SB

243

3668

SENATE COMMITTEE REPORT
First Committee of Referral

DATE: 1/27/10

FURTHER: Finance

Date of 5-Day Notice: 2/4/10
(in accordance with Uniform Rule 23)

DATE TURNED IN TO OFFICE: 3/19/10

Resources Committee considered SENATE BILL NO. 243

SB 243 NO ROYALTY ON GEOTHERMAL RESOURCE

"An Act removing the royalty obligation for geothermal resources."

and recommends:

[ ] be **replaced** with [ ] **SCS** or [ ] **CS** SB 243 (RES)

[ ] adopt **previous** [ ] **SCS** or [ ] **CS** ________ (____)

[ ] attached amendment(s)

[ ] adopt ________ Letter of Intent

[ ] further referral to ________ Committee

SENATE BILL:
[✓] Same Title
[ ] New Title

HOUSE BILL:
[ ] Same Title
[ ] Technical Title Change
[ ] New Title w/ SCR #____

NEW FISCAL NOTE(S):

Department	Date	Fiscal	Indet	Zero	FN#
DNR	02/09			✓	
REV	02/10			✓	

PREVIOUS FISCAL NOTE(S):

Department	Date	Fiscal	Indet	Zero	FN#

[ ] **APPROPRIATION - no fiscal note**

SIGNATURES AND RECOMMENDATIONS:	PRINTED LAST NAME	DO PASS	DO NOT PASS	NO REC	AMEND
[signature]	Stevens			✓	
[signature]	French			✓	
CO-CHAIR: [signature]	McGuire	✓			
CO-CHAIR: [signature]	Wielechowski			✓	

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FISCAL NOTE

STATE OF ALASKA
2010 LEGISLATIVE SESSION

Fiscal Note Number: 1
Bill Version: CSSB 243(RES)
(S) Publish Date: 3/22/10

Identifier (file name): SB 243 DNR-OGD-02092010
Title: No Royalty on Geothermal Resources
Sponsor: Sen McGuire
Requester: SRES

Dept. Affected: Natural Resources
RDU: Resource Development
Component: Oil and Gas Development
Component Number: 439

Expenditures/Revenues (Thousands of Dollars)

Note: Amounts do not include inflation unless otherwise noted below.

	Appropriation Required	Information					
OPERATING EXPENDITURES	**FY 2011**	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
Personal Services							
Travel							
Contractual							
Supplies							
Equipment							
Land & Structures							
Grants & Claims							
Miscellaneous							
TOTAL OPERATING	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
CAPITAL EXPENDITURES							
CHANGE IN REVENUES ( )							

FUND SOURCE (Thousands of Dollars)

1002 Federal Receipts							
1003 GF Match							
1004 GF							
1005 GF/Program Receipts							
1037 GF/Mental Health							
Other Interagency Receipts							
TOTAL	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Estimate of any current year (FY2010) cost: ______

POSITIONS

Full-time							
Part-time							
Temporary							

ANALYSIS: *(Attach a separate page if necessary)*

SB 243 eliminates royalties from any state geothermal lease entered into for geothermal resources after the effective date. Under AS 38.05.140(d) the commissioner, for the purpose of encouraging the greatest ultimate resource recovery, already has the authority to reduce royalties on an entire leasehold for geothermal resources in order to promote development. Implementing this bill during the immature state of the geothermal industry may only result in the transfer of state resource revenue to private developers.

Prepared by: Kevin Banks — Phone 269-8800
Division: Oil and Gas — Date/Time 2/9/10 1:00 PM
Approved by: Tom Irwin — Date 2/9/10 5:15pm
Natural Resources

(Revised 11/6/2009 OMB)

ALASKA STATE LEGISLATURE

SENATOR LESIL McGUIRE
SENATOR BILL WIELECHOWSKI
Co-Chairs, Senate Resources Committee

MEMORANDUM

Memorandum

To: Leg. Legal

From: Shalon Szymanski, Committee Aide
Senate Resources Committee

Date: March 19, 2010

Re: Final CS Request

Please create a FINAL Senate Resources CS for SB 243, work order number 26-LS1346\E.

If you have any questions or need further information, please feel free to contact me on my direct line, 465-4522

Thank you!

3671

26-LS1346\E
Bullock
3/16/10

CS FOR SENATE BILL NO. 243(RES)

IN THE LEGISLATURE OF THE STATE OF ALASKA

TWENTY-SIXTH LEGISLATURE - SECOND SESSION

BY THE SENATE RESOURCES COMMITTEE

Offered:
Referred:

Sponsor(s): SENATOR MCGUIRE

A BILL

FOR AN ACT ENTITLED

"An Act relating to the royalty obligation for geothermal resources."

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF ALASKA:

* **Section 1.** AS 38.05.181(g) is amended to read:

(g) Each geothermal lease shall be conditioned upon payment by the lessee of a royalty of **1.75 percent** [NOT LESS THAN 10 PERCENT BUT NOT MORE THAN 15 PERCENT] of the gross revenues derived from the production, sale, or use of geothermal resources under the lease **during the first 10 years immediately following the date the geothermal resource first generates gross income and 3.5 percent of the gross revenues derived from the production, sale, or use of geothermal resources under the lease after that first 10-year period**. Royalties may be taken in kind rather than in value if the commissioner determines that taking in kind would be in the best interest of the state.

* **Sec. 2.** The uncodified law of the State of Alaska is amended by adding a new section to read:

APPLICABILITY; AMENDMENT OF EXISTING LEASES. (a) Section 1 of this

Act applies to a lease for a geothermal resource or the renewal of a lease for a geothermal resource entered into on or after the effective date of this Act.

(b) The commissioner of natural resources shall offer the royalty rates in AS 38.05.181(g), as amended by sec. 1 of this Act, as an amendment to a lease or renewal of lease entered into before the effective date of this Act.

ALASKA STATE LEGISLATURE

Session
State Capitol Building, Room 125
Juneau, Alaska 99801-1182
Phone (907) 465-2995
Fax (907) 465-6592

Interim
716 West Fourth Avenue, Suite 430
Anchorage, Alaska 99501
Phone (907) 269-0250
Fax (907) 269-0249

Chair
Senate Special Committee on Energy
Senate Committee on World Trade, Technology and Innovations

Co-Chair
Senate Resources Committee

Member
Senate Judiciary Committee

SENATOR LESIL MCGUIRE

Changes to Senate Bill 243 in CS SB 243 (RES) 26-LS1346\E

Please note that the following is not an authoritative list of changes to the bill. The current version of the bill itself is the best statement of its contents.

Section 2: Applicability; Amendment of Existing Leases

1. Inserted new language directing the Commissioner of Natural Resources to offer the royalty terms established in section 1 as an amendment to an existing lease or to the renewal of an existing lease.

Prepared By: Michael Pawlowski, Aide to Senator McGuire

26-LS1346\R
Bullock
3/10/10

CS FOR SENATE BILL NO. 243(RES)

IN THE LEGISLATURE OF THE STATE OF ALASKA

TWENTY-SIXTH LEGISLATURE - SECOND SESSION

BY THE SENATE RESOURCES COMMITTEE

Offered:
Referred:

Sponsor(s): SENATOR MCGUIRE

A BILL

FOR AN ACT ENTITLED

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BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF ALASKA:

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* **Sec. 2.** The uncodified law of the State of Alaska is amended by adding a new section to read:

APPLICABILITY. Section 1 of this Act applies to a lease for a geothermal resource or

L

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the renewal of a lease for a geothermal resource entered into on or after the effective date of this Act.

ALASKA STATE LEGISLATURE

Session
State Capitol Building, Room 125
Juneau, Alaska 99801-1182
Phone (907) 465-2995
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Chair
Senate Special Committee on Energy
Senate Committee on World Trade, Technology and Innovations

Co-Chair
Senate Resources Committee

Member
Senate Judiciary Committee

SENATOR LESIL MCGUIRE

Date: 2/8/10
Version: 26-LS1346\A

SPONSOR STATEMENT – SB 243

"An Act removing the royalty obligation for geothermal resources."

Electric power generated from geothermal sources is a clean, sustainable and environmentally friendly alternative to fossil fuels. It can play a major part in meeting the future energy needs of the railbelt and other regions.

The problem for any company seeking to build a commercial grade geothermal plant in Alaska is high capital costs that run 25-50 percent higher than the Lower-48. Operational costs could run 100 percent higher than the rest of the country.

Senate Bill 243 assists companies in developing geothermal resources discovered in commercial quantities on state land by lifting the 10 to 15 percent royalty payment obligation currently in state statute.

SB 243 is a common sense effort to make geothermal power projects economically viable and produce more affordable and reliable electric power for homes and businesses.

Geothermal electrical generation has been used for decades all over the world and creates "green" jobs. Alaska can now join other states and nations using geothermal sources to create a safe and secure source of electricity.

I urge all my colleagues to support SB 243 and move our state towards a secure energy future.

LEGAL SERVICES
DIVISION OF LEGAL AND RESEARCH SERVICES
LEGISLATIVE AFFAIRS AGENCY
STATE OF ALASKA

(907) 465-3867 or 465-2450
FAX (907) 465-2029
Mail Stop 3101

State Capitol
Juneau, Alaska 99801-1182
Deliveries to: 129 6th St., Rm. 329

MEMORANDUM January 28, 2010

SUBJECT: Sectional summary for SB 243; removing the royalty obligation for geothermal resources (Work Order No. 26-LS1346\A)

TO: Senator Lesil McGuire
Attn: Mike Pawlowski

FROM: Donald M. Bullock Jr.
Legislative Counsel

You have requested a sectional summary of the above-described bill.

As a preliminary matter, note that a sectional summary of a bill should not be considered an authoritative interpretation of the bill and the bill itself is the best statement of its contents. If you would like an interpretation of the bill as it may apply to a particular set of circumstances, please advise.

Section 1. Amends AS 38.05.181(c) by deleting language that requires a royalty obligation in conjunction with a noncompetitive geothermal lease.

Section 2. Amends AS 38.05.181(d) by deleting royalty share as an alternative term in a competitive geothermal lease sale.

Section 3. Amends AS 38.05.181(e) by deleting language that states that the rent paid on a geothermal lease is a credit against the royalty accruing on the lease.

Section 4. Amends AS 38.05.0181(f) by deleting a reference to royalties as a term to be considered in the renegotiation of a geothermal lease.

Section 5. Amends AS 38.05.182(a) to delete the statutory section providing for a geothermal resource royalty in a spanned citation for statutes that provide for royalties that may be taken in kind rather than in money.

Section 6. Deletes AS 38.05.181(g), which requires a royalty to be paid for the sale or use of a geothermal resource.

Section 7. Adds a section to uncodified law to state that secs. 1 - 5 of the Act apply to a lease or renewal of a lease for a geothermal lease entered into on, or after, the effective date of the Act.

DMB:ljw
10-048.ljw

3678

FISCAL NOTE

STATE OF ALASKA
2010 LEGISLATIVE SESSION

Fiscal Note Number: 2
Bill Version: CSSB 243(RES)
(S) Publish Date: 3/22/10

Identifier (file name): SB243-REV-TAX-2-10-10
Title: Geothermal Royalties
Sponsor: Senator McGuire
Requester: (S) Resources

Dept. Affected: Revenue
RDU: Taxation and Treasury
Component: Tax Division
Component Number: 2476

Expenditures/Revenues (Thousands of Dollars)

Note: Amounts do not include inflation unless otherwise noted below.

	Appropriation Required	Information					
OPERATING EXPENDITURES	**FY 2011**	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY 2015**	**FY 2016**
Personal Services							
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Contractual							
Supplies							
Equipment							
Land & Structures							
Grants & Claims							
Miscellaneous							
TOTAL OPERATING	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
CAPITAL EXPENDITURES							
CHANGE IN REVENUES ( )							

FUND SOURCE (Thousands of Dollars)

1002 Federal Receipts							
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1004 GF							
1005 GF/Program Receipts							
1037 GF/Mental Health							
Other Interagency Receipts							
TOTAL	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Estimate of any current year (FY2010) cost:

POSITIONS

Full-time							
Part-time							
Temporary							

ANALYSIS: *(Attach a separate page if necessary)*

SB 243 would eliminate state royalties on geothermal production. Royalty volumes are not taxable. Therefore, by eliminating state royalty on geothermal production, the taxable volume of geothermal production would be increased.

There are currently no commercial geothermal projects in Alaska. However there are projects that may begin exploration or development at a number of locations around the state including Naknek, Akutan, Chena and Mt. Spurr.

The increase in state taxes would vary based on the volume and value of geothermal production but is estimated to range from approximately $100,000 for a 5MW facility to $1.8 million for a 50MW facility. Due to uncertainty about future development the fiscal impact of this legislation can not be accurately determined at this time.

Prepared by: Cody Rice, Petroleum Economist — Phone 907-269-1024
Division: Tax Division — Date/Time 2-9-10; 6:21pm
Approved by: Ginger Blaisdell, Director, Administrative Services Division — Date 2-10-10; 9:33am

(Revised 11/6/2009 OMB)

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BRIEFING PAPER

THE CASE IN SUPPORT OF SB243 FOR REMOVING ROYALTY OBLIGATIONS FOR GEOTHERMAL RESOURCES

EXECUTIVE SUMMARY

Geothermal power offers reliable baseload power that delivers consistent megawatt-hours 24 hours per day, 365 days per year, which is something that most other forms of renewable resources cannot provide. In fact, for a utility or regional transmission organization, a geothermal power plant shows up in a resource plan much like a conventional power plant. Geothermal power is also unique in its lack of emissions, minimal land use, low visual impact and other environmental merits.

Geothermal energy is extremely cost competitive when compared to other forms of renewable energy and fossil-fuel based processes (e.g. natural-gas based plants, as indicated by studies performed by the California Energy Commission[1] [2]).

