formulated the concept of the solar carport and completed the project using a number of local contractors. Laguna Industries, Inc., owned and operated by the Pueblo of Laguna, manufactured the steel and aluminum components. The Pueblo of Zia granted permission to incorporate the traditional Zia sun symbol in the decoration of the solar carport. The color and texture of the structure complements that of the IPCC.

The project was made feasible by a grant from the New Mexico Department of Energy, Minerals and Natural Resources. Successful demonstration of the technology has stimulated similar projects at Native American facilities at the Pueblo of Laguna and the Southwest Indian Polytechnic Institute (SIPI).

---

the growth of renewables here. Finally, and perhaps most importantly, the lack of public information, education, and outreach on renewable energy, its applications, costs, and benefits is a formidable barrier in evidence throughout New Mexico and the nation.

Incentives In comparison to other states, New Mexico offers virtually no incentives to encourage development of a vibrant renewable energy industry within the state. [Note: When this paper went to press, the New Mexico Legislature had under consideration a number of bills that would provide incentives for renewable energy development.] There is a solar access law on the books (Solar Rights Act); and the New Mexico Public Regulation Commission has a net metering rule (NMPRC Rule 571) in effect that benefits small (<10 kilowatts) residential and commercial renewable electric systems. In addition, the Electric Utility Industry Restructuring Act establishes a System Benefits Charge/Fund in 2007; it will provide considerable funding ($4-6 million annually) for renewables projects here. Other proposed incentives that should be reviewed in New Mexico include:

- *Renewable portfolio standards*, which require utilities to build or procure renewable energy so that it constitutes a certain minimum percentage of their total electric generating capacity.
- *Green pricing programs*, whereby electric utilities offer an optional service through which their customers can support a greater level of utility

investment in renewable energy technologies.

- *Tax credits* for renewable energy production and equipment, which help reduce the cost of renewable projects by credits against taxes owed.
- *Tax rebates* for purchase and installation of renewable energy technologies, which also assist in lowering the investment cost of renewables.
- *Demonstration project funding*, particularly for renewable projects at state facilities and in high visibility locations.
- *Funding for public information, education, and outreach on renewable energy*.

CONCLUSIONS AND RECOMMENDATIONS

New Mexico has the appropriate mix of natural, physical, and human resources to become a national leader in the renewable energy arena. Stimulating growth of the renewable energy industry here will generate both jobs and revenues within our borders, particularly in rural areas. Moreover, increased development and use of renewables will diversify the state's energy supply mix, improve air quality, reduce water consumption from prospective power generation, and enhance our energy security through greater reliance on domestic resources. Given the potential benefits to New Mexico from renewable energy development, one goal is clear: overcoming the barriers that stand in the way of development and implementing industry incentives. Doing so is in the best interests of New Mexico and its citizens.

REFERENCES AND ADDITIONAL INFORMATION

New Mexico Energy, Minerals and Natural Resources Department, New Mexico's Natural Resources 2001; this and previous annual reports are available from the Department at 1220 S. St. Francis Drive, P.O. Box 6429, Santa Fe, NM 87505 505/476-3200).

New Mexico Energy, Minerals and Natural Resources Department homepage: http://www.emnrd.state.nm.us

Database of State Incentives for Renewable Energy: http://www.dsireusa.org

Larsen, C., and Rogers, H., 2000, National Summary Report on State Financial and Regulatory Incentives for Renewable Energy, North Carolina Solar Center (NCSC), Industrial Extension Service, North Carolina State University, December 2000; this report is available from the NCSC at Box 7401, Raleigh, NC 27695 (919/515-3480).

National Renewable Energy Laboratory, 1999, Choices for a Brighter Future: Perspectives on Renewable Energy, DOE/GO-10099-878, September 1999.

National Renewable Energy Laboratory homepage: http://www.nrel.gov

New Mexico Solar Energy Association homepage: http://www.nmsea.org

Porter, K., Trickett, D, and Bird, L., 2000, REPiS: The Renewable Electric Plant Information System, National Renewable Energy Laboratory (NREL), NREL/TP-620-28674, August 2000; this report is available from NREL at 1617 Cole Boulevard, Golden, CO 80401.

U.S. Department of Energy, Energy Information Administration, Renewable Energy Annual 2000, DOE/EIA-0603(2000), March 2001. http://www.eia.doe.gov/fuelrenewable.html

U.S. Department of Energy, Energy Information Administration, Renewable Energy 2000: Issues and Trends, DOE/EIA-0628(2000), February 2001. http://www.eia.doe.gov/cneaf/solar.renewables/rea_issues/rea_issues_sum.html

U.S. Department of Energy/Energy Efficiency and Renewable Energy homepage: http://www.eren.doe.gov

U.S. Department of Energy/Energy Information Administration homepage: http://www.eia.doe.gov

New Mexico's Geothermal Energy Resources

James C. Witcher, *Southwest Technology Development Institute, New Mexico State University*

Geothermal energy is rarely mentioned by policy makers and the media as a viable renewable energy source or a cost-competitive alternative to fossil fuels. As a result, this survey of geothermal use and its economic impact in New Mexico may surprise many. Geothermal energy is a prominent (perhaps the leading) renewable resource in New Mexico in terms of economic impact. Given the large geothermal resource base in the state, the potential for future economic benefits is enormous.

GEOTHERMAL RESOURCES

An accessible geothermal resource base is defined as heat that is stored in the conventionally drillable part of the earth's crust. This heat is continually augmented by radioactive decay of naturally occurring uranium, thorium, and potassium in the earth's crust, and by heat that is conducted into the crust from the even hotter core and mantle below. In other words, the crust acts as a low grade nuclear reactor, with additional heat provided from deeper within the earth. In regions with young and active volcanoes, locally intense heat may be introduced into the crust by magma that rises upward through weaknesses in the crust from partially melted regions of the mantle.

Geothermal resources result from geologic processes that provide a ground-water flow path to concentrate deep-seated heat at economically drillable depths. Elements involved are: 1) a recharge source for the water; 2) a heat source; 3) an upflow zone; and sometimes, 4) a discharge zone. The most porous and permeable upper portions of the upflow zone and the shallow lateral-flow discharge zone are where geothermal resources are most easily exploited.

The shape of a typical geothermal reservoir may resemble a small isolated summer thunder cloud or thunderhead. The anvil or sheared-off top of the thunderhead is analogous to a lateral-flow discharge zone or outflow plume of a geothermal resource, and the rising cauliflower-like bulk of the thunderhead resembles the upflow zone. All currently proven reserves in New Mexico are the result of circulation of ground water that sweeps up heat from deep-seated bedrock. Fault and fracture zones may concentrate and redirect the hot water flow upward. Where these systems intersect the surface, hot springs are found. Heat from active or young volcanoes is not required for this type of geothermal resource.

CLASSIFICATION OF USES AND RESOURCES

We classify geothermal resources as high temperature, intermediate, or low temperature. High-temperature resources are those that are greater than 350° F; they are suitable for electrical power generation in excess of 20 megawatts. Intermediate temperature resources are those between 190° and 350° F; they are suitable for small-scale electrical power generation at rates of 3–10 megawatts. Low-temperature resources are those less than 190° F and at least 15°–30° F above the local mean annual surface temperature. Low-temperature resources are the most common and can be used in a variety of "direct-use" geothermal heating applications, including greenhousing, aquaculture, space and district heating, ground-coupled heat pumps, and many industrial uses (such as cooking, curing, or drying) that require large amounts of low-grade heat. High- and intermediate-temperature geothermal resources may also be used in direct-use applications by "cascading" residual heat from power production to lower-temperature applications, enhancing the overall efficiency and economics of use.

CURRENT GEOTHERMAL USE

Electric Power Geothermal-generated electricity is currently being produced at the 32-acre Burgett Geothermal Greenhouse in the Animas Valley near Cotton City (Fig. 1). The Burgett power plant is a model for how geothermal electricity may best be produced in New Mexico. The facility extracts energy in a cascaded system, whereby 230° F water from geothermal wells is first fed into the power plant heat exchangers at a rate of 1,200 gallons per minute; the 185° F outflow from the power plant is used for space heating of the greenhouses. The Burgett power plant is called binary because heat from the geothermal water boils isopentane, whose pressurized vapor drives a turbine. This so-called working fluid powers three modular 0.3-megawatt units, and the electricity is used on location at the greenhouse.

Geothermal Aquaculture Geothermal energy offers several advantages for fish culture. Many species have accelerated growth rates in warm water. Geothermal water can be used as a growth medium, adding to the agriculture receipts in the state without consumptive use of valuable fresh water supply. The AmeriCulture Fish Farm at Cotton City (Fig. 1) raises tilapia, a fish increasingly popular for its taste, from eggs produced on site. AmeriCulture is heated at much lower costs than fossil fuels with a downhole heat exchanger installed in a 400-foot-deep well. AmeriCulture markets tilapia fry to growers and researchers nationwide.