Multiple western states (e.g. California, Nevada, Hawaii, Utah and Oregon) recognize the merits of geothermal power and have generated geothermal power for decades. These states, among many others, also have multiple new geothermal projects under development.

Although believed to be rich in geothermal resources in various regions around the state, Alaska has yet to develop a single utility-size geothermal power plant. One major hurdle for geothermal development is the relatively high capital cost associated with exploration, drilling and development, as well as high operation and maintenance costs due to the remoteness of resources and the harsh terrain and climate. While capital costs for development and construction of geothermal power plants in other states is typically around $4,000/kW[3], in Alaska estimates typically increase 25%-50%. Operation and maintenance costs of geothermal plants in Alaska are expected to be as much as 100% higher than the respective lower 48 states, again due to the typical remoteness of the plants.

In other western states, geothermal power projects rarely are required to pay State royalties. A report by the Geothermal Energy Association explains geothermal royalties vary depending on land ownership type (Federal, state, private) yet tend to range from 0.5% to 5.5% of revenues[4]. The majority of the geothermal projects currently under development in the US are on Federal lands, where BLM regulations call for revenue royalties of 1.75% during the first 10 years and 3.5% thereafter.

[1] http://www.energy.ca.gov/2009publications/CEC-200-2009-017/CEC-200-2009-017-SD.PDF

[2] http://www.energy.ca.gov/2007publications/CEC-200-2007-011/CEC-200-2007-011-SD.PDF

[3] Climate Change Business Journal, April/May 2009

[4] http://www.geo-energy.org/publications/reports/Socioeconomics%20Guide.pdf

In Alaska, despite the fact that geothermal development faces greater financial challenges compared to other states, the current statutes call for royalty rates of 10%-15%, similar to oil, gas and mineral regulations. Ormat believes this rate is cost-prohibitive and is one of the reasons no utility-size geothermal plant has ever been built in the state.

Financial analysis shows that removing the 10-15% royalty obligation will lower the operations and maintenance cost by 10-15%, therefore lowering the kWh cost by 10-15%. Removing royalty obligations from geothermal power plants in Alaska will serve to acknowledge the unusually high costs of geothermal development, operation and maintenance while incentivizing geothermal development in the state. This will ultimately lower the cost of clean, reliable power to the ratepayers.

Paul Thomsen
Director, Policy & Business Development
Main: (775) 356-9029 Ext. 32237
Cell: (775) 313-6569
6225 Neil Road
Reno, NV 89511
www.ormat.com | pthomsen@ormat.com

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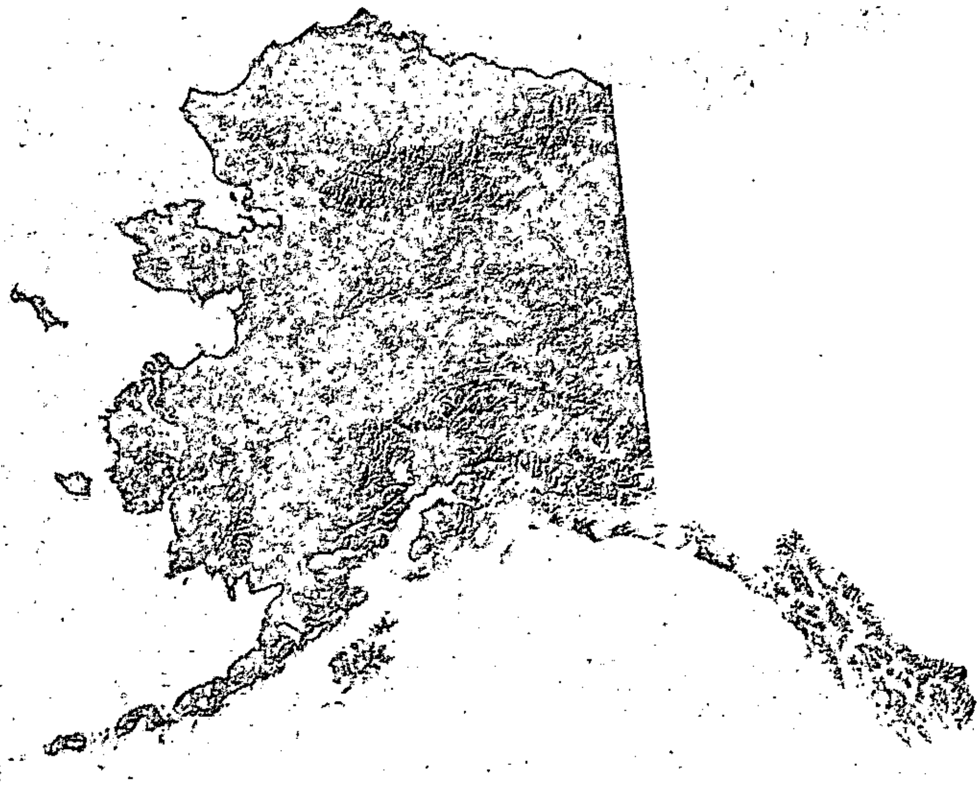
RENEWABLE ENERGY ATLAS OF ALASKA



A Guide to Alaska's Clean, Local, and Inexhaustible Energy Resources

July 2007

Why Renewable Energy is Important

As concerns about rising fossil fuel prices, energy security, and climate change increase, renewable energy can play a key role in producing local, clean, and inexhaustible energy to supply Alaska's growing demand for electricity, heat, and transportation fuel. Because there are little or no fuel costs associated with generating electricity from renewable sources, more Alaskans are looking to resources like wind, geothermal, hydroelectric, ocean, and biomass to hedge against the increasing cost of natural gas and diesel.

Renewable energy resources provide low-risk energy that, over the long term, can lower costs. With some of the best renewable energy resources in the country, Alaska has an opportunity to be a leader in their development and bring new revenue streams into the state's economy.

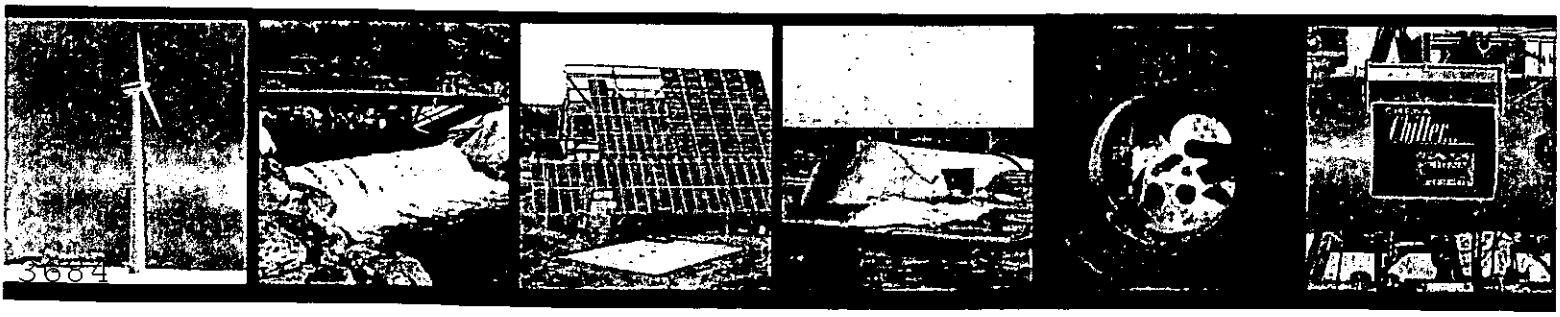
The Renewable Energy Atlas of Alaska is designed as a resource for policy makers, advocates, landowners, developers, utility companies and others interested in furthering the production of electricity and fuels from wind, solar, biomass, geothermal, hydro and ocean power resources. Produced with the use of GIS technology, this Atlas brings together the best renewable resource maps and data into a single comprehensive publicly available document. While the maps contained in this atlas do not eliminate the need for on-site resource assessment, they do provide an estimate of the available resources.

This atlas is posted on the Alaska Energy Authority website, www.akenergyauthority.org. Map data will be available in interactive format at the State of Alaska's new energy inventory web site at www.energyinventory.alaska.gov.

Table of Contents

Photo Credits
Above, left to right: Doug Ogden, Jim D. Barr, Michael DeYoung, Danny Daniels, Michael DeYoung, Doug Ogden.

Below, left to right: TDX Power, Cordova Electric Cooperative, Alaska Energy Authority, Ocean Power Delivery, Ltd., Alaska Energy Authority, Chena Hot Springs Resort.



Alaska's Energy Infrastructure

With 20% of the country's landmass and less than 1% of its population Alaska's unique geography has driven development of its energy supply infrastructure—power plants, power lines, natural gas pipelines, bulk fuel "tank farms" and related facilities. Alaska has over 200 remote, stand-alone electrical grids serving villages as well as larger transmission grids in Southeast Alaska and the Railbelt. The Railbelt electrical grid follows the Alaska Railroad from Fairbanks through Anchorage to the Kenai Peninsula and provides 80% of the state's electrical energy.

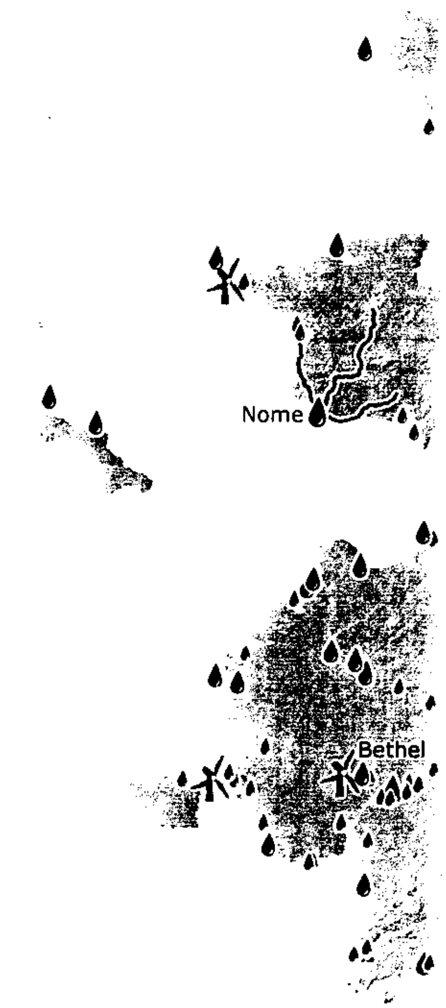
Powered by wood until 1927, Fairbanks switched to coal after the Railroad provided access to Nenana and Healy coalfields. The Anchorage area has enjoyed relatively low-cost heating and power since expansion of the Eklutna hydro plant in 1955 and the development of major Cook Inlet oil and gas discoveries in the 1960s.

Completed in 1986, the state-owned Willow - Healy Intertie now provides a diversity of energy sources to the six Railbelt electrical utilities.

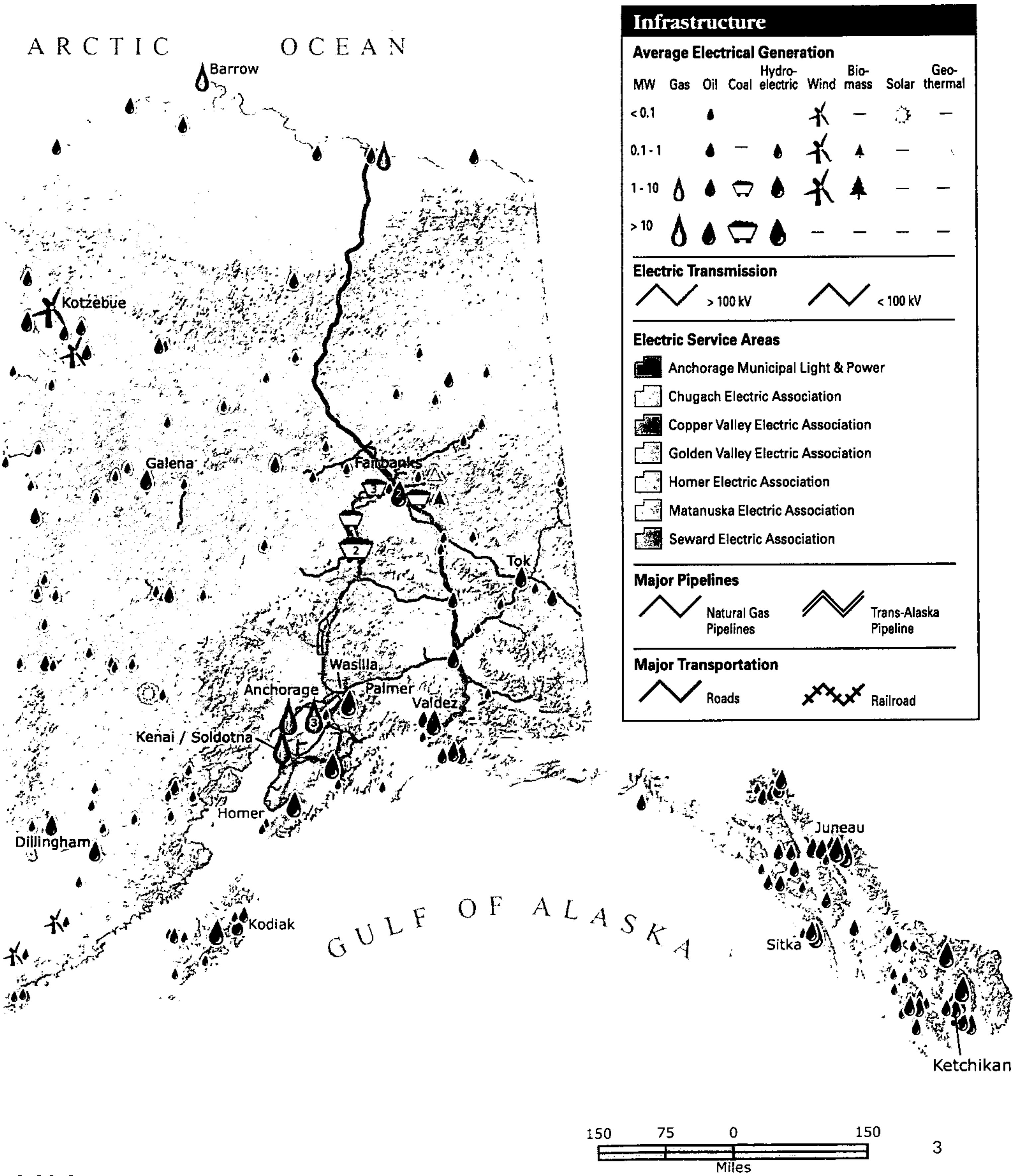
Approximately 70% of the Railbelt's electricity comes from natural gas generators. Major power generation facilities in the Railbelt include Chugach Electric Association's 430 MW natural gas-fired plant west of Anchorage at Beluga, Anchorage Municipal Light and Power's 266 MW natural gas-fired plant in Anchorage, Golden Valley Electric Association's 129 MW facility near Fairbanks fueled by oil from the Trans-Alaska Pipeline, and the 126 MW state-owned Bradley Lake hydroelectric plant near Homer. In total, 1,340 MW of installed power generation capacity exists along the Railbelt to serve an average load of approximately 500 MW and a peak load of over 800 MW.

During the early 1980s the state completed four hydropower projects to serve Ketchikan, Kodiak, Petersburg, Valdez, and Wrangell. With a total generating capacity of 76 MW, the "Four Dam Pool" projects displace the equivalent of approximately 20 million gallons of diesel fuel per year for power production. Other major hydro facilities supply the communities of Juneau and Sitka.

With a few notable exceptions, most of the rest of Alaska's power and heating needs are fueled by diesel that is barged from Lower 48 suppliers or transported from petroleum refineries in Nikiski, North Pole, and Valdez. After freeze-up, many remote communities must rely on the fuel that is stored in tank farms, or pay a premium for fuel flown in by air tankers. Currently state and federal authorities are supporting a large program to fix leaky tanks, improve power generation and end use efficiency, and exploit local energy sources such as wind and hydro.

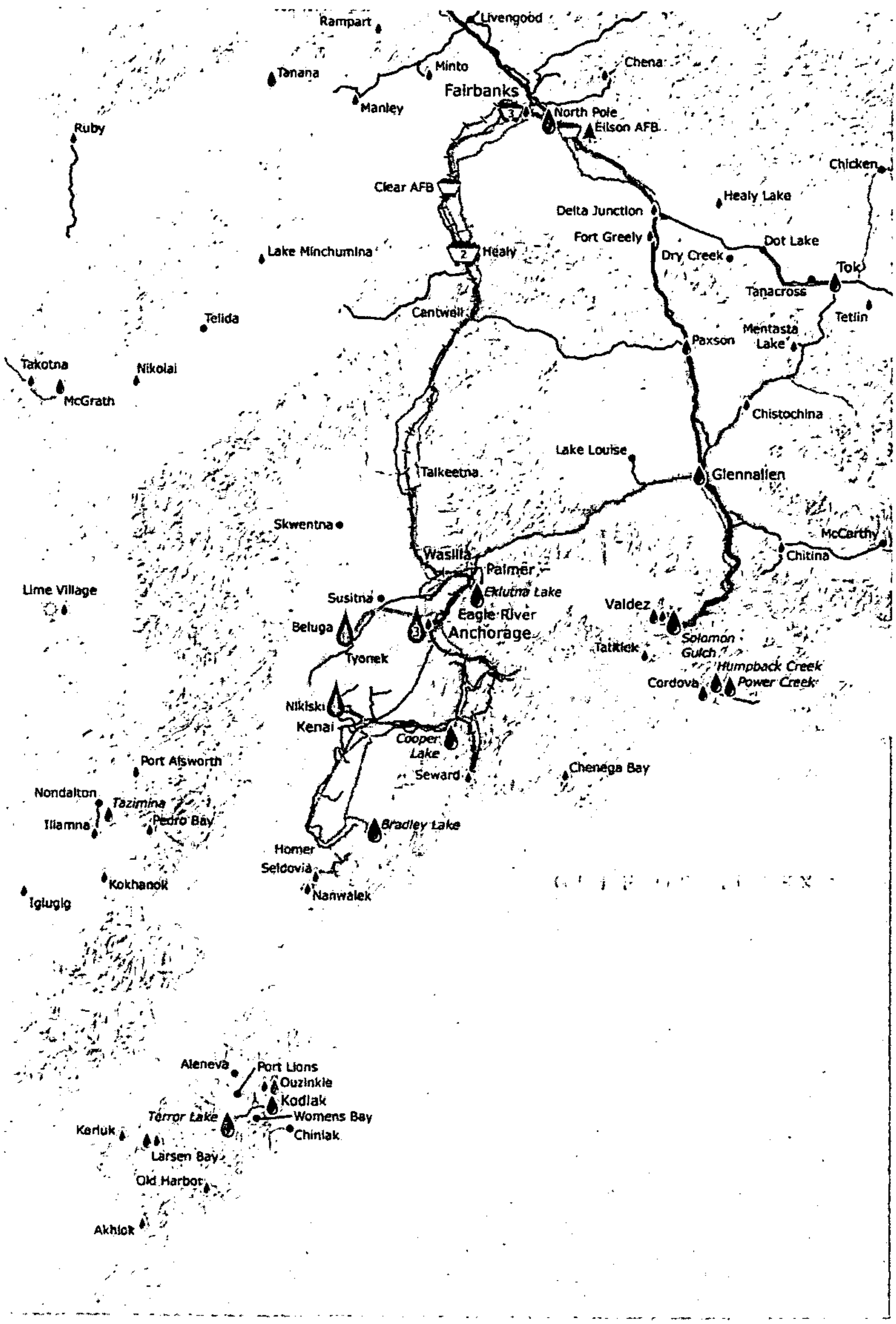


Alaska's Renewable Energy Resources



3686

Infrastructure: Fairbanks to Kodiak



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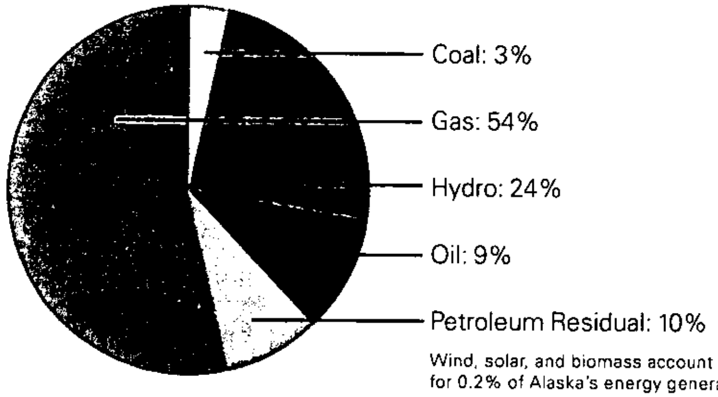
Infrastructure: Southeast Alaska

Statewide Electrical Generation in Alaska by Energy Source



Wind, solar, and biomass account for 0.2% of Alaska's energy generation.

Infrastructure

Average Electrical Generation

MW	Gas	Oil	Coal	Hydro-electric	Wind	Bio-mass	Solar	Geo-thermal
< 0.1						—		—
0.1 - 1			—				—	
1 - 10							—	—
> 10					—	—	—	—

Electric Transmission

> 100 kV

< 100 kV

Electric Service Areas

- Anchorage Municipal Light & Power
- Chugach Electric Association
- Copper Valley Electric Association
- Golden Valley Electric Association
- Homer Electric Association
- Matanuska Electric Association
- Seward Electric Association

Major Pipelines

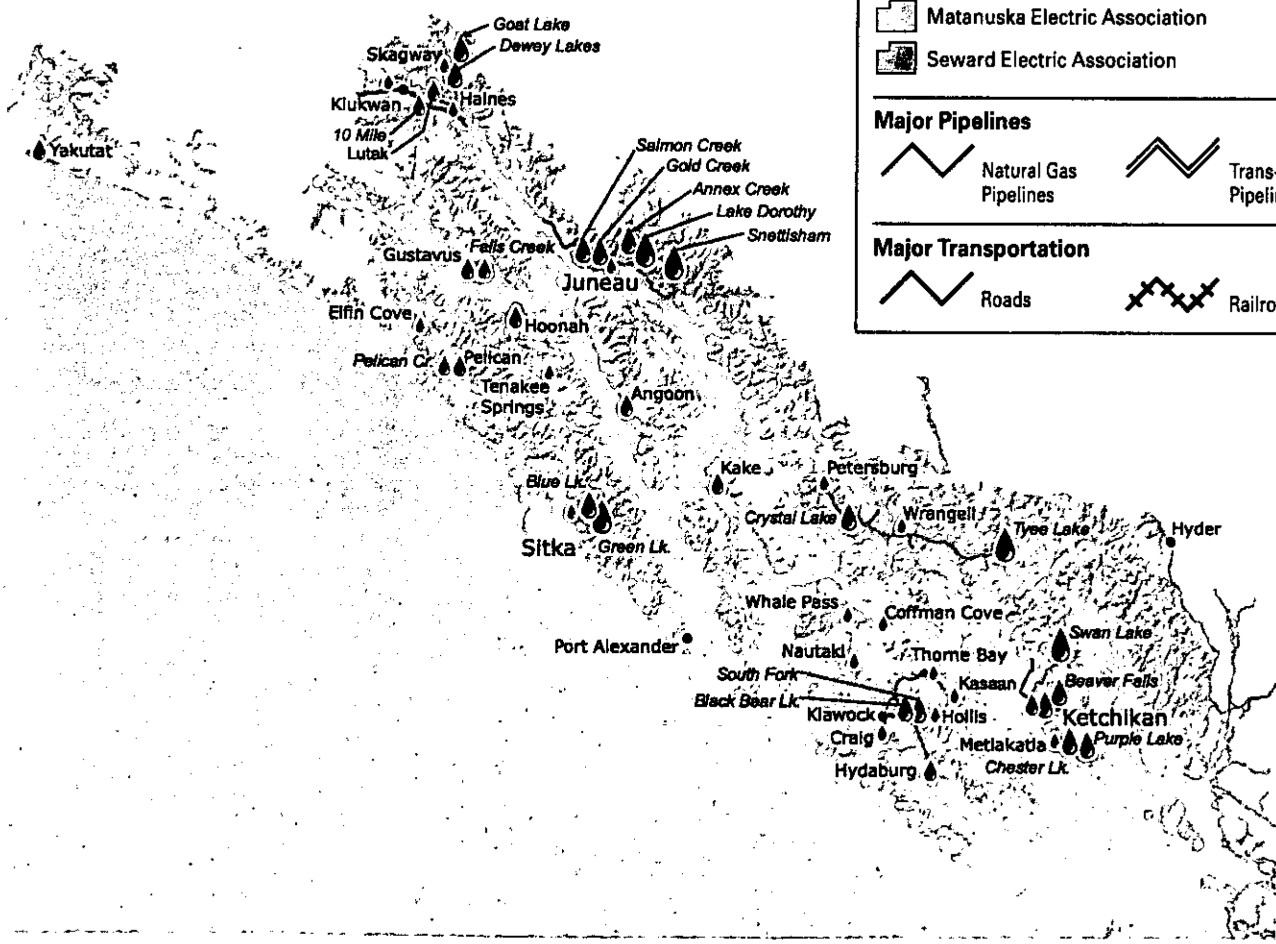
Natural Gas Pipelines

Trans-Alaska Pipeline

Major Transportation

Roads

Railroad

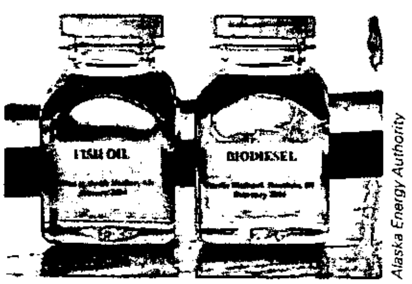


Biomass

Alaska's primary biomass fuels are wood, sawmill wastes, fish byproducts, and municipal waste.

Wood remains an important renewable energy source for Alaskans, with over 100,000 cords per year used for space heating statewide. Closure of the major pulp mills in Sitka and Ketchikan in the 1990s brought an end to large-scale wood-fired power generation in Alaska. However, recent increases in oil prices have raised interest in using sawdust and wood wastes as fuel for lumber drying, space heating, and small-scale power production. Alaska has also seen renewed interest in converting low-value wood and wood wastes to liquid fuels such as ethanol.

Groundfish processors in Unalaska, Kodiak and other locations produce approximately 8 million gallons of pollock oil every year as a byproduct of fish meal plants. Much of the oil is used as boiler fuel for drying the fish meal or exported to Pacific Rim markets for livestock and aquaculture feed supplements and other uses. In 2001, with assistance from the State of Alaska, processor UniSea Inc. conducted successful tests of raw fish oil/diesel blends in a 2.2 MW engine generator.



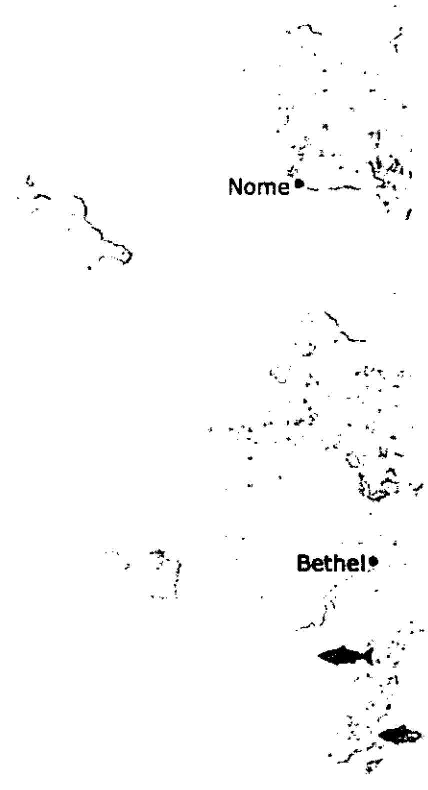
Raw fish oil and fish oil biodiesel from the Unisea plant in Dutch Harbor.