Geothermal Space and District Heating The aridity and high elevation of parts of New Mexico creates significant heating loads on cold winter nights. Where shallow geothermal resources co-exist with large heating demands, geothermal space and district heating can compete favorably with fossil fuel. Many of these sites are also suitable for spas.

A district geothermal heating system on the New Mexico State University campus in Las Cruces, in operation since 1982 uses as much as 260 gallons per minute of 143˚ F water that is produced from a depth of 980 feet. Geothermal water is passed through a heat exchanger to heat fresh water that is fed into space and domestic hot water loops on campus as needed. The cooled geothermal water is then returned to the reservoir, injected into the reservoir margin beneath the NMSU golf course. Geothermal heat is used to heat dorms, academic buildings, and athletic facilities on the eastern third of the campus. Geothermal heat also provides domestic hot water for showers in the dorms and athletic facilities.

At Gila Hot Springs, a 300-foot-deep flowing well provides 165˚ F water for geothermal space and district heating of a trailer court, rental cabins, store, and several homes.

Geothermal Greenhousing The most important use of geothermal energy in New Mexico is for greenhouses (Fig. 2). Geothermal greenhousing accounts for more than half of the greenhouse acreage in the state. In fact, New Mexico leads the nation in geothermal greenhouse acreage. The success and growth in the geothermal greenhouse industry in New Mexico can be attributed to several factors, including a good climate with abundant sunshine and low humidity, inexpensive land, co-existence of geothermal resources with a supply of fresh water, a good agricultural labor force, and the availability of favorable shallow geothermal resources. Current geothermal greenhouses draw water from wells less than 1,000 feet deep, with resource temperatures ranging from 143˚ to 240˚ F.

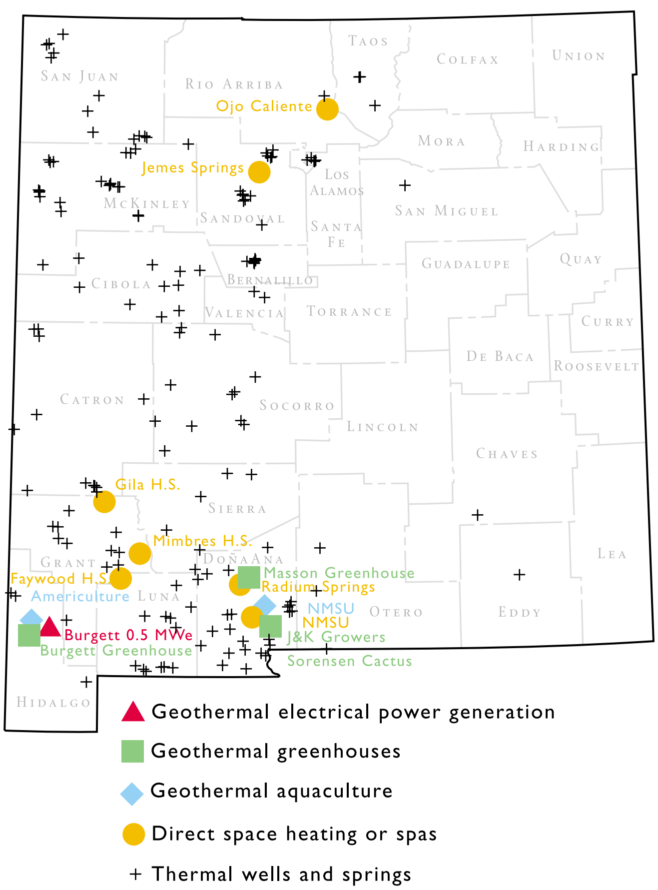


FIGURE 1 Geothermal resources and uses in New Mexico.

ECONOMIC IMPACT

Figure 2 illustrates the importance of geothermal greenhousing in New Mexico. A total of 52 acres are heated using geothermal energy, representing a capital investment of over $18 million, a payroll of more than $6 million, and gross receipts exceeding $22 million. This places geothermal greenhouse sales among the top ten agriculture sectors in the state. The Burgett Geothermal Greenhouse near Cotton City is the largest employer (and largest business) in Hidalgo County. The Masson Radium Springs Farm geothermal greenhouse is the largest employer in northern Doña Ana County.

ATTRIBUTES AND POLICY

Geothermal development resembles oil and gas in leasing, royalties, and drilling. Exploration and evaluation of geothermal resources borrow methodologies used in oil and gas, ground water, and mineral exploration.

Geothermal energy is environmentally friendly. Geothermal operations, including electrical power

Site	Location	Product	Size (acres)	Employees/Jobs (persons)	Payroll $/yr	Capital investment ($)	Sales $/yr	Energy Use (MMbtu/yr)	Energy savings ($/yr)
Burgett Geothermal Greenhouse	Animas/ Cotton City	Cut roses	32	256	3,741,696	11,200,000	13,920,000	134,400	403,200
Masson Radium Springs	Radium Springs	Potted plants and flowers	17	136	1,987,776	5,950,000	7,395,000	71,400	214,200
J & K Growers	Las Cruces	Potted plants and flowers	2	16	233,856	700,000	870,000	8,400	25,200
Sorenson Cactus	Las Cruces	Decorative cactus	1	8	116,928	350,000	435,000	4,200	12,600
TOTALS			52	416	6,080,256	18,200,000	22,620,000	655,200	218,400

FIGURE 2 List of current commercial geothermal greenhouses in New Mexico with acerage, estimated cost attributes, and energy use.

Assumption	Category	Amount	Units
1	Employees per acre	8	persons
2	Average hourly wage w/benefits	$7.00	$/hr
3	Annual work hours	2088	hrs/yr
4	Capital investment per acre ~$8 per sq ft	$350,000.00	$
5	Value of sales per acre ~$10 per sq ft	$435,000.00	$/yr
6	Energy use per acre per year southern NM	4,200	MMbtu/yr
7	Energy cost MMbtu geothermal natural gas with boiler losses	$1.50 $4.50	$/MMbtu $/MMbtu

Cost and energy assumptions used to construct the above table.

production, have a small land-use footprint. Greenhouse gas emissions are typically zero for binary systems. In most cases, spent geothermal fluids are injected back into the reservoir, resulting in minimal impact to fresh-water supplies. With the use of heat exchangers, harmful scaling and corrosion can be controlled, and fluids can be isolated from both the natural environment and surface geothermal equipment.

One impediment to geothermal growth is the initial capital costs associated with resource exploration, testing, and well drilling. However, geothermal energy has the advantage of low operations and maintenance costs, without the volatility associated with fuel costs. Most of the surface equipment used by geothermal operations is "off the shelf" and has well-known engineering characteristics and costs. This is especially true with direct-use installations, such as those outlined above.

Geothermal policy at the federal level and in most of the geothermal industry focuses on electrical power generation. However, in New Mexico more than 5,000 megawatts of electric power is produced by traditional fossil fuels, and only about 40-45% of this electric power is used in state. The Valles Caldera in the Jemez Mountains is the only resource with proven reserves that exceed 20 megawatts. This is the only resource in the state with magma as a probable heat source. Development of this site by industry is unlikely, as the area has been transferred to the U.S. Department of Agriculture under the Valle Grande/Valles Caldera Preservation Act.

Inferred reserves at other sites in New Mexico are all probably less than 5 megawatts. Small-scale geothermal electric power generation at these sites only makes good sense if it is done in conjunction with cascaded direct use, and the generated power is used on site to assist or augment a direct-use operation. For comparison, the gross receipts or cash flow of an acre of greenhouse that grow potted plants is equivalent to 1 to 2 megawatts of electric power generation with wholesale energy sales of $0.10 per kilowatt-hour. Federal and state geothermal policy should emphasize direct-use geothermal endeavors in New Mexico over stand-alone electric power generation. Federal royalty rules for direct-use and regulatory requirements for low- and intermediate-temperature drilling on federal lands are impeding geothermal development in the state. These should be modified to provide a realistic framework for future development.

CONCLUSIONS AND FUTURE POTENTIAL

Geothermal energy is a potentially powerful vehicle for rural economic development in New Mexico. The future of direct-use geothermal energy may include chile and onion drying, cheese and milk processing, additional aquaculture, greenhouses, and district heating. Small-scale electrical power generation is very likely to occur in a cascaded mode with direct-use development. The accessible geothermal resource base is vast, and the options for economic use are many.

Net Metering in New Mexico

Patrick K. Scharff, *Public Service Company of New Mexico*

In recent years, many electricity consumers have installed small renewable-resource electric generators to offset their consumption of commercial electric power. Often these generators produce power in excess of customer demand. In 1978 the federal Public Utility Regulatory Act (PURPA), in an effort to promote energy efficiency through the use of cogeneration and renewable-resource generators, made provisions for consumers with qualifying generators to sell excess power back to the utilities. Under the provisions of PURPA, and the subsequent implementation of rules by the Federal Energy Regulatory Commission (FERC) and state regulatory agencies, utilities are required to connect with "qualifying facilities" (QFs) and to purchase power generated by them, generally at a wholesale rate. Before the enactment of PURPA, utilities dealt with customer-owned generation on a case-by-case basis. New Mexico implemented the PURPA QF requirements in New Mexico Public Regulation (NMPRC) Rule 570 in 1988.