Since then, the company has expanded the operation and now uses approximately one million gallons of up to 70% fish oil for power production each year. Currently state, federal, university, and industry groups are testing fish oil biodiesel storage, handling and performance in diesel generators and developing a portable demonstration module for recovering a portion of the estimated 13 million gallons of fish oil returned to the ocean each year as processing waste. Local groups in Anchorage, Fairbanks, and other communities are converting waste fry oil into fuels for heating and transportation.

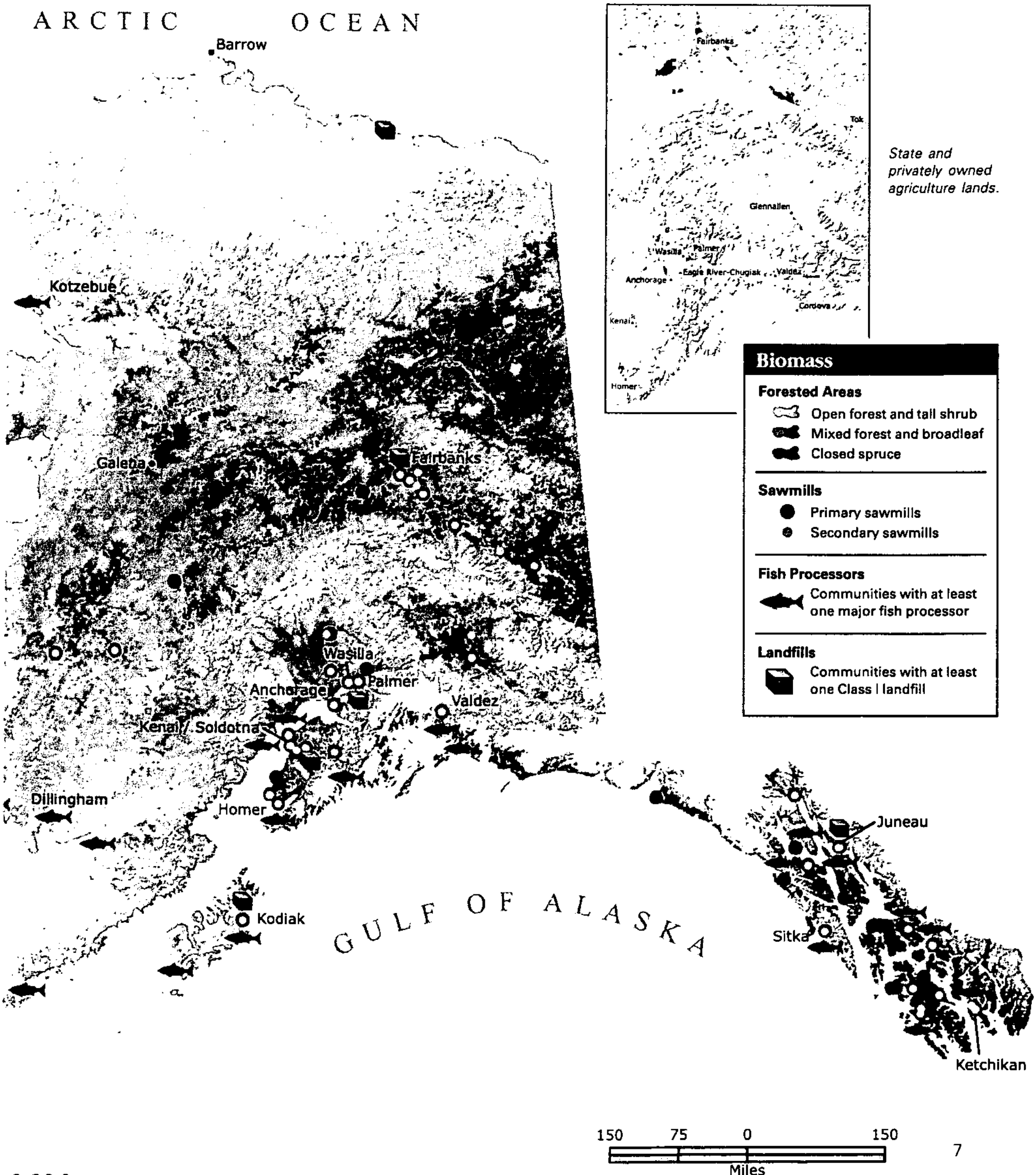
Alaskans generate approximately 650,000 tons of garbage per year. Eielson Air Force Base, near Fairbanks, densifies paper separated from the local waste stream and then co-fires the 4 cm square "cubes" at the base's coal-fired power plant. Beginning in 1997, the facility has produced 600-3000 tons per year of "refuse-derived fuel" providing up to 1.5% of the base's heat and power. Conventional recycling of paper, approximately half of Fairbanks' waste stream, is economically marginal given the distance to Lower 48 markets.

Energy recovery from Anchorage landfill gas is viable, according to a report prepared in 2005 for the Municipality of Anchorage. The landfill will produce methane with an energy equivalent of approximately 1.9 million gallons of diesel fuel per year over the next ten years. The gas could be used to heat nearby military or school facilities, or be converted to 2.5 MW of electrical power, enough to supply 2,500 homes in the Railbelt.

It is also possible that Alaska's agricultural lands may be used to produce energy crops, such as rapeseed, to produce biodiesel.



Alaska's Renewable Energy Resources



3690

Geothermal

Alaska has four distinct geothermal resource regions: 1) The Interior Hot Springs, which include the band of hot springs that runs east-west from the Yukon Territory of Canada to the Seward Peninsula, 2) The Southeast Hot Springs 3) The Wrangell Mountains, and 4) The Ring of Fire Volcanoes, which includes the Aleutians, the Alaska Peninsula, and Baranof Island.

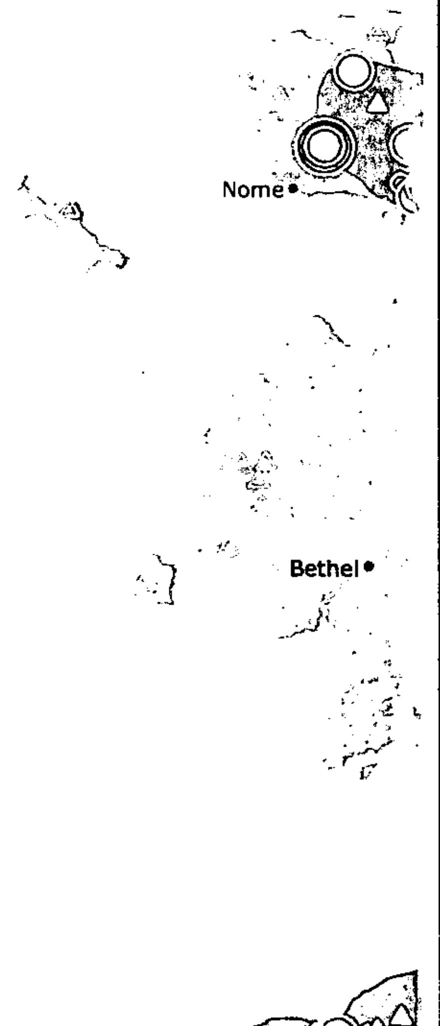
The Interior Hot Springs and the Southeast Hot Springs are low to moderate temperature geothermal systems with surface expression as hot springs. The Wrangell Mountains are composed of several active volcanoes that may have geothermal energy development potential. The Ring of Fire is an active volcanic arc that circles the Pacific and hosts high-temperature hydrothermal systems. These systems are seen on the surface as hot springs, geysers, and fumarole fields.

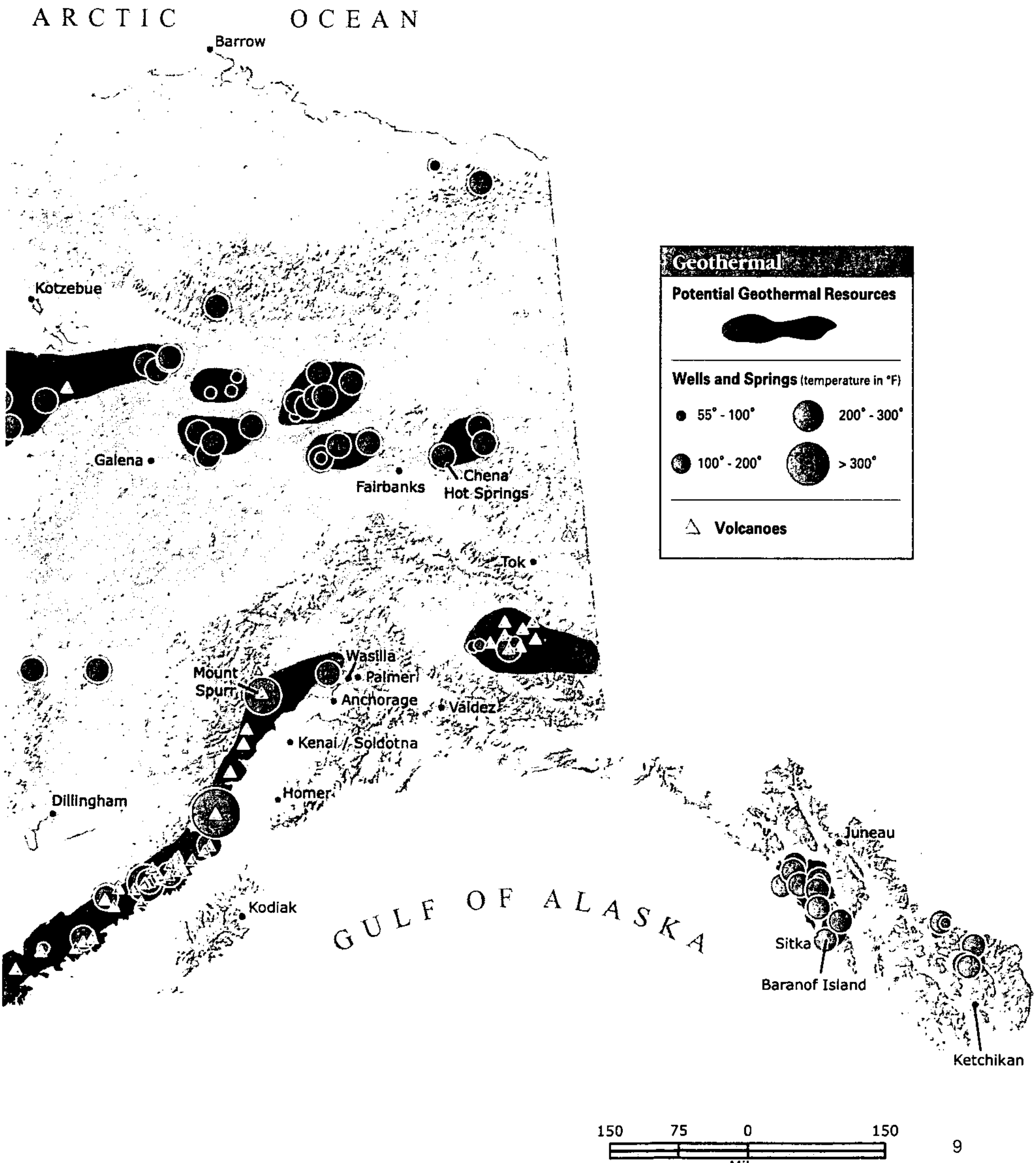
The use of geothermal resources falls into two categories: direct use and electricity production. Direct use of geothermal energy includes all non-electricity-producing applications. Potential applications for direct use of geothermal energy in Alaska include district heating, greenhouses, absorption chilling, mariculture, process heating in the seafood industry, swimming pool heating, and hydrogen production.

Three large-scale geothermal electric power generation projects have been proposed in Alaska: the Mt. Makushin project to provide power to the City of Unalaska, the Akutan project to provide power to the City of Akutan, and the Mt. Spurr project to provide power to the Railbelt grid. If developed, the Makushin and Akutan projects would also provide district heat and process heat to local, municipal, and fish processing customers. Each of these proposed geothermal power projects has the potential to produce tens and possibly hundreds of megawatts of electric power.

In the Interior, Chena Hot Springs Resort serves as an example of diverse use of geothermal energy. The resort has installed the first geothermal power plant in Alaska with assistance from state and federal agencies. The project includes two 200 kW organic rankine cycle generators, and displaces 150,000 gallons of diesel per year. Based on $2.50/gallon fuel prices, the $2.1 million project saves over $375,000 per year. In addition to the electric power plant, the Chena Resort uses its geothermal resources for outdoor baths, district heating, swimming pool heating, and to provide heat and carbon dioxide to its greenhouses. The site also demonstrates the use of geothermal energy for refrigeration. The resort installed a 16 ton absorption chiller in 2005 to provide chilling to an outdoor ice museum, which is kept frozen year-round. The chiller uses water from a 165°F geothermal well as a heat source, and a 40°F creek as a heat sink. This technology has potential applications in other Alaska communities that could use waste or geothermal heat to provide cooling for fish processing, ice production and community cold storage.

Naknek Electric Association is actively investigating geothermal potential and development of a regional electrical transmission system.

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Homer
Dillingham
Kodiak
GULF OF ALASKA
Juneau
Sitka
Baranof Island
Ketchikan
Geothermal
Potential Geothermal Resources
Wells and Springs (temperature in °F)
55° - 100°
200° - 300°
100° - 200°
> 300°
Volcanoes
150
75
0
150
Miles

3692

Hydroelectric

Hydroelectric power, Alaska's largest source of renewable energy, supplies 24 percent of the state's electrical energy. In 2007, 27 hydro projects provide power to Alaska utility customers, ranging in size from the 105 kW Akutan hydro project in the Aleutians to the 126 MW state-owned Bradley Lake project near Homer, which supplies 8% of the Railbelt's electrical energy. An additional 20 privately-owned hydro projects are catalogued in the Alaska Energy Authority's database.

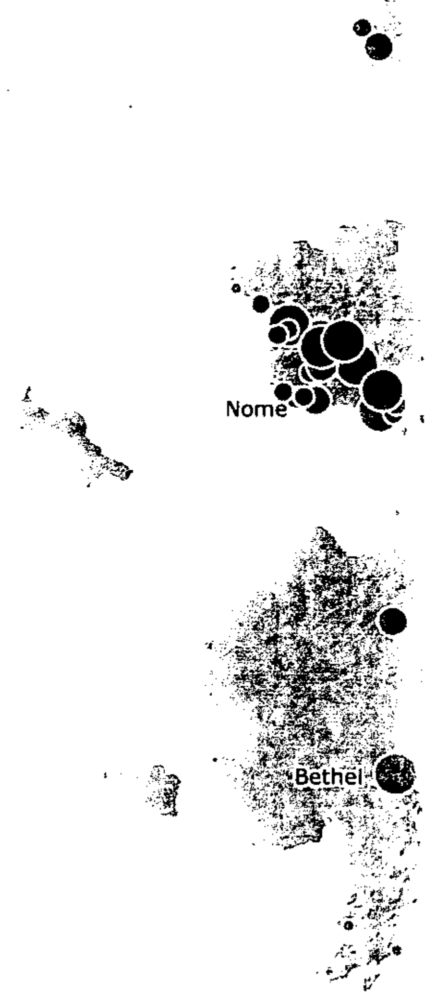
Most of the state's developed hydro resources are located near communities in Southcentral, the Alaska Peninsula, and Southeast—mountainous regions with moderate to high precipitation. Outside the Railbelt, major communities supplied with hydropower are Juneau, Ketchikan, Sitka, Wrangell, Petersburg, Kodiak, Valdez, Cordova, and Glenallen.

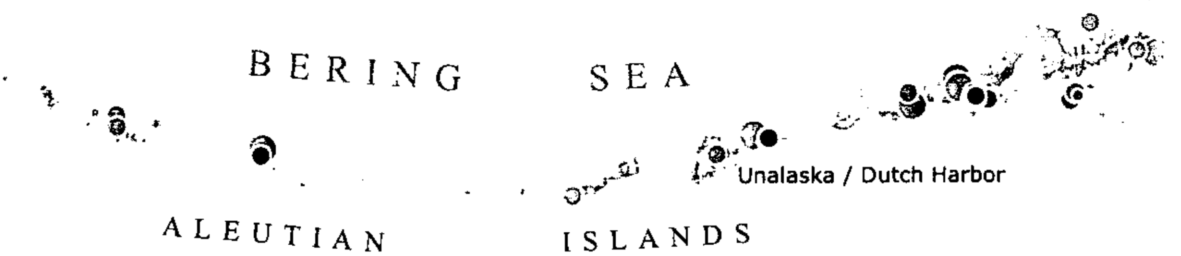
Like Bradley Lake, the 8 MW Blue Lake project near Sitka is an example of a project that stores energy by impounding water in a reservoir behind a dam. The dam is approximately 145 feet high with a spillway 342 feet above sea level. Water travels from the lake through a 1.3 mile tunnel to the main powerhouse, which discharges water near sea level. The project can store over 100,000 acre-feet of water— enough buffer between inflow and outflow to power Sitka for over a month—and supplies 60 percent of Sitka's average annual power requirements.

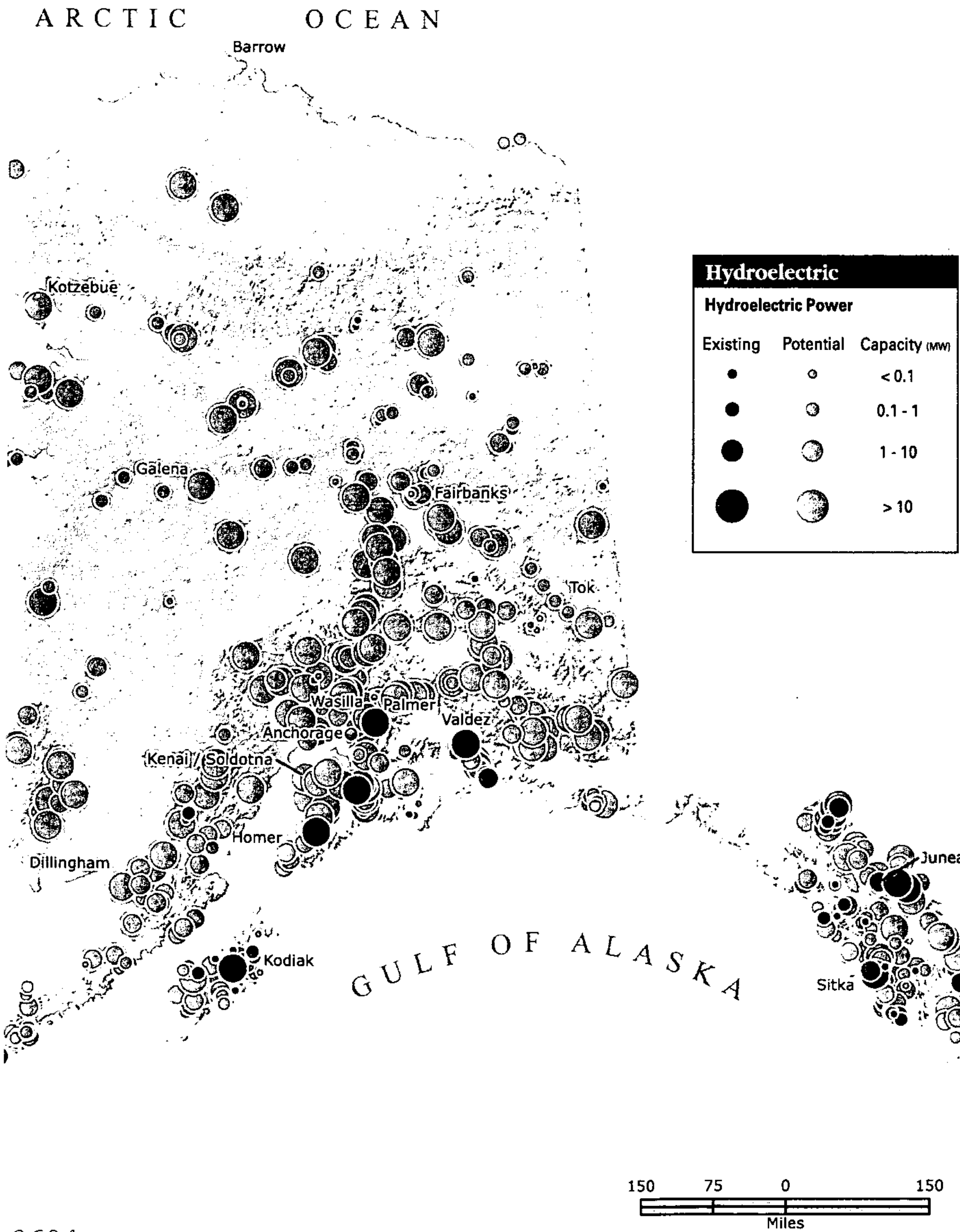
Other projects provide hydro storage without dam construction through the natural impoundment of an existing lake. The 31 MW Crater Lake project, part of the state-owned Snettisham project near Juneau, includes a "lake tap" 200 feet below the normal level of the lake that supplies water to a powerhouse at sea level through a 1.5 mile tunnel.

In contrast to projects providing storage, smaller "run-of-river" projects use more modest structures to divert a portion of the natural river flow through turbines to make power. An example is the 824 kW Tazimina project near Iliamna. Here water is diverted through an intake 250 feet upstream from a 100 foot waterfall through a steel pipe to an underground powerhouse. Water is released back into the river near the base of the falls.

Many rural communities located on the Yukon and other large rivers are interested in using river current for generating power. In 2002 Alaska Power and Telephone proposed testing UEK Corporation's 90 kW twin propeller system in the Yukon's 5.5 mph flow near Eagle. The propellers resemble underwater wind turbines anchored under the river's surface. Although funding for this demonstration is not yet available, current efforts directed toward developing tidal energy resources may advance this concept.



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Kodiak
GULF OF ALASKA
Juneau
Sitka
Ketchikan
Hydroelectric
Hydroelectric Power
Existing
Potential
Capacity (MW)
< 0.1
0.1 - 1
1 - 10
> 10
150
75
0
150
Miles

3694

Ocean

Alaska has 34,000 miles of coastline, more than all other states combined. For centuries the sea has provided rich marine resources that attracted people to the Alaska coast. Now another potential marine resource is being considered: harvesting energy from the ocean.

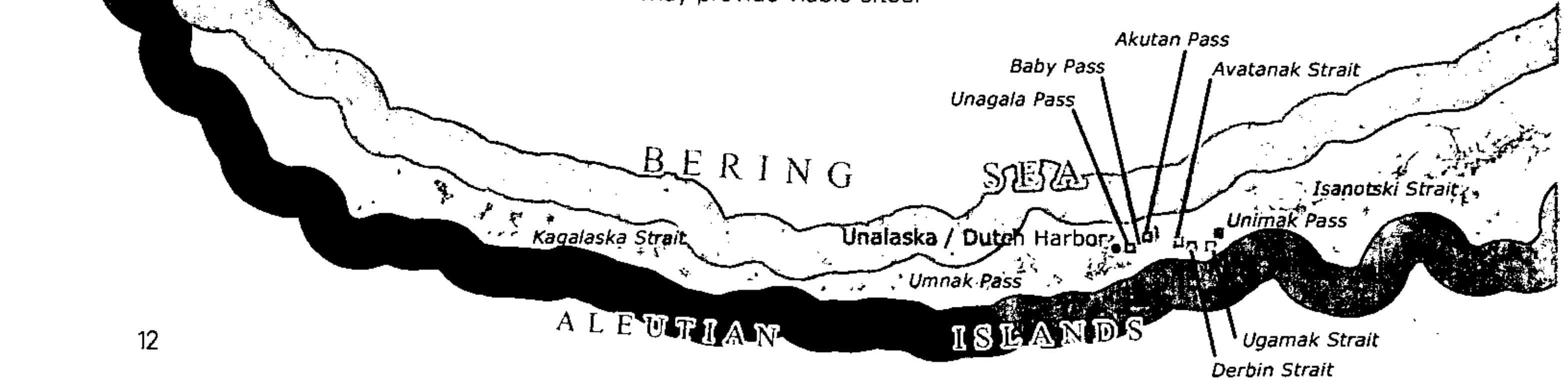
Ocean energy falls into three general categories: ocean thermal energy conversion (OTEC), tidal energy, and wave energy. OTEC applications are limited to tropical areas such as Hawaii and the southern Atlantic Coast, and are not suited for development in Alaska. That leaves tidal and wave energy, with each having the potential to meet some of Alaska's energy needs, although the technology for exploiting those potentials are not yet commercially available. Some tidal energy technology may also be used in river applications (*see Hydroelectric, page 10*).

Tidal energy is a concentrated form of the gravitational energy exerted by the moon and, to a lesser extent, the sun. This energy can be converted into electricity in two ways: by dams that force water through turbines at high and low tidal stages, and by underwater turbines that are turned by tidal flow. One of the significant benefits of tidal energy is that the tides are predictable for centuries in advance.

This map gives estimates of average tidal flow electrical generation potential for 35 sites based on the assumption that 15% of the available energy in each tidal stream is captured. Cook Inlet, with North America's second largest tidal range, has attracted interest as an energy source for the Railbelt for many years. In 2006, the Electric Power Research Institute, in partnership with the Alaska Energy Authority, Chugach Electric and ML&P, completed a tidal energy study at Cairn Point on Knik Arm. The study results showed that an estimated 17 MW of power could be generated using tidal energy, enough to power 17,000 homes. Since the report was published, the Federal Energy Regulatory Commission has issued eight preliminary tidal energy permits to energy developers for Alaska projects.

Wave energy is the result of wind acting on the ocean surface. Alaska has one of the best wave resources in the world, with parts of the Aleutian Islands coast averaging more than 50 kW per meter of wave front. The total wave power flux on southern Alaska's coast alone is estimated at 1,250 TWh per year, or almost 300 times the amount of electricity Alaskans use every year. Similar to other renewable energy sources in Alaska, a challenge to using wave energy is the lack of energy demand near the resource.

Much of Alaska's wave energy is dissipated on remote, undeveloped shorelines. The greatest wave energy resources are at the western end of the Aleutian Chain, while substantial resources are found on the southern side of the Alaska Peninsula and the outer coastline of Kodiak and southeast Alaska. There are currently no wave energy projects in Alaska; however several communities such as Yakutat may provide viable sites.

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Fire Island
Upper Cook Inlet
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Wasilla
Pt Possession
North Foreland
Anchorage
Valdez
Creek
The Forelands
Kenai
Soldotna
Harriet Point
East of Kalgin Island
Cape Ninilchik
Bainbridge Passage
Homer
Dillingham
Clarks Point
Chugach Passage
Cape Current Narrows
Whale Passage
Kodiak
GULF OF ALASKA
North Inian Pass
North Passage (Icy Strait)
Juneau
South Passage (Icy Strait)
South Inian Pass
Kootzhanoo Inlet
Sergius Narrows
Turn Point
Sitka
South Ledge
Spike Rock
Tonowek Narrows
Ketchikan
Tlevak Narrows
Ocean
Tidal Electric Generation Potential
MW
1.3 - 25
25 - 50
50 - 75
75 - 100
100 - 220
Wave Power Potential
kW/m
26 - 30
30 - 40
40 - 50
50 - 56
150 75 0 150
Miles

Solar

lthough Alaska's northern location presents the challenge of minimal solar energy during the long winter when energy demand is greatest, solar energy fulfills an important role in space heating and off-grid power generation.