The purchase and sale agreement between a PURPA qualifying facility and an electric utility requires the use of two meters: one to measure the flow of energy from the utility to the customer and one to measure the flow of energy from the customer to the utility. Any energy that is not consumed by the customer at the time it is produced flows back into the utility grid through the second meter. Under PURPA QF rules, the customer pays full retail price for the energy that flows into the customer's premises from the grid, and the utility purchases energy flowing out into the grid at the utility's "avoided cost." (Avoided cost refers to the utility's avoided cost of production, although in some states, like New Mexico, a proxy for the wholesale cost of energy is used.) The difference between avoided cost and retail rates can be substantial.

Today consumers who generate their own power through the use of qualifying generators have new and better options available to them. New Mexico is one of 34 states with a "net metering rule" for small renewable-resource electric generating facilities. Net metering rules in effect allow these customers to sell excess electricity back to the utility at retail value, offsetting their consumption over the billing period. Meters literally turn backward when the generators are producing excess energy. Net metering rules are exclusively state initiatives that are the result of consumers' desire to resolve the difference between retail and avoided cost rates, and an interest in wider use of renewable resources. A few states implemented single-meter net metering when enacting the provisions of PURPA. Others, like New Mexico, implemented single-meter net metering several years later. Of the 34 states that have net metering, 32 have implemented their rules since 1995.

New Mexico's net metering rule, NMPRC Rule 571, was implemented by the Public Regulation Commission's September 1999 order in Docket 2847. PRC Rule 571 is applicable to all renewable-resource generators rated at 10 kilowatts or less. However, as a practical matter, net metering rules in all states are applied almost exclusively to solar electric systems, because of their reliability and consistent performance. One of Public Service Company of New Mexico's (PNM) net metering customers, however, does have a 400-watt wind generator connected to the grid. New Mexico's net metering rule allows utilities to choose between paying avoided cost (1 to 3 cents per kilowatt-hour for PNM) or giving kilowatt-hour credits for excess energy at the end of each billing period.

Like other states, New Mexico's net metering rule is intended to foster and encourage the use of renewable energy resources. However, New Mexico's net metering rule is different from the rules of other states (and more favorable to the use of renewable resources) in two very important aspects. First, other states have a limit on the total amount of net metering capacity that can be connected to the grid. New Mexico's rule has no such limit. Second, most other states do not allow kilowatt-hour credits to be carried forward from month-to-month. The few states that do allow kilowatt-hours to be carried forward month-to-month require all credits to be reset to zero at the end of the year with no payment for any remaining balance. New Mexico's net metering rule allows excess energy credits to accumulate from month-to-month and year-to-year.

The Public Service Company of New Mexico (PNM) provides kilowatt-hour credits for any excess energy at the end of each billing period. These kilowatt-hour credits are applied to future bills when the total energy produced is less than the kilowatt-hours consumed during the billing period. When the kilowatt-hour

State	Utilities	Eligible fuels	Eligible customers	Limit on system size	Limit on overall enrollment[1]
Arizona	IOUs and RECs	Renewables & cogeneration	All customer classes	≤ 100 kW	None
Arkansas	All utilities	Solar, wind, hydro, geothermal, and biomass[2]	All customer classes	≤ 25 kW (residential); ≤ 100 kW (commercial or agricultural)	None
California[3]	All utilities	Solar and wind	All customer classes	≤ 1000 kW	None
Colorado	Individual utilities	All resources	All customer classes	≤ 10 kW	None
Hawaii	All utilities	Solar, wind, hydro, and biomass	Residential or small commercial	≤ 10 kW	0. 5% of each utility's peak demand
Idaho	IOUs	Renewables & cogeneration	Idaho Power only; residential and small commercial	100 kW	None
Iowa	IOUs only	Renewables	All customer classes	No limit	None
Minnesota	All utilities	Renewables & cogeneration	All customer classes	< 40 kW	None
Montana	IOUs	Solar, wind or hydro	All customer classes	≤ 50 kW	None
Nevada	All utilities	Solar and wind	All customer classes	≤ 10 kW	100 customers for each utility
New Mexico	All utilities	Renewables & cogeneration	All customer classes	≤ 10 kW	None
North Dakota	IOUs only	Renewables & cogeneration	All customer classes	≤ 100 kW	None
Oklahoma	All utilities	Renewables & cogeneration	All customer classes	≤ 100 kW and annual output ≤ 25,000 kWh	None
Oregon	All utilities	Solar, wind, fuel cell and hydro	All customer classes	≤ 25 kW	No less than 0.5% of utility's historic single-hour peak load; beyond 0.5% eligibility can be limited by regulator authority
Texas	IOUs and RECs	Renewables only	All customer classes	≤ 50 kW	None
Washington	All utilities	Solar, wind, hydro and fuel cells	All customer classes	≤ 25 kW	0.1% of 1996 peak, with no less than half for renewables
Wyoming	IOUs and RECs, Munis exempt	Solar, wind, and hydropower	All customer classes	≤ 25 kW	None

[1]In all cases, energy generation is netted against energy consumption on an equal basis, down to zero net energy use during the designated period. Treatment of "net excess generation" is relevant only when total generation exceeds total consumption over the entire billing period, i.e. the customer has more than offset his/ her total electricity use and has a negative meter reading.

[2]The Arkansas law also extends eligibility to fuel cells or microturbines if the fuel is derived entirely from renewable resources.

FIGURE 1 Summary of "net metering" programs in states west of the Mississippi River. Portions of this table are reprinted by permission of the Interstate Renewable Energy Council (IREC) and Thomas J. Starrs, Kelso Starrs & Associates, LLC.

Treatment of net excess generation (NEG)	Enacted	Citation/reference
Monthly NEG purchased at avoided cost	1981	Ariz. Corp. Comm. Decision No. 52345
Not specified	2001	HB 2325 (enacted April 2001, effective October 2001)
Customers are billed annually; excess generation is granted to the utility. Also allows bi-directional time-of-use metering	1995	Cal. Pub. Util. Code § 2827 (as amended 1998, 2000, and 2001).
NEG carried over month-to-month	1994	Public Service Co. of CO, Advice Letter 1265; Decision C96-901; and various RECs
Monthly NEG is granted to utility	2001	House Bill 173
Monthly NEG purchased at avoided cost	1980	ID PUC Orders No. 16025 (1980); 26750 (1997)
Monthly NEG purchased at avoided cost	1983	IA Legislature & IA Utilities Board, Utilities Division Rules § 15.11(5)
Monthly NEG purchased at “average retail utility energy rate”	1983	Minn. Stat. § 261B. 164(3)
NEG credited to following month; at end of annual period any unused credits are granted to utility without compensation	1999	S.B. 409
Annualization allowed; no compensation required for NEG	1997	Nev. Rev. S. Ch. 704
At utility’s option, customer is credited on the next bill for (1) purchase of NEG at utility’s avoided cost; or (2) kilowatt-hour credit for NEG that carries over from month to month.	1999	17 N. M. Admin. Code 10.571
Monthly NEG purchased at avoided cost	1991	N. D. Admin. Code § 69-09-07-09
Monthly NEG is granted to utility	1990	Okla. Corp. Comm. Schedule QF-2
NEG purchased at avoided cost or credited to following month; at end of annual period unused credits shall be granted to low-income assistance programs, credited to customer, or “dedicated to other use” as determined by regulatory authority	1999	Or. Rev. Stat. 757.300
Monthly NEG purchased at avoided cost	1986	Tex. PUC, Substantive Rules, § 25.242(h)(4)
NEG credited to following month; at end of annual period any unused credits are granted to utility without compensation	1998	Wash. Rev. Code § 80.60 (amended 2000)
NEG credited to following month; at end of annual period any unused credits are purchased by utility at avoided cost	2001	WY Legislature, House Bill 195, signed into law February 2001, effective July 2001

[3]The 2001 amendments, which (A) extended eligibility to all customer classes; (B) extended the system size limit to 1,000 kW (1 MW); and (C) eliminated the overall “cap” of 0.1% of each utility's peak demand applies through the end of 2002 only. Absent further amendment these provisions would revert to the pre- 2001 requirements.

credits are applied to a current bill, PNM's net metering customers receive full retail value for the excess energy they have produced in prior months. When a PNM customer discontinues net metering service all remaining kilowatt-hour credits are purchased at the avoided cost rate.

In terms of tangible capital costs, renewable-resource energy systems are generally quite expensive. They are much more expensive to purchase and install than traditional electricity generating alternatives. However, there are significant advantages. By allowing the meter to turn backward during periods of excess energy production, the net metering customer is effectively using the utility grid as a means of storing energy for use during periods of low or no production. This use of the grid to effectively store energy allows lower-cost grid-connected systems to be constructed without the additional expense of physical batteries to store excess production. A typical one-kilowatt photovoltaic system without batteries costs about $10,000 and will produce approximately 2,100 kilowatt-hours of electricity per year. Battery energy storage can add 10–20% or more to the installed cost of a photovoltaic system, depending upon the amount of storage needed. With a typical useful life expectancy of only five years, batteries add significantly to the lifetime cost of ownership for a solar electric system. There are obvious environmental advantages to this, as well.