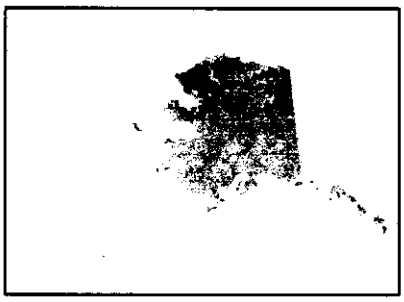
Most Alaskans know that careful house design and construction can minimize the use of heating fuel. "Passive solar" design includes proper southern orientation and the use of south facing windows that transfer the sun's energy into the house through natural processes of conduction, convection, and radiation. Passive solar design employs windows, thermal mass, and proper insulation to enable the building itself to function as a solar collector.

"Active solar" heating systems use pumps or fans to move energy to a point of use, such as a domestic hot water tank. A typical home demands a large amount of fuel year-round for domestic hot water, so using the sun to heat water for even seven or eight months a year saves significant amounts of energy. A larger role for active solar hot water systems may emerge as advances in heating systems allow solar heated fluid to supply in-floor systems currently heated by conventional fuel boilers.

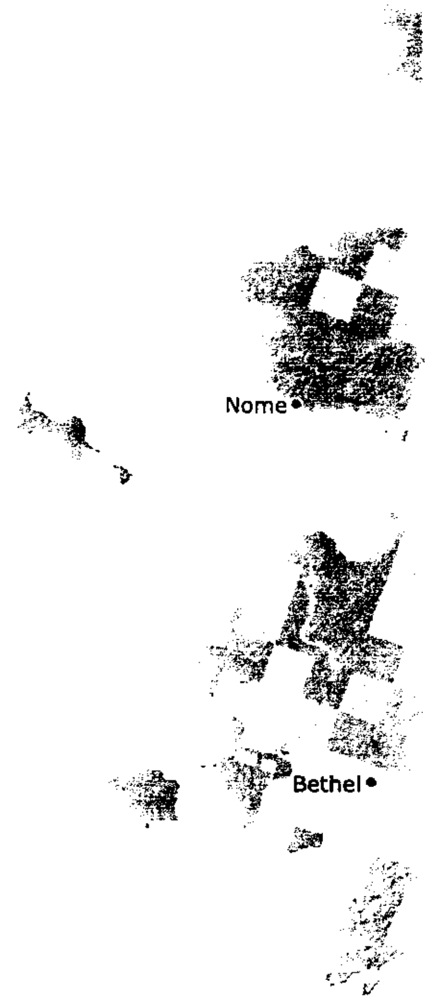
The state's largest utility-connected photovoltaic power system is in the remote community of Lime Village. Placed on line in 2001, the 106-panel hybrid photovoltaic-diesel-battery system can generate up to 12 kW.

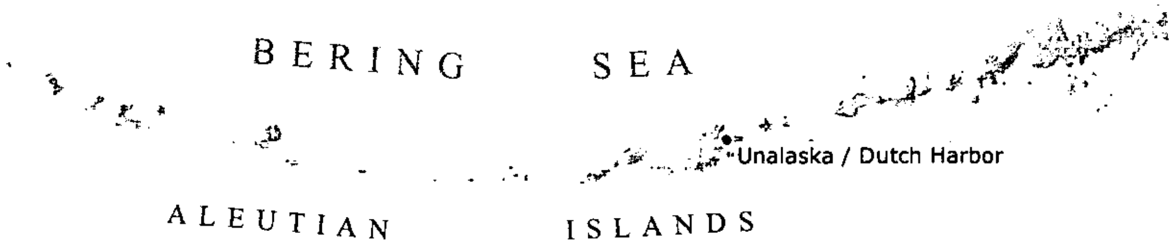
Although large utility-scale solar electric projects such as a 64 MW solar thermal plant in Nevada are being built in the Lower 48, significant utility-scale solar generation is unlikely in Alaska due to high capital costs and low yearly solar power output. For off-grid cabin owners, remote government installations, and other places where a relatively small amount of electricity is needed and proven generation options are limited, solar photovoltaics remain an excellent choice. As the price of solar panels continue to drop, more people are likely to consider solar electricity economical, especially if the cost of fossil-fueled electricity continues to rise.

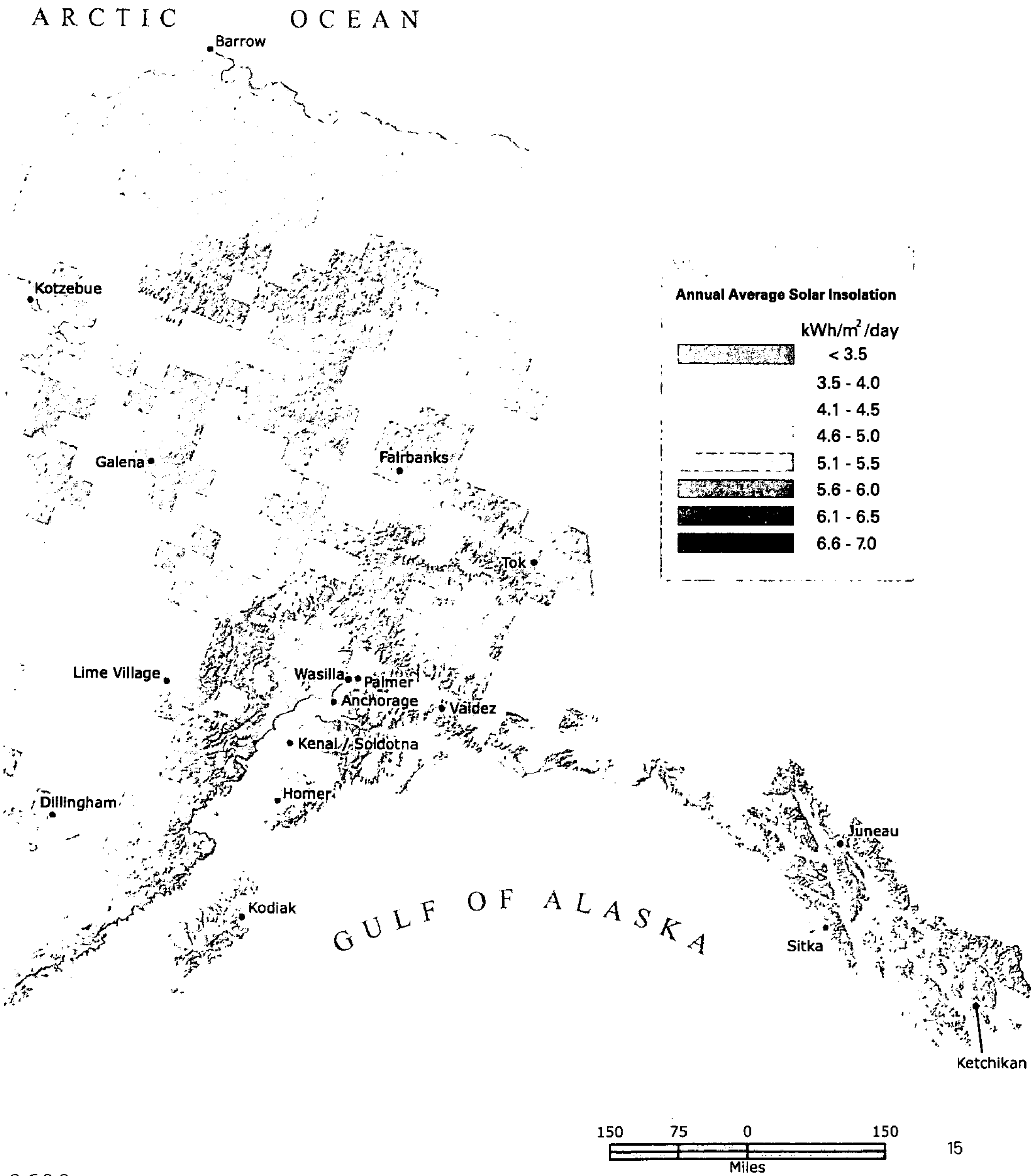
December Average Insolation



June Average Insolation



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Kodiak
GULF OF ALASKA
Juneau
Sitka
Ketchikan
Annual Average Solar Insolation
kWh/m2/day
< 3.5
3.5 - 4.0
4.1 - 4.5
4.6 - 5.0
5.1 - 5.5
5.6 - 6.0
6.1 - 6.5
6.6 - 7.0
150
75
0
150
Miles

3698

Wind

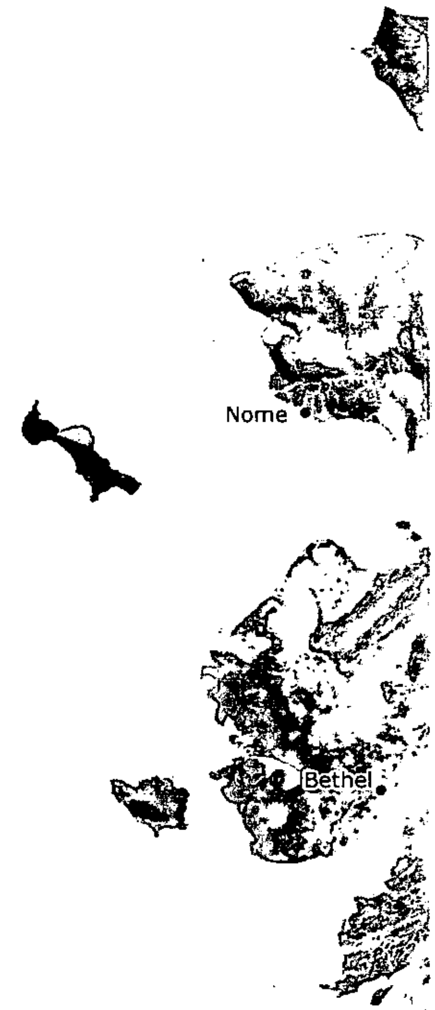
Alaska has abundant wind resources suitable for power development. Costs associated with fossil fuels and improvements in wind power technology make harnessing this clean, renewable energy source a growing opportunity for many Alaskans.

The wind map on these pages provides an initial indication of the potential for wind energy development. Wind power density, represented as watts per square meter, is divided into seven power classes. Wind energy feasibility depends on size of electrical load, price of displaced fuel such as diesel or natural gas, foundation cost, and other site-specific variables.

Much of the best winds are located in the western and coastal portions of the state. The winds in these regions tend to be associated with strong high and low pressure systems and related storm tracks. In parts of southwest Alaska, turbines may actually need to be sited away from some of the best winds to avoid extreme gusts and turbulence. In the interior, average wind speeds tend to be much lower, although localized wind resources can be found near elevated terrain or channeled passes like those near Healy and Delta. Katabatic winds, created by variation in air mass temperatures, are found in places like the upper Matanuska Valley and near Seward and Juneau. In parts of Southeast Alaska, offshore locations are promising, but steep terrain and large forested areas limit onshore potential. Site-specific wind resource data has been collected through the Alaska Energy Authority's anemometer loan program.

Wind power technologies being used or planned in Alaska range from small wind chargers at off-grid homes or remote camps, to medium-sized machines displacing diesel fuel in isolated village wind-diesel hybrid power systems, to large industrial turbines greater than 1 MW. On the Railbelt, several of the major utilities are examining wind power as a way to diversify future sources of energy and hedge against rising natural gas prices. Initial studies by Chugach Electric Association and land owner Cook Inlet Region, Inc. at Fire Island west of Anchorage indicate a wind power class 4 to 5. Golden Valley Electric Association has made substantial progress in developing the Eva Creek Wind project located near existing transmission lines north of Healy. 50 MW projects at Fire Island and Eva Creek would each be capable of supplying approximately 3% of the Railbelt's electrical energy.

Alaska's first wind farm, located in Kotzebue in a Class 4 to 5 wind resource, has been displacing a significant portion of the utility's diesel fuel with wind power since 1997. On St. Paul Island in the Bering Sea, the Tanadgusix Corporation (TDX) takes advantage of a Class 7 wind resource to provide electricity, as well as heat produced from excess wind energy, to a large industrial facility. Alaska Village Electrical Cooperative recently installed 300 kW wind projects in Toksook Bay and Kasigluk. An intertie from Toksook Bay also provides electricity to Nightmute and Tununak. Other projects are underway or planned in Kodiak, Sand Point, Nikolski, Hooper Bay, Chevak, Gambell, and Savoonga.