The average PNM residential customer usage is about 6,400 kilowatt-hours of electricity per year. Although net metering helps to offset the 20–35 cents per kilowatt-hour cost of solar electric energy, the high initial cost of photovoltaic systems prohibits their purchase by most consumers. At the end of 2001, PNM had only 14 net metering customers, with a total of 30.4 kilowatts of solar panel capacity and 400 watts of wind power capacity. These systems are installed in Albuquerque, Corrales, and Santa Fe. One of the consequences of single-meter net metering is that the total energy produced by PNM's net metering customers cannot be tracked. However, using the National Renewable Energy Laboratory's PVWatts software, we estimate that a reasonable approximation of the annual energy production of PNM's net metering customers is about 64,000 kilowatt-hours.

To encourage consumer use of renewable energy, several states, most notably California, have implemented financial incentives in addition to net metering. These additional financial inducements include rebates or buy downs for new renewable energy systems and tax incentives. Additional information on net metering, the specifics of individual state net metering rules, current state financial incentives, and renewable energy technology can be found at the internet Web sites below.

WHERE CAN I GET MORE INFORMATION?

1 Energy Efficiency and Renewable Energy Network (EREN) sponsored by the U.S. Department of Energy at www.eren.doe.gov
2 National Renewable Energy Laboratory (NREL) at www.nrel.gov
3 Interstate Renewable Energy Council (IREC) at www.irecusa.org
4 Database of State Incentives for Renewable Energy (DSIRE) at www.dsireusa.org
5 Solar Electric Power Association (SEPA) at www.solarelectricpower.org
6 A Performance Calculator for Grid-Connected PV Systems (PVWatts) at http://rredc.nrel.gov/solar/codes_algs/PVWATTS

Renewable Energy Incentives in New Mexico and Bordering States

Benjamin Luce, *New Mexico Solar Energy Association*

Renewable energy technology now offers a number of proven and cost-effective options that could greatly benefit New Mexico, both in economic development and in diminishing the environmental impacts of power generation. These include utility-scale wind power and photovoltaics. Utility-scale wind farms (one megawatt and up) can generate bulk power at a cost of 3–5 cents per kilowatt hour (kWh), which makes wind power competitive with other more traditional methods of power generation. Photovoltaics are more appropriate for those highly motivated consumers who are willing to invest in the equipment necessary to contribute through "net-metering," or for remote applications.

New Mexico is surrounded by states (with the exception of Oklahoma) that currently have aggressive policies and incentives for both utility- and residential-scale renewable energy development. Some of these incentives, mostly financial, have been in place since the late 1980s or early 1990s. More recently, other types of incentives, including mandatory requirements for renewable energy called "portfolio standards," have been introduced. These standards require public utilities to incorporate renewable sources of power in their energy mix. Such standards have already led to the installation of hundreds of megawatts of renewable electricity generation and are likely to lead to thousands of new megawatts of renewables by the end of the decade. A single megawatt is enough to power roughly 1,000 homes.

The incentives responsible for most of the existing utility-scale generation in neighboring states are:

- Renewable portfolio standards (RPS) adopted by Texas and Nevada, which mandate the addition of renewables to the mix in significant percentages
- Voluntary green pricing programs in Colorado and Texas. These programs allow consumers to choose to buy power generated by alternative means, usually at a higher rate. Such programs rely on consumer demand.

In addition to policy-based incentives, a whole range of financial incentives, including rebates and tax incentives, are also in place in states bordering New Mexico. These are extremely important for the successful development of residential-scale renewable energy businesses, as well as utility-scale generation. At the time of this writing, the New Mexico Public Regulatory Commission (PRC) is considering introducing a renewable portfolio standard, and several New Mexico state legislators are drafting bills that would create tax incentives for renewable energy.

New Mexico lags significantly in providing these incentives. New Mexico's deregulation legislation did mandate a systems benefit fund (see below), and made a recommendation that the PRC investigate the possibility of renewable portfolio standards. On this basis, the PRC proposed a portfolio standard rule that mandated 5% renewable energy, which would apply to the "standard offer" option (the default option for customers who opt not to choose). Unfortunately, this standard would be subject to a cap of $.001/kWh increase on the average utility bill, which could severely limit its impact. Moreover, following the deregulation debacle in California, the legislature has delayed the implementation time for electricity deregulation by five years, and this delay applies to both the systems benefit fund and the portfolio standard as well.

As of this writing, financial incentives for renewable energy generation in New Mexico are simply nonexistent. New Mexico needs, and deserves, aggressive and effective policy incentives to promote renewable energy development now. The New Mexico renewable energy industry will be hopelessly out-paced by out-of-state competitors if effective incentives are not introduced soon.

Figure 1 summarizes incentives in neighboring states and New Mexico. Note that New Mexico is conspicuously lacking in both conventional financial incentives such as tax incentives, and policy incentives such as renewable portfolio standards and systems benefit funds. Figure 2 compares the renewable portfolio standards of states bordering New Mexico in more detail.

Note that, although Arizona's program has roughly a ten times smaller target figure than the other stan-

Incentive	Arizona	Nevada	Colorado	Oklahoma	Texas	New Mexico
System benefit fund						1–S (delayed)
Disclosure of generation source and related emissions	1–S	1–S			1–S	1–S (delayed)
Renewable portfolio standard	1–S	1–S			1–S	1–S (delayed)
Net–metering	1–S	1–S	1–S, 2–L	1–S	1–S, 1–L	1–S
Line extension analysis	1–S		1–S		1–S	1–S
Solar contractor licensing	1–S	1–S	1–L			
Renewable energy equipment certification	1–S		2–L	1–S	1–S	
Solar & wind access laws	1–S	1–S	1–S, 1–L			1–S
Construction and design policies	1–S, 2–L		1–S, 3–L		1–S, 1–L	
Green power programs						
Green pricing	4–U	1–U	3–U, 6–L		3–U, 3–L	1–U
Green power purchasing/aggregating	1–L		3–L			
Public education/assistance	2–L		3–L		2–L	1–L, 1–S
Demonstration projects	2–L		2–L		2–L	2–L, 2–S
Research and outreach						
Personal tax	2–S					
Corporate tax					1–S	
Sales tax	1–S					
Property tax		1–S			1–S	
Rebates	1–L	1–L	1–S		1–L	
Grants						
Loans	1–S				1–L	
Industry recruiting		1–S			1–S	
Leasing programs	1–U				1–U	
Equipment sales					1–U	

FIGURE 1 Summary of incentives in place in neighboring states and New Mexico. S = state, L = local, U = utility. Numbers indicate number of incentives.

dards, in terms of total number of megawatts of renewable energy required, more than half of Arizona's renewable energy must be solar, which is about ten times as expensive as wind, geothermal, and other forms of renewable energy. Therefore, Arizona's relatively low standard is quite comparable in cost to the other higher standards.

Green pricing programs, which allow consumers to choose to buy power generated by renewable sources of energy, even if it's at a higher rate, are one of the great successes of the 1990s for renewable energy. Many such programs now exist in the United States. Roughly one in five Americans can now choose to have some or all of their electricity supplied by renewable energy sources. Public support for these programs was established through many surveys of public opinion. Public Service Company of New Mexico (PNM) has even conducted a small focus group study in Albuquerque, which indicated strong support, comparable to that found in other states. Colorado presently has over 18,000 customers, including many large businesses, participating in green power programs. These programs have been oversubscribed from the start. The DSIRE Web site (listed at the end of this article) has extensive information on many of these programs.

NEW MEXICO'S WIND RESOURCE

New Mexico is in the big leagues with respect to wind power, having the twelfth largest resource potential in the U.S. (much greater than California's resource; see Fig. 3). The developable resource is estimated to be capable of providing roughly 435 billion kWh annually, enough to power 40 million households. Comparing this to New Mexico's total electricity use of about 17 billion kWh/yr, we find that New Mexico's wind resource potential is about 25 times larger than its current consumption of electric power.

Note that New Mexico has approximately one-third the wind resource of North Dakota, the state with the largest resource. Also note that there is a dramatic decrease in wind power resource after New Mexico; Idaho, the next state after New Mexico, has less than one-quarter of New Mexico's resource. That is not to say that wind power cannot be a significant contributor in these states; California is also ranked lower than New Mexico and is currently producing utility-scale wind power.

NEW MEXICO'S SOLAR RESOURCE POTENTIAL

New Mexico's solar resource potential is enormous. Assuming 15% efficient solar (photovoltaic or solar thermal electric) collectors, and factoring in the fact that the sun shines strongly roughly eight hours a day, one square kilometer of solar collectors could produce electricity equivalent to a continuous 50 megawatt generator. (The peak power of the sunlight intersecting one square kilometer on a clear day is actually equivalent to 1 gigawatt; we can only capture about 5% because of collector efficiency, spacing considera-

Provisions	Arizona	Nevada	Texas
Total amount of renewable energy electricity production mandated (by percent)	1.1%	15%	(about 3.3%)
Total amount of renewable energy electricity production mandated (in megawatts)	(about 180 MW)		2000 MW
Effective date	3/30/01	1/1/03	1/1/02
Target date for achieving total amount	2009	2013	2009
Trading credits program	Yes	Yes	Yes: administered by state
Eligible technologies	Solar thermal electricity, photovoltaics, wind, biomass, hydro, geothermal electric, waste	Solar thermal electricity, photovoltaics, wind, biomass, geothermal electric	Solar thermal electricity, photovoltaics, wind, biomass, hydro, geothermal electric, wave, tidal, landfill gas
Applicable sectors	Utility, investor-owned utility, publicly owned utility, rural cooperative	Utility, investor-owned utility, publicly owned utility	Utility
Initial minimum	0.2%		400 MW
Year enacted	2000	2001	1999
Existing renewables			880 MW
Penalties	Yes	Yes-administrative fines	lesser of $50 per MWh or 200% of the average cost of credits traded during the year
Minimum required amount of solar (as a percentage of the renewable contribution)	Solar must make up 50% in 2001, increasing to 60% for 2004 through 2012	Solar must be 0.5% of total electricity delivered, to be achieved beginning 2004 by adding at least .01% annually	Solar must make up at least 5% of the renewable energy generated
Funding for building of new generation	Funding from existing system benefits charges and a new surcharge to be collected by the state's regulated utilities.	Cost of doing business	Cost of doing business

FIGURE 2 Renewable portfolio standards of states bordering New Mexico.

tions, and the diurnal cycle.) The fact remains, with our current technology, solar energy could provide for all of New Mexico's electricity needs.

Many studies have confirmed that, with existing technology, an area roughly 100 miles by 100 miles (an area less than one-third of 1% of U.S. land area) could in principle supply all of the current electricity demand of the United States. Preliminary results of a study by RDI Consulting[1] confirms that an area roughly ten times this size exists in western states alone with suitable solar resources, taking into account well-buffered land exclusions for military bases, national forests, parks, and Wilderness, cropland, highways, waterways, urban areas, lakes, and altitudes greater than 9,000 feet. This clearly establishes the sunbelt of the U.S. as a potential "solar Saudi Arabia."

Rank	State	B kWh
1	North Dakota	1,210
2	Texas	1,190
3	Kansas	1,070
4	South Dakota	1,030
5	Montana	1,020
6	Nebraska	868
7	Wyoming	747
8	Oklahoma	725
9	Minnesota	657
10	Iowa	551
11	Colorado	481
12	New Mexico	435
13	Idaho	73
14	Michigan	65
15	New York	62
16	Illinois	61
17	California	59
18	Wisconsin	58
19	Maine	56
20	Missouri	52

FIGURE 3 The top twenty states for wind energy potential as measured by annual energy potential in the billions of kWh, factoring in environmental and land use exclusions for wind class of 3 and higher.

In summary, we should note that many European countries implemented incentives and standards similar to those described above in the 1990s, slightly before today's low-cost wind-power technology was perfected. This directly enabled the development of the now multi-billion dollar European wind-power industry, which currently dominates the market. Due to the solid base of U. S. government-funded research and development on various solar power technologies, New Mexico and other western states presently have a short window of opportunity to develop a similar lead in utility-scale solar power, an option that was simply not available to most European countries because of their weather. Western states stand to benefit enormously from their vast wind-power resources, as well. Together, the potential benefits of developing these renewable energy resources includes significant economic development, job creation, and a more secure energy infrastructure, in addition to a cleaner environment. Adoption of incentives by New Mexico like those described above would greatly help our state to make these potential benefits a reality.

FOOTNOTES

[1]The RDI Study was conducted by Dr. Arnold Leitner, Senior Consultant with RDI Consulting, 720-548-5415, arnold_leitner@platts.com. It was commissioned by the Western Governor's Association and Congress and extensively critiqued by representatives of fossil fuel industries.

Some Renewable Energy Policy Organizations in New Mexico

New Mexico Solar Energy Association (www.nmsea.org): Educationally oriented. The NMSEA SunChaser2 Education program takes renewable energy technology and concepts to schools and events, reaching 7,000 students and 3,000 adults each year). Home design competition, solar home tours, workshops, Large Solar Fiesta Event (exhibits and workshops), Taos Solar Village (exhibits). Makes various equipment available upon request (giant SunOven, courtesy of Sandia Labs, etc.).

Coalition for Clean Affordable Energy (www.cfcae.org): A coalition of eight environmental groups:

- New Mexico Solar Energy Association (www.nmsea.org)
- Rio Grande Chapter of the Sierra Club (www.sierra.nm.org/)
- Conservation Voters Alliance (www.earthwaves.net/nmcva/)
- NM Citizens for Clean Air and Water (http://members.aol.com/nmcit/)
- Southwest Research and Information Center (www.sric.org/)
- National Parks Association (www.npca.org/home.html)
- Land and Water Fund of the Rockies (www.lawfund.org)
- New Mexico Public Interest Research Group (www.nmpirg.org)

Many of these groups are directly involved in renewable energy policy work, outside of the coalition. CCAE lobbies the legislature, files comments at the PRC, participates on press releases on energy issues. Broad scope: concerned with all consumer and environmental issues related to energy. CCAE played a role in crafting New Mexico's deregulation legislation, and in several of the rules promulgated by the PRC based on that legislation.

Energy Conservation and Management Division of the New Mexico Energy, Minerals and Natural Resources Department (http://www.emnrd.state.nm.us/ecmd/): Provides testimony, public education and information, conducts research related to energy conservation, efficiency, and renewable energy. The current Director, Chris Wentz, chairs the New Mexico Sustainable Energy Collaborative (see below). The division also funds many projects by groups such as NMSEA, Rebuild New Mexico, and others.

New Mexico Sustainable Energy Collaborative (e-mail Chris Wentz: cwentz@state.nm.us): A large, informal collaboration between utilities, advocacy groups, solar businesses, and others, which formed following the Alternative Energy Symposium initiated by PNM in December 2000. The collaborative includes many of the organizations listed here, including NMSEA and CCAE. The general purpose of the collaborative is to promote renewable energy in New Mexico by formulating comments, draft regulations, and draft legislation that enjoys a broad consensus among stakeholders. The first official act of the collaborative was to file comments on renewable energy in response to the recent Notice of Inquiry from the NM PRC.

New Mexico Solar Industries Association (contact Chuck Marken at 505-243-4900): A collection of New Mexico solar companies that occasionally pursues policy work.

Note: An excellent source of information on renewable energy incentives is the Database of State Incentives for Renewable Energy (DSIRE), which can be accessed online at http://www.dsireusa.org.

Using Energy Wisely: Increasing Energy Conservation and Efficiency for the Consumer

A Report of the National Energy Policy Development Group

What follows is a modified excerpt from "Reliable, Affordable, and Environmentally Sound Energy for America's Future, the National Energy Policy, May 2001." The full report is available at http://www.whitehouse.gov/energy/.

Energy efficiency is the ability to use less energy to produce the same amount of lighting, heating, transportation, and other energy services. For a family or business, conserving energy means lower energy bills. For the country as a whole, greater energy efficiency helps us make the most of U.S. energy resources, reduces energy shortages, lowers our reliance on energy imports, mitigates the impact of high energy prices, and reduces pollution. Improvements in efficiency can be particularly effective in reducing energy demand when energy is most expensive.

Conservation and energy efficiency are important elements of a sound energy policy. Improved energy efficiency is the result of many decisions, including those of individual consumers; manufacturers of cars and appliances; home builders; and state, federal, and local government officials. The federal government can promote energy efficiency and conservation by including the dissemination of timely and accurate information regarding the energy use of consumers' purchases, setting standards for more energy efficient products, encouraging industry to develop more efficient products, and searching for more innovative technologies that improve efficiency and conservation through research and development.

Since 1973 the U.S. economy has grown nearly five times faster than energy use (126% versus 26%). Had Americans continued to use energy as intensively as in 1970, the U.S. would have consumed about 177 quadrillion Btus of energy last year, compared to about 99 quadrillion Btus actually consumed. [A Btu (British thermal unit) is the amount of heat required to raise the temperature of one pound of water (about one pint) one degree Fahrenheit at sea level. Put another way, it is approximately the same amount of energy contained in a wooden match head.]

Gains in energy efficiency over the last three decades were built on a combination of technological improvements, better management practices, and learning to put these technologies and practices to their best use in automobiles, homes, offices, factories, and farms. In many areas the results have been quite impressive. New home refrigerators use about one-third of the electricity they used in 1972. Compact fluorescent lights use about 25% of the electricity of the incandescent bulbs they replace. Automobiles use roughly 60% of the gasoline they did in 1972 per mile driven.