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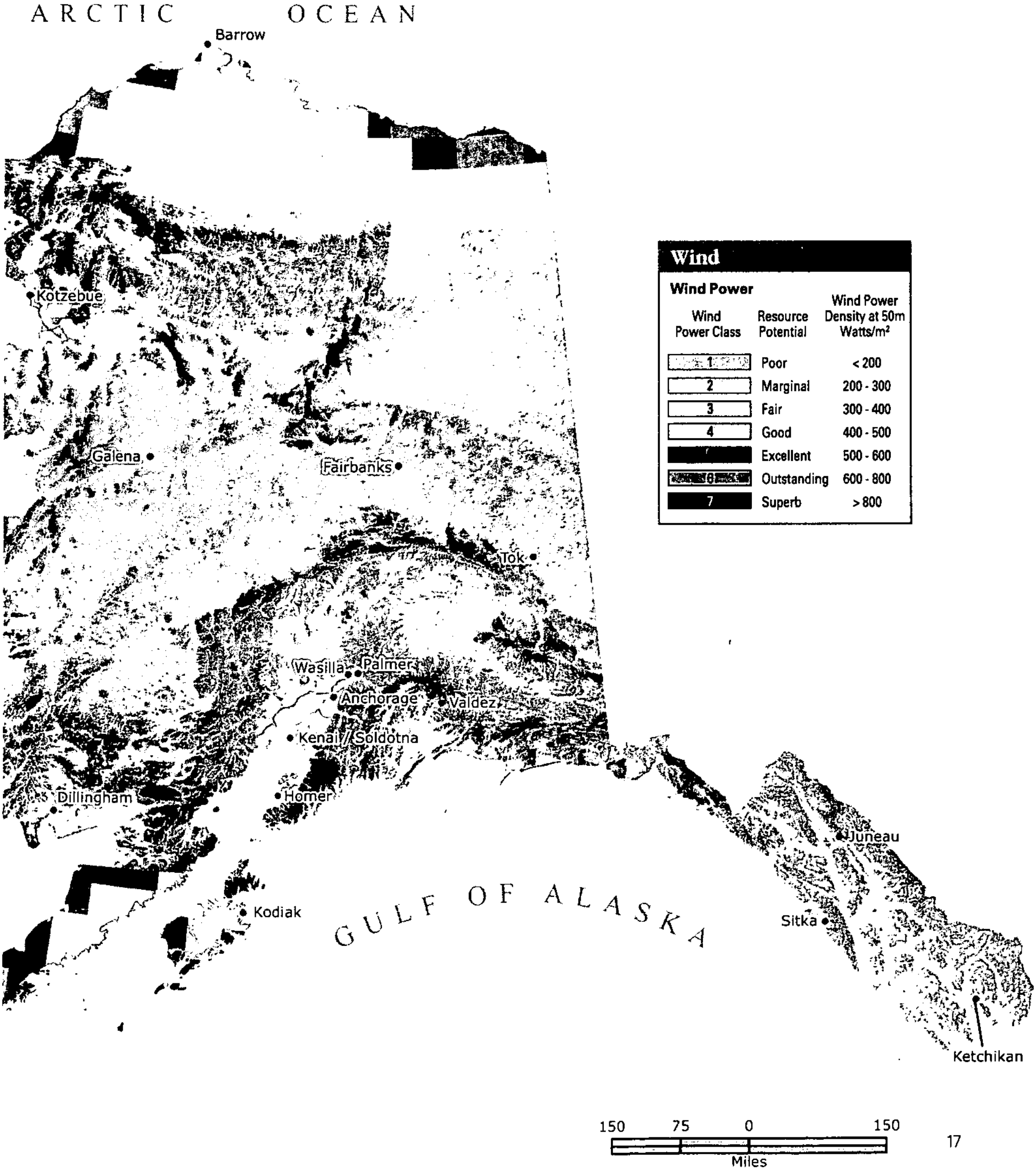
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Kodiak
GULF OF ALASKA
Juneau
Sitka
Ketchikan
Wind
Wind Power
Wind Power Class
Resource Potential
Wind Power Density at 50m Watts/m²
1 Poor < 200
2 Marginal 200 - 300
3 Fair 300 - 400
4 Good 400 - 500
Excellent 500 - 600
6 Outstanding 600 - 800
7 Superb > 800
150 75 0 150
Miles

3700

Renewable Energy Policies

State and federal policies that encourage renewable energy projects play an important role in their development.

At the federal level the production tax credit (PTC) is the primary incentive tool. The PTC was passed by Congress to even the playing field between the renewable energy industry and the heavily subsidized fossil fuel and nuclear industries. The PTC currently allows the owners of qualifying renewable energy projects to take 1.9 cents off their tax bill for every kilowatt-hour of renewable energy generated during the first ten years of the project. Though the tax credit is an important part of renewable energy project financing, one criticism of the PTC has been its short term duration. Congress has reauthorized the tax credit a year or two at time, making it difficult for investors to plan development of renewable energy resources far into the future.

Because there are few other federal policies that support renewable energy development besides the PTC, individual state policies have been the primary drivers of renewable energy development in the United States. The three primary policies used across the country are net metering, renewable portfolio standards, and renewable energy funds. A fourth policy area focuses on state set electrical tariffs being used in countries like Canada, Germany, and Spain.

Net Metering

State net metering rules provide an incentive for individuals and businesses to invest in their own small renewable energy systems by allowing them to sell back into the grid any excess power they produce. Forty states now offer some form of net metering. Different rules in each state determine the maximum amount of power an individual can sell back to the utility, the price at which the utility must purchase the power, and the length of time an individual producer can "bank" the power they produce before a "net" bill must be calculated.

Rich Seifert

Home near Fairbanks that uses a combination of photovoltaic cells for power, an active solar water heater, and passive solar design.

Although it is possible for individuals to sell power back in some Alaska utility districts, Alaska does not have a statewide net metering law that would make it much easier to do so.

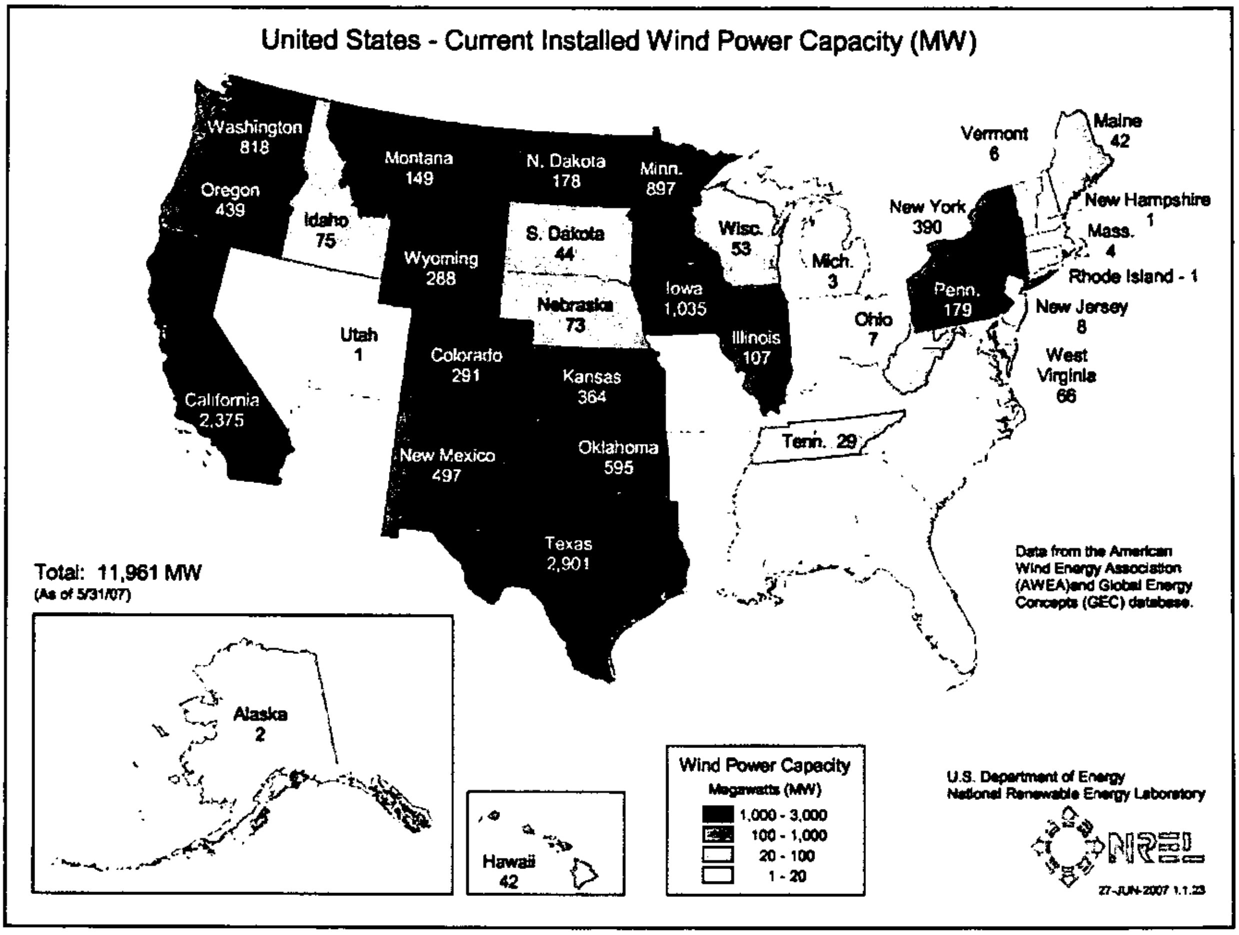
Alaska Energy Authority

Renewable energy creates jobs for Alaskans

In the Fairbanks area Golden Valley Electric Association (GVEA) has developed the Sustainable Natural Alternative Power (SNAP) program. SNAP allows GVEA customers who wish to support renewable energy development to do so by contributing to a fund that is held in escrow by the utility company. Individuals in the GVEA service area who want to produce up to 25 kW of renewable electricity for the grid are paid from the escrow fund in proportion to the amount of power they produce.

Renewable Portfolio Standards

Twenty-two states and the District of Columbia now have a policy known as a renewable portfolio standard (RPS). An RPS is a state law that requires utility companies to generate a specified percentage of their electricity from renewable resources by a certain date. For example, Nevada law mandates that investor owned utilities in that state produce 20% of their electricity from renewables by the year 2015. The percentage and the end date range widely across the various states that have an RPS. Utilities are typically given interim milestones, and must pay a fine if they do not reach those milestones. Most states allow utilities to purchase renewable energy credits (RECs) to meet the RPS standard and avoid paying fines. The RPS approach makes different entities and renewable energy resources compete to meet the standard.



National Renewable Energy Laboratory

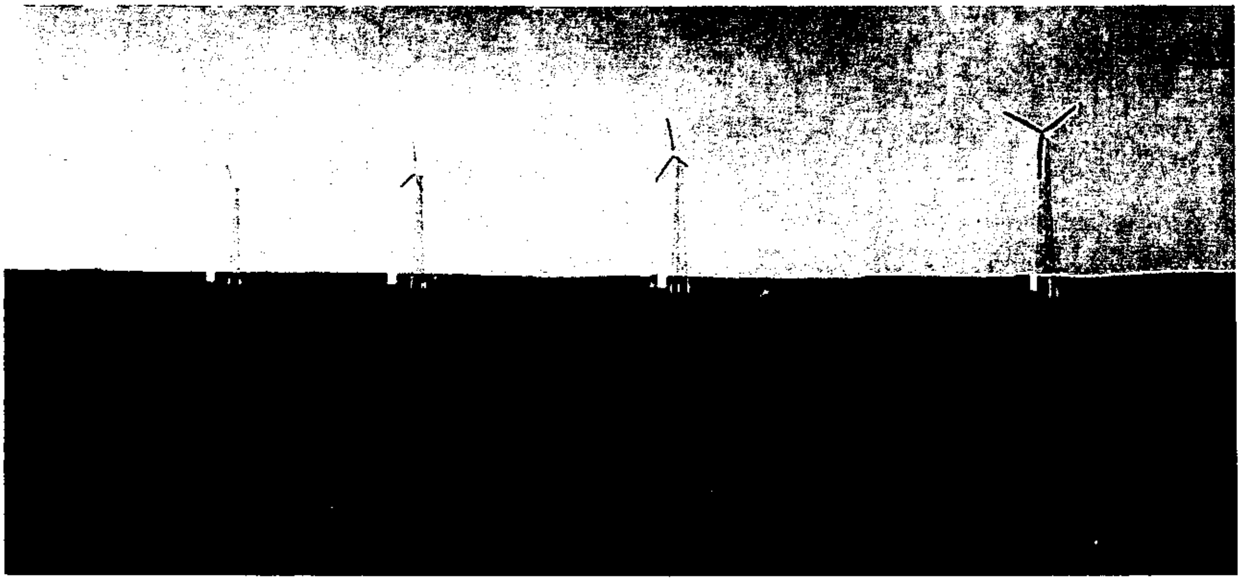
Wind is the fastest growing energy sector in the world. The U.S now ranks second in total installed wind generation capacity behind Germany, although the U.S. still generates less than 1% of its electricity from wind. Denmark already generates over 20% of its electricity from wind, followed by Spain at 8% and Germany at 6%.

Renewable Energy Funds / System Benefit Charges

Fifteen states have renewable energy funds (sometimes called clean energy funds), most of which are supported by small, mill-rated surcharges on energy sold to consumers. These surcharges are sometimes referred to as system benefit charges. Renewable energy funds provide support for the development of renewable energy by helping to remove market barriers, lowering financing costs, developing infrastructure, and educating the public. For example, the system benefit charges in Oregon are deposited into an independent trust that funds eligible wind, solar electric, biomass, small scale hydro, tidal, geothermal, and fuel cell projects. These projects are supported by grants, loans, rebates, equity investments, and other financing mechanisms used by the fund.

Terms of the various funds vary from state to state. Some states have scheduled funds to last only five years. Other states have open-ended funds. Longer-term funds provide greater stability for renewable energy developers. It's estimated that over the next 20 years the combined renewable energy funds of the 15 states will invest about $4.5 billion in renewable energy generation.

In the states that have both an RPS and a renewable energy fund, the two policies complement each other in stimulating the renewable energy market. RPS standards "pull" renewable energy technologies into a state by providing a long-term market that reduces investment risk and provides a level playing field for developers. On the other hand, renewable energy funds "push" clean energy technologies by lowering market barriers through direct investment incentives



Four 66 kW Integrity wind turbines that make up part of Kotzebue Electric Association's 957 kW wind farm. By the end of 2006 Kotzebue will have 1155 kW of installed wind capacity. In a typical year the wind farm displaces over 100,000 gallons of diesel fuel.

and supporting the infrastructure needed to develop renewable energy. For example, in California, the fund is used to buy down the above-market costs of renewable energy. And of course, the development that takes place as a result of renewable energy funds helps states meet their RPS requirements.