CONSUMER CHOICES

The two most important factors in consumers' decisions about purchasing an energy efficient product are price and the life of the product. When energy prices are high, consumers tend to weigh energy efficiency more heavily. Unless consumers are informed about the price of energy, they may not have the incentive to select the most energy efficient product. As an example, consumers do not receive timely signals about rising electricity costs in order to make adjustments to their energy use and efficiency. When consumers' peak costs are averaged with off-peak costs, the higher cost of peak electricity supplies is masked. As a result, consumers may not recognize the benefits of investing in technologies that best target peak consumption. Some energy efficiency improvements are easiest and most cost effective to undertake when first building new factories, cars, equipment, appliances, and buildings. Some energy-using equipment, like computers, are used for only a few years before being replaced. Other equipment is used from five to twenty years, such as home appliances, home electronics, and lighting systems. Buildings can last a half a century or more.

In a typical U.S. home, appliances are responsible for about 20% of the energy bills. Refrigerators, freezers, clothes washers, dryers, dishwashers, and ranges and ovens are the primary energy-using appliances in most households. Taking steps to save energy while using these appliances, and replacing old inefficient appliances with modern ones can save money.

The federal government established a mandatory program in the 1970s requiring that certain types of new appliances bear a label to help consumers compare the energy efficiency of various products. Under this program, all refrigerators, freezers, clothes washers, and dishwashers are sold with yellow Energy Guide labels to indicate their energy efficiency. These labels provide an estimated annual operating cost of the appliance, and also indicate the cost of operating the models with the highest annual operating cost and the lowest annual operating cost. By comparing a model's annual operating cost with the operating cost of the most efficient model, you can compare their efficiencies. This labeling program ensures that consumers have the information they need to make the right decisions when they purchase major home appliances. However, Energy Guide labels are not currently required for some products, such as kitchen ranges, microwave ovens, clothes dryers, on-demand water heaters, portable space heaters, and lights.

The federal government not only ensures that consumers have information on the energy efficiency of major home appliances, it also promotes the most energy efficient products through the Energy Star program, a joint program run by the Department of Energy and the Environmental Protection Agency. Energy Star is only awarded to appliances that significantly exceed minimum energy efficiency standards. The Energy Star program does not extend to all products. Energy efficiency would be further promoted if the Energy Star program were expanded to a broader range of products.

Energy efficiency can also be improved by the establishment of minimum energy efficiency standards. Congress enacted legislation in 1987 and 1988 to establish minimum energy efficiency standards for many major appliances. These standards apply to manufacturers, not consumers. Appliance manufacturers must produce products that meet the minimum level of energy efficiency. These rules do not affect the marketing of products manufactured before the standards went into effect, and any products made beforehand can be sold. The new standards will stimulate energy savings that benefit the consumer, and reduce fossil fuel consumption, thus reducing air emissions.

These laws established minimum energy efficiency standards for many appliances, including refrigerators, refrigerator freezers, freezers, room air conditioners, fluorescent lamp ballasts, and incandescent reflector lamps, clothes dryers, clothes washers, dishwashers, kitchen ranges, and ovens, pool heaters, and water heaters. The Energy Policy Act of 1992 added standards for fluorescent and incandescent reflector lamps, plumbing products, electric motors, and commercial water heaters, and heating, ventilation, and air conditioning systems. Under current law, the Department of Energy can raise the minimum energy efficiency standards for these appliances if certain criteria are met, such as cost, technological feasibility, and the impact on competition among appliance manufacturers. In addition, the Department can set energy efficiency standards for appliances not covered by these laws.

RESIDENTIAL BUILDINGS

There are significant opportunities to improve the energy efficiency of buildings and homes through technologies and better practices. For existing homes, immediate options for improving efficiency include reducing air infiltration with caulking and weather stripping, installing modern thermostats, sealing ductwork, and adding insulation. These steps can reduce the 40% share of residential energy bills that go toward heating and cooling. Additional savings are possible when efficient appliances are purchased or major home renovations are undertaken. Installing a new, more efficient gas furnace can save up to 20% annually on natural gas. New buildings offer the greatest energy efficiency opportunities and can be designed to be both more comfortable and more efficient, cutting heating and cooling costs by close to 50%.

TRANSPORTATION

Transportation plays a key role in a growing U.S. economy, comprising 16% of GDP in 1998, 10.5% of total employment, and 27% of total U.S. energy consumption. Trucks and automobiles account for over three-fourths of the sector's petroleum use, with the remainder attributable to rail, ship, air, and pipeline systems. Mass transit ridership has increased by 21% since 1996. Automobiles today use roughly 60% of the gasoline they did in 1972 per mile driven, due in part to new technology, such as better engine and design controls, improved transmission, weight reduction, and improved aerodynamics. Despite the adoption of more efficient transportation technologies, average fuel economy for passenger vehicles has remained relatively flat for ten years and is, in fact, at a twenty-year low, in large part due to the growth and popularity of low-fuel-economy pickup trucks, vans, and sport utility vehicles.

Opportunities for reducing oil demand in the transportation sector include increasing conservation, vehicle efficiency, and alternative fuels. Conservation can be improved by car pooling, telecommuting, and increasing transit choices. For example, an increase in the average fuel economy of the on-road vehicle fleet by three miles per gallon would save one million barrels of oil a day, or about half of the global shortfall between supply and demand that triggered the oil price increases since 1998. In addition, fuel conservation can be further improved by technologies to reduce congestion.

A recent analysis indicates that the fuel economy of a typical automobile could be enhanced by 60% by increasing engine and transmission efficiency and reducing vehicle mass by about 15%. Several promising efficiency technologies are being presented to the U.S. market. For example, some automobile manufacturers have already introduced hybrid vehicles, and others have announced that they will introduce hybrid vehicles within the next several years. Advanced lightweight materials offer up to 6% improvement in mileage for each 10% reduction in body weight. Although promising, it may be many years before hybrids become a substantial part of the automotive fleet.

The average car now lasts fourteen years, and newer cars have even more longevity. Vehicle efficiency improvements require significant technological changes. Development of new-car production models requires at least three to four years, which limits the rate at which new technologies can enter the market. Making fundamental changes, such as switching to the use of a fuel cell, would take even longer. Once those new vehicles are in the showroom, it then takes several more years before they constitute any sizable percentage of total vehicles.

Because of the large economies of scale in automobile manufacturing, new technologies with limited early production runs often enter the market at higher initial costs. In this highly competitive international market, higher initial production costs can be a significant impediment to the introduction of new technologies. Unless U.S. automakers can remain competitive with their overseas counterparts, it is unlikely they will invest in new, more efficient technologies. Vehicle efficiency technologies, such as advanced engines, fuel cells, and cutting-edge electronic drive-train technologies, will become widely available only when component costs are reduced or demand is increased.

CONSUMER CHALLENGES

Consumers face certain challenges that could be addressed by Decision Makers in government and industry:

- *Insufficient Information* Monthly energy bills generally report only total electricity or natural gas used, leaving families and businesses unsure about which energy services are most responsible for their energy use, and which investments could best help them reduce their costs. In addition, consumers may be unsure about the credibility of the energy saving claims of individual manufacturers, salesmen, and designers. This incomplete information causes imperfections in the marketplace that hinder purchases of efficient technologies that would actually save families and businesses money.
- *Lack of Availability* Frequently, the most energy efficient products cost more and are not widely available, especially in smaller communities. Builders who would like to construct more efficient homes and businesses face the same problem at the wholesale level. For example, to keep costs down, builders are less likely to install top-of-the-line, highly efficient products. The less expensive and generally less efficient products are heavily stocked and deeply discounted due to volume ordering. The decisions made about the energy efficiency of buildings and homes are not usually made by the consumer who will ultimately pay the energy bills. The incentive is for the builders to choose the material that poses the least cost to the builder, which is not necessarily the most energy efficient choice.
- *Lack of Automation* People often walk out of their offices and homes with the lights on and the air conditioner running. Turning off unused appliances, electronics, and lights is not always easy. Lack of automation (e.g., daylight sensors) means that conservation mostly depends on people turning off switches. Some appliances and electronics, such as stereos, video tape players, and televisions, continue to use electricity even after they are turned off.
- *Higher Initial Costs* Efficient products often cost more than less efficient versions, especially when they are first introduced to the market. Unless consumers can verify the resulting savings, they may be reluctant to pay the additional costs. Businesses that adopt labeling programs that spell out energy savings may be more successful in selling a more efficient, yet initially more expensive product. Higher initial costs can be particularly difficult for the purchaser or builder of a new home or office building.

Energy Efficiency Programs in New Mexico

Harold Trujillo and Louise Martinez, *Energy Conservation and Management Division, New Mexico Energy Division, New Mexico Energy, Minerals and Natural Resources*

Energy efficiency technologies improve the way we use energy, and they have the potential to extend our energy resources to accommodate future generations and the inevitable growth of New Mexico's economy. Effective technologies are designed to reliably save energy over the life of the product. The word "conservation" applied to energy use typically describes a conscious effort or behavioral habit adopted to reduce consumption. Examples are turning off electric lights and lowering thermostats. Conservation requires a continual application of effort in order to be effective. However, energy efficiency programs achieve the same goals without the required diligence on the part of individuals. Both energy efficiency and conservation are important methods for improving human comfort, preserving the environment, and increasing New Mexicans' disposable income, and they should be part of New Mexico's energy portfolio.

The Energy Conservation and Management Division (ECMD) of the New Mexico's Energy, Minerals and Natural Resources Department is responsible for planning and administering energy efficiency and renewable energy technology programs, including development and use of solar, wind, geothermal, and biomass resources, as well as alternative fuels transportation. In addition, ECMD provides technical assistance and information in these areas to government agencies, Indian tribes and pueblos, educational institutions, and the general public.

The U.S. Department of Energy (DOE) also implements a number of energy efficiency programs in New Mexico. These include the Federal Energy Management Program (FEMP), targeted at achieving energy savings in federal buildings; and the Building America Program, which works directly with contractors to improve residential construction techniques to save energy. Some DOE programs, such as Rebuild America, are administered by ECMD and other New Mexico state agencies.

The state energy program, funded by DOE, is a major collaboration between DOE and the State of New Mexico. The Energy Conservation and Management Division of EMNRD is charged with the responsibility of administering the program in New Mexico. It is the umbrella program that is used to help all economic sectors in New Mexico. The state legislature provides funds for salaries and benefits. All funds used to implement projects throughout the state are provided by DOE through a basic grant and then supplemented with competitive DOE grants. Each year we compete with 13 other states to get about a half million dollars of DOE funds for special projects. Those special projects include DOE efforts such as Rebuild America, Codes and Standards, Alternative Fuels, Clean Cities, Pollution Prevention, Distributed Generation, Renewable Energy Assessment, Million Solar Roofs, Energy Smart Schools, and now Building America. We can also participate in FEMP projects. All the work done by New Mexico relating to energy conservation is based on the comprehensive plan we put together for DOE.

RESIDENTIAL SECTOR PROGRAMS

The adoption of new energy codes improves the energy efficiency of all new construction over the life of the building. Between 1977 and 1984, improved energy codes for residential buildings reduced energy consumption from 81,700 Btu/ft^2 (British thermal units per square foot) down to 75,000 Btu/ft^2. ECMD is currently working with the New Mexico Construction Industries Commission to update the codes to the 2000 International Energy Conservation Code. ECMD provides technical assistance to contractors and homeowners. Several grants have been obtained from DOE to assist with training, and the development of compliance materials. In addition to ECMD programs, the New Mexico Mortgage Finance Authority administers the Weatherization Assistance Program (WAP). WAP, formerly administered by ECMD, helps low-income New Mexicans improve the energy efficiency of their dwellings, saving both energy and money.

COMMERCIAL SECTOR PROGRAMS

- *Public Facility Energy Efficiency and Water Conservation Act of 1993* This act has made it possible, since its inception, to implement over $25 million worth of projects, with annual savings of over $3.9 million, 77.5 million kilowatt-hours of electricity and 4.7 million therms of natural gas. Part of the energy savings is used to recoup the cost of the project. The advantage of the act is that an energy service company provides the energy audit, design, installation, and up-front financing, including the guaranteed performance bond. Since 1993, 29 public schools, Torrance County, cities of Portales and Tucumcari, New Mexico Highlands University, and Eastern New Mexico University have implemented energy performance contracts. ECMD has statutory responsibility to review all proposals to ensure that the savings are reasonable and accurately estimated.

• *State Government Energy Management Program* Under Executive Order 99-40 (November 1999), Cabinet-level state agencies were directed to reduce their energy consumption by 4% by June 30, 2002. Preliminary results show that as of June 2001 energy consumption was reduced by 17% over the 1998 fiscal year base. These savings represent enough electricity to operate over 1,000 New Mexico homes for one year and enough natural gas to annually heat over 1,800 New Mexico homes. As lead agency, ECMD provides technical and financial assistance in improving the energy performance of over 1,000 state-owned and -operated buildings, maintaining a state utility bill database that contains nearly 1,700 accounts from 30 utilities. The database provides important feedback for agencies to evaluate the results of their efforts as shown in Figure 1. The utility bills for 13 cabinet-level departments during fiscal year 1998 totaled $8.9 million. Several agencies have exceeded expectations for reducing energy consumption and costs. For example, the Health Department—New Mexico's largest state agency—reduced its energy usage by 39.1%.

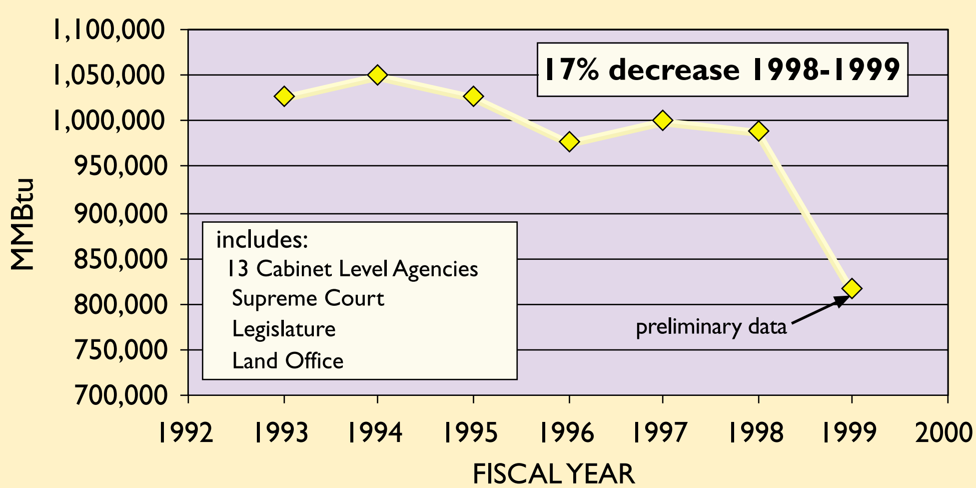
Southern New Mexico Correctional Facility completed a lighting retrofit project in December 1999 that resulted in a savings of $35,410 per year. The project cost $89,920 and paid for itself in 2.5 years. The project replaced 3,389 magnetic ballasts with electronic ballasts, and new energy efficient lamps were installed. The entire project was completed in four months, using inmate work crews.

The New Mexico Highway and Transportation Department (HTD) established a comprehensive energy management plan for its headquarters building that resulted in over $600,000 in savings as of June 1998, compared to the 1992 fiscal year base. The lighting system was renovated with electronic ballasts and 32-watt lamps.

More than 30 patrol buildings in Districts II, III, IV, and V were upgraded with energy efficiency lighting, ceiling and wall insulation, and infrared heating systems. HTD spent $540,143 (of which ECMD provided $388,858). HTD leads all other state agencies in savings over the last five-year period.

• *Public School Construction Plans Review* ECMD reviews construction plans as required by the

Figure 1. STATE GOVERNMENT ENERGY CONSUMPTION, 1993-1999



Data From State Government Utility Bill Database (www.emnrd.state.nm.us/)

State Department of Education for minimum energy efficiency requirements. In 2001 ECMD reviewed 94 plans representing $139 million in construction expenditures.

• *Rebuild America/Rebuild New Mexico* This program provides information,training, and tech nical assistance to private commercial building owners and local government participants. Over 59 participants, with more than 42.4 million square feet of building space, are improving their energy efficiency. Energy audits have identified potential savings of more than $750,000 per year. In partnership with the Youth Conservation Corps, 31 at-risk youth in Albuquerque and Taos Pueblo have been trained to make energy efficiency improvements.

TRANSPORTATION SECTOR PROGRAMS

• *Energy Policy Act /Alternative Fuels Conversion Act* Increasing public concern about the cost of pollution, environmental impacts, and national security issues prompted the federal government to enact the Energy Policy Act of 1992 (EPACT). It requires accelerated acquisition of alternative fuel vehicles by federal, state, and fuel-provider fleets.

In 1992 New Mexico enacted legislation known as the Alternative Fuels Conversion Act [Sections 13-1B-1 to -7, NMSA1978] and developed an energy policy goal to meet EPACT requirements, to meet state mandates, and to increase use of alternative fuels derived from New Mexico's own abundant energy resources. There are many types of alternative transportation fuels, including compressed natural gas (CNG), liquefied petroleum gas (propane), ethanol, and electricity. New Mexico's Alternative Fuels Transportation Program is managed by ECMD and funded by the U.S. Department of Energy. DOE established the Clean Cities Program, a voluntary program that works to develop partnerships that promote commitments to using alternative fuels as a substitute to gasoline and diesel. This program facilitates the implementation of EPACT and promotes the use of alternative fuels by providing special funding under the state energy program.

New Mexico school districts have been using CNG school buses since the mid-1990s. The Los Lunas, Belen, and West Las Vegas School Districts continue to operate CNG buses. ECMD provides funding for the purchase of these alternatively fueled buses, as well as incremental costs for purchasing CNG buses for the University of New Mexico's Park-and-Ride shuttle.

To reduce congestion and to help improve air quality, funding is also provided to develop ride-share and park-and-ride programs that encourage commuters to use carpools, vanpools, and public transportation to get to their destinations. The city of Las Cruces has reported that in the year 2000 a total of 1.012 million gallons of gasoline were saved by carpools and vanpools operating in that area.

INDUSTRIAL SECTOR PROGRAMS

• *Oil Industry* Opportunities exist to save energy in the production of oil and gas. Measures that reduce operating costs range from simple low-cost maintenance such as proper lubrication to higher-cost items such as replacement of electric motors. Operating costs are critical to producers when oil prices are low. ECMD contracted for the publication, Pollution Prevention Best Management Practices Manual, tailored to the New Mexico oil and gas industry to address energy savings. Training was provided to over 80 industry personnel.

• *Pollution Prevention Programs* ECMD continues to provide technical support to the Green Zia Environmental Excellence Program, which facilitates and publicly recognizes pollution prevention and energy efficiency efforts; the program is administered by the Environment Department. ECMD also coordinated with the Waste-Management Education and Research Consortium (WERC), a consortium for environmental education and technology development based at New Mexico State University, in funding and establishing a Pollution Prevention Technical Resources Center in Albuquerque to provide such assistance.

BENEFITS OF ENERGY EFFICIENCY PROGRAMS

• *Competitive Edge* Energy is an operating cost of production. Any price increase will cascade through the nation's economy. Businesses that improve their energy efficiency are in a better position to compete in the world market, even during high-cost periods. From experience, energy service companies find conservation opportunities that reduce energy bills by 20–25% on average. Businesses can increase their profit margins, and government entities can reduce costs passed on to the taxpayer.

• *Imported energy* Energy efficiency can reduce our reliance on imported oil and reduce our trade deficit.

• *Life Safety* Energy efficient buildings are safer and can prevent losses to life and property. According to the Risk and Insurance Management Society Inc., energy-efficient windows are more resistant to breakage by fires, thieves, or windstorms. Insulated pipes reduce the potential for freeze damage.

• *Economic Development* Energy efficiency and conservation efforts generate revenues for New Mexico. For example, energy service companies have implemented over $21 million of infrastructure improvements that were financed by the private sector and paid for from energy savings; the taxpayers did not have to pay for these improvements.

• *Air Quality* The United States, with 5% of the world's population, produces 23% of the world's greenhouse gases. Energy efficiency improvements help to reduce emissions of pollutants and greenhouse gases.

• *Resource life* Through changes in production, design, and technology, energy efficiency can extend natural resources. Energy efficiency helps to sustain our economy, environment, and community over the long term for future generations.

• *Demand Stress* One way to provide for resource diversification and a hedge against the price volatility of conventional fuels is energy efficiency. Demand/price stress is reduced on our current resources. Efficiency also allows time to develop cost-effective renewable and fuel cell technologies.

Low-Temperature Fuel Cells: Revolutionizing Energy Use

Kenneth R. Stroh, Sharon Thomas, and Marcia Zalbowitz,
Los Alamos National Laboratory, LALP-02-6

For many years Los Alamos National Laboratory has been engaged in an extensive research and development program in low-temperature fuel cells. Fuel cells can produce electricity and heat from hydrogen, natural gas, petroleum fuels, and fuel gases derived from coal and biomass. Fuel cells use fuels without combustion. Instead, they work by using chemical reactions, converting the chemical energy in a fuel into electric energy with reduced emissions of both greenhouse gases and noxious pollutants. Fuel cells have the potential to radically change energy use with worldwide impact.

Fuel cells have been around since 1839, but it took 20 years of research for NASA to demonstrate potential applications of fuel cells to provide power during space flight. Industry soon recognized the commercial potential of fuel cells but encountered technical barriers and high investment costs; fuel cells were not economically competitive with existing energy technologies. Since 1984 the Office of Transportation Technologies at the U.S. Department of Energy has been supporting research and development of fuel cell technology, and as a result hundreds of companies around the world are now working toward making fuel-cell technology pay off.

HOW FUEL CELLS WORK

A fuel cell is an electrochemical energy conversion device. It is two to three times more efficient than an internal combustion engine in converting fuel to power. The fuel cell produces electricity and heat, using fuel (there are several options) and oxygen from the air. When the fuel is hydrogen, the only emission is water. One common low-temperature type of fuel cell is the polymer electrolyte membrane (PEM) fuel cell. In the PEM fuel cell, hydrogen flows into the fuel cell, and a platinum catalyst facilitates the separation of the hydrogen gas into electrons and protons. These then pass through a membrane and, again with the help of a platinum catalyst, combine with oxygen and electrons to produce water. The electrons that cannot pass through the membrane become electric current. The current travels through an external circuit and powers an electric motor.

TYPES OF FUEL CELLS AND FUELS

There are five types of fuel cells (Fig. 1). For each, it is the electrolyte that defines the type. Polymer electrolyte membrane (PEM) fuel cells (described above) are low-temperature, direct hydrogen fuel cells that hold much promise for portable fuel cells. Known drawbacks are (1) that they must run on hydrogen fuel, and (2) they can operate only within a narrow temperature range, because they contain and produce water, which cannot be allowed to freeze or boil. The cost of polymer membranes is high ($100 per square foot), which inhibits their widespread use today.

In addition to the direct hydrogen fuel cell, research is currently underway to develop a fuel cell system that can operate on various types of common hydrocarbon fuels such as gasoline or natural gas. In such a fuel-flexible system, called a reformate/air system, a PEM fuel cell is fueled with hydrogen generated by an onboard reformer that converts hydrocarbon fuels into hydrogen-rich mixtures. Technical challenges lie in the reforming process, which requires high temperatures (700°C to 1,000°C). The reforming process also generates sulfur and carbon monoxide that can poison the fuel cell catalyst. Such a system lacks the zero emission characteristics of pure hydrogen systems, but it is still an improvement over the internal combustion engine (whose emissions are higher still), and the necessary fuels are readily available.

Direct methanol fuel cells use liquid methanol rather than hydrogen as a fuel. The advantage with these is that the fuel is liquid and can be distributed in a way that is familiar to consumers. In addition, the system does not require a reforming subsystem or a hydrogen storage subsystem. This technology is still relatively new, and several challenges remain. In particular, a great deal more platinum is required than for direct hydrogen fuel cells, and some methanol fuel crosses through the membrane, decreasing and wasting fuel.

APPLICATION OF LOW-TEMPERATURE FUEL CELLS

The low-temperature technologies being developed at Los Alamos are particularly attractive for applica-

Fuel cell	Electrolyte	Operating temp. (°C)	Applications	Advantages	Disadvantages
Polymer electrolyte/ membrane (PEM)	Solid organic polymer Poly-perfluoro-sulfonic acid	60–100	Electric utility Portable power Transportation	Solid electrolyte reduces corrosion and management problems Low temperature Quick startup	Low temperature requires expensive catalysts High sensitivity to fuel impurities
Alkaline (AFC)	Aqueous solution of potassium hydroxide soaked in a matrix	90–100	Military Space	Cathode reaction faster in alkaline electrolyte —so high performance	Expensive removal of CO_2 from fuel and air streams required
Phosphoric acid (PAFC)	Liquid phosphoric acid soaked in a matrix	175–200	Electric utility Transportation	Up to 85% efficiency in in co-generation of electricity and heat Impure H_2 as fuel	Platinum catalyst Low current and power Large size/weight
Molten carbonate (MCFC)	Liquid solution of lithium, sodium and/or potassium carbonates, soaked in a matrix	600–1000	Electric utility	High temperature advantages*	High temperature enhances corrosion and breakdown of cell components
Solid oxide (SOFC)	Solid zirconium oxide to which a small amount of yttria as added	600–1000	Electric utility	High temperature advantages	High temperature enhances breakdown of cell components

* High temperature advantages include higher efficiency and the flexibility to use more types of fuels and inexpensive catlysts as the reactions involving breaking of carbon-to-carbon bonds in larger hydrocarbon fuels occur much faster as the temperature is increased.

FIGURE 1 Types of fuel cells.

tions with multiple start-stop cycles, such as battery replacement, portable power, vehicular propulsion, and residential energy systems. Every major automobile manufacturer in the world is currently developing fuel-cell vehicles. The modular nature of fuel-cell power systems enables the generation of heat and power for small-scale residential applications. PEM fuel cells offer the advantage of minimal maintenance, because there are no moving parts in the system. The potential for utility-scale systems is currently being studied (see paper by Berger et al., this volume).

RELATED RESEARCH AT LOS ALAMOS NATIONAL LABORATORY

Los Alamos National Laboratory has worked with industry on fuel-cell and related technology since the mid-1970s, through both the government-funded core research program and through cooperative research and development agreements with private industry. The Los Alamos research program ranges from fundamental investigation of ion transport and electrochemistry through materials development and component optimization. In addition to fuel cells, current research and development includes supporting technologies such as hydrocarbon fuel reforming to generate a hydrogen-rich gas stream on demand, gas-cleanup technologies to make such streams compatible with PEM systems, and advanced sensors and controls. Theory and model development will further enable knowledge-based innovation; current research goals include cost reduction, durability, and performance improvement.