Renewable Energy Credits (RECs)

Utilities recognized years ago that there was a market demand for clean renewable energy when customers agreed to pay more for resources like wind. Today, rather than charging a premium for renewable source power, most utilities sell the social and environmental attributes of renewable energy separately from the actual electrons in the form of certificates. Also known as "green tags," renewable energy certificates (RECs) are essentially the bragging rights that are created when renewable energy is produced. Each REC represents the production of one megawatt hour of renewable energy and the displacement of approximately 1,400 pounds of CO_2 emissions. Buyers of RECs include utilities trying to meet state RPS requirements, as well as a growing number of federal agencies and corporations committed to supporting increased renewable energy production. For example, Fortune 500 company Whole Foods is buying RECs from wind farms to offset 100% of the electricity used in all of its facilities in the United States and Canada.

Renewable Energy Alaska Project (REAP) and the Bonneville Environmental Foundation (BEF) recently joined forces to create the first REC containing renewable energy from Alaska. *Denali Green Tags* are available through the BEF website, and contain the social and environmental attributes from small village wind projects in rural Alaska.

Steam vent on Kiska Volcano in the Aleutian Islands. Several communities in the Aleutians are considering developing their geothermal resources.

3703

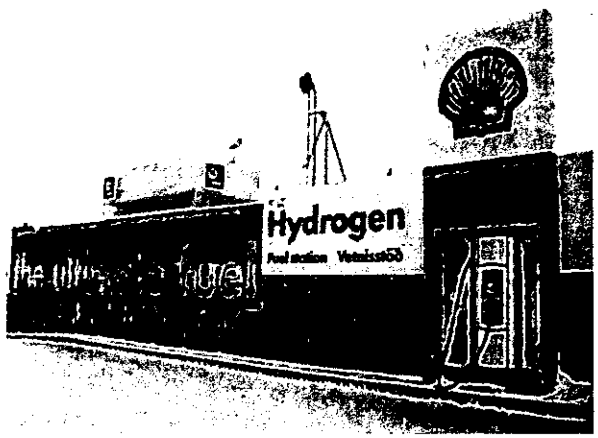
Electricity Feed Laws and Advanced Renewable Tariffs

Electricity feed laws and advanced renewable tariffs (ARTs) are used in a number of European countries and are considered by many to be the world's most successful policy mechanism for stimulating rapid renewable energy development. They give renewable energy producers guaranteed access to the electric grid at a price set by the regulatory authority, giving producers the contractual certainty needed to finance renewable energy projects. They also enable homeowners, farmers, cooperatives and others to participate on an equal footing with large commercial developers of renewable energy. Currently 16 countries in the European Union use some form of feed law.

ARTs are the modern version of Feed Laws. They differ from the simpler feed laws in several important ways. Tariffs are differentiated by technology. (There is one price for wind energy, another price for solar, etc.). Tariffs within each technology can also be differentiated by project size or, in the case of wind energy, by the productivity of the resource. Tariffs for new projects are also subject to periodic review to determine if the program is sufficiently robust. For example, programs are reviewed every two years in France, and every three years in Germany.

The Canadian province of Ontario recently enacted a type of Advanced Renewable Tariff called a Standard Offer Contract. The program offers 11cents/kWh (Canadian) to producers of wind, biomass and small hydro energy and 42 cents/kWh for solar photovoltaic energy. The contracts are for 20 years, and will be adjusted for inflation as time goes on. (This price compares to the 2006 residential retail price for electricity in Ontario of just under $0.06/kWh). There is no limit to the number of projects that may apply for a contract, but the size of each project is capped at 10 MW. The contracts are available to anyone, including homeowners, businesses and commercial energy producers.

Many commentators are looking to Ontario's new policy to become a model that other North America jurisdictions will follow. Recently the State of Washington passed a modest version of a feed law for small solar projects. It gives businesses and homes with solar photovoltaics a credit of 15 cents/kWh for electricity generated by the PV system. The credit is capped at $2,000 annually and runs until



Chris Rose, REAP

Hydrogen filling station in Reykjavik, Iceland. Iceland gets 99% of its electricity and over 90% of heat for buildings from its geothermal and hydroelectric resources. Ninety-three percent of Icelanders support the government's goal to be the first nation in the world to replace its use of fossil fuels in autos and boats with hydrogen fuel.

2015. The law also combines economic multipliers to increase the system owner's credit up to 54 cents/kWh if the project's components are manufactured in Washington.

Alaska

Two state documents have recently made policy recommendations calling for the increased development of renewable energy in Alaska. In 2003 the Alaska State Legislature commissioned the Alaska Energy Policy Task Force to develop a long-term energy policy for Alaska. In its written report to the Legislature the Task Force established goals to "promote research, development, and demonstration of clean and renewable energy" and to "promote conservation and energy efficiency across all of Alaska." It also recommended that Alaska "increase the proportion of renewables in long-term fuel sources," including hydroelectric generation.

The 2004 Alaska Rural Energy Plan, which was supported by state and federal agencies, concluded that wind energy development was feasible in a substantial number of rural communities, and recommended an aggressive program of resource assessment and turbine deployment in rural Alaska. The Alaska Energy Authority has begun to implement the plan through its anemometer loan and rural power system upgrade programs.

Glossary

Absorption Chiller - A device that uses heat energy rather than mechanical energy to cool an interior space through the evaporation of a volatile fluid.

Active Solar - A solar water or space-heating system that uses pumps or fans to circulate the fluid (water or heat-transfer fluid like diluted antifreeze) from the solar collectors to a storage tank subsystem.

Alternative Fuels - A term for "non-conventional" transportation fuels derived from natural gas (propane, compressed natural gas, methanol, etc.) or biomass materials (ethanol, methanol, or biodiesel).

Anemometer - An instrument for measuring the velocity of wind; a wind gauge.

ASTM - Abbreviation for the American Society for Testing and Materials, which is responsible for the issue of many standard methods used in the energy industry.

Availability - Describes the reliability of power plants. It refers to the number of hours that a power plant is available to produce power divided by the total hours in a set time period, usually a year.

Avoided Cost - The incremental cost to an electric power producer to generate or purchase a unit of electricity or capacity or both.

Biodiesel - A domestic, renewable fuel for diesel engines derived from natural oils like fish and vegetable oil; produced by a chemical process which removes the glycerin from the oil and meets a national specification (ASTM D 6751).

Biomass - Organic matter that is available on a renewable basis, including agricultural crops and agricultural wastes and residues, wood and wood wastes and residues, animal wastes, municipal wastes, and aquatic plants.

Bioenergy – Electrical, mechanical, or thermal energy or fuels derived from biomass.

Capacity Factor - The ratio of the average power output of a generating unit to the capacity rating of the unit over a specified period of time, usually a year.

Co-firing - Using more than one fuel source to produce electricity in a power plant. Common combinations include biomass and coal, biomass and natural gas, or natural gas and coal.

Cogeneration - The generation of electricity and the concurrent use of rejected thermal energy from the conversion system as an auxiliary energy source.

Conduction - The transfer of heat through a material by the transfer of kinetic energy from particle to particle; the flow of heat between two materials of different temperatures that are in direct physical contact.

Convection - The transfer of heat by means of air currents.

Dam - A structure for impeding and controlling the flow of water in a water course that increases the water elevation to create hydraulic head. The reservoir creates, in effect, stored energy.

District Heating System - Local system that provides thermal energy through steam or hot water piped to buildings within a specific geographic area. Used for space heating, water heating, cooling, and industrial processes. A common application of geothermal resources.

Distributed Generation - Localized or on-site power generation, which can be used to reduce the burden on a transmission system by generating electricity close to areas of customer need.

Distribution Line - One or more circuits of an electrical distribution system on the same line or poles or supporting structures, usually operating at a lower voltage relative to a transmission line.

Domestic Hot Water - Water heated for residential washing, bathing, etc.

Electrical Energy - The amount of work accomplished by electrical power, usually measured in kilowatt-hours (kWh). One kWh is 1,000 Watts generated for one hour and is equal to 3,413Btu.

Energy - The capability of doing work; different forms of energy can be converted to other forms, but the total amount of energy remains the same.

Energy Crop - A plant grown with the express purpose to be used in biomass electricity or thermal generation.

Energy Storage - The process of storing, or converting energy from one form to another, for later use. Storage devices and systems include batteries, conventional and pumped storage hydroelectric, flywheels, compressed gas, hydrogen, and thermal mass.

Ethanol - A colorless liquid that is the product of fermentation used in alcoholic beverages, in industrial processes, and as a fuel.

Feedstock - A raw material that can be converted to one or more products.

Fossil Fuels - Fuels formed in the ground from the remains of dead plants and animals, including oil, natural gas, and coal. It takes millions of years to form fossil fuels.

Fuel - Any material that can be burned to make energy.

Fuel Oil - Any liquid petroleum product burned for the generation of heat in a furnace or firebox, or for the generation of power in an engine. Domestic (residential) heating fuels are classed as Nos. 1, 2, 3; Industrial fuels as Nos. 4, 5, and 6.

Generator - A device for converting mechanical energy to electrical energy.

Geothermal Energy - Energy produced by the internal heat of the earth; geothermal heat sources include: hydrothermal convective systems; pressurized water reservoirs; hot dry rocks; manual gradients; and magma. Geothermal energy can be used directly for heating and cooling or to produce electric power.

Head – A measure of fluid pressure, commonly used in water pumping and hydro power to express height that a pump must lift water, or the distance water falls. Total head accounts for friction and other head losses.

Heat Pump - An electricity powered device that extracts available heat from one area (the heat source) and transfers it to another (the heat sink) to either heat or cool an interior space or to extract heat energy from a fluid.

Hybrid System - An energy system that includes two different types of technologies that produce the same type of energy; for example, a wind turbine and a solar photovoltaic array combined to meet electric power demand.

Hydroelectric Power Plant - A power plant that produces electricity by the force of water falling through a hydro turbine that spins a generator.

Hydrogen - A chemical element (H_2) that can be used as a fuel since it has a very high energy content.

Landfill Gas - Naturally occurring methane produced in landfills that can be burned in a boiler to produce heat or in a gas turbine or engine-generator to produce electricity.

Large-scale or Utility-scale - A power generating facility designed to output enough electricity for purchase by a utility.

Load - Amount of electricity required to meet customer demand at any given time.

Meteorological (Met) Tower - A structure instrumented with anemometers, wind vanes, and other sensors to measure the wind resource at a site.

Ocean Energy Systems - Energy conversion technologies that harness the energy in tides, waves, and thermal gradients in the oceans.

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Ocean Thermal Energy Conversion (OTEC) - The process or technologies for producing energy by harnessing the temperature differences between ocean surface waters and that of ocean depths.

Organic Rankine cycle – A system that uses a hydrocarbon instead of water as a working fluid to spin a turbine, and therefore can operate at lower temperatures and pressures than a conventional steam process.

Panel (Solar) - A term generally applied to individual solar collectors, and typically to solar photovoltaic collectors or modules.

Passive Solar Design - Construction of a building to maximize solar heat gain in the winter and minimize it in the summer, thereby reducing the use of mechanical heating and cooling systems.

Peak load – The amount of electricity required to meet customer demand at its highest.

Penstock - A component of a hydropower plant; a pipe that delivers water to the turbine.

Photovoltaics (PV) - Devices that convert sunlight directly into electricity using semiconductor materials. Most commonly found on a fixed or movable panel; also called solar panels.

Power - Energy that is capable of doing work; the time rate at which work is performed, measured in horsepower, Watts, or Btu per hour.

Production Tax Credit (PTC) – An incentive that allows the owner of a qualifying energy project to reduce their taxes by a specified amount. The federal PTC for wind, geothermal, and closed-loop biomass is 1.9 cents per kWh.

Radiation - The transfer of heat through matter or space by means of electromagnetic waves.

Railbelt - The portion of Alaska that is near the Alaska Railroad, generally including Fairbanks, Anchorage, and the Kenai Peninsula.

Renewable Resource - Energy sources which are continuously replenished by natural processes, such as wind, solar, biomass, hydroelectric, wave, tidal, and geothermal.

Run-of-River Hydroelectric - A type of hydroelectric facility that uses the river flow with very little alteration and little or no impoundment of the water.

Small-scale or Residential-scale - A generating facility designed to output enough electricity to offset the needs of a residence, farm or small group of farms, generally 250 kW or smaller.

Solar Energy - Electromagnetic energy transmitted from the sun (solar radiation).

Solar Radiation - A general term for the visible and near visible (ultraviolet and near-infrared) electromagnetic radiation that is emitted by the sun. It has a spectral, or wavelength, distribution that corresponds to different energy levels; short wavelength radiation has a higher energy than long-wavelength radiation.

Tidal Power - The power available from either the rise and fall or flow associated with ocean tides.

Transmission Grid - The network of power lines and associated equipment required to deliver electricity from generating facilities to consumers through electric lines.

Turbine - A device for converting the flow of a fluid (air, steam, water, or hot gases) into mechanical motion.

Wave Energy - Energy derived from the motion of ocean waves.

Wind Energy - Energy derived from the movement of the wind across a landscape. Wind is caused by the sun heating the atmosphere, earth, and oceans.

Wind Turbine - A device that converts energy in the wind to electrical energy, typically having two or three blades.

Windmill - A device that converts energy in the wind to mechanical energy that is used to grind grain or pump water.

Wind Power Class - A class based on wind power density ranging from 1 (worst) to 7 (best).

Wind Power Density - The amount of power per unit area of a free windstream.

Wind Resource Assessment - The process of characterizing the wind resource, and its energy potential, for a specific site or geographical area.

UNITS

Ampere - A unit of measure for an electrical current; the amount of current that flows in a circuit at an electromotive force of one Volt and at a resistance of one Ohm. Abbreviated as amp.

Amp-Hours - A measure of the flow of current (in amperes) over one hour.

Barrel (Petroleum) - Equivalent to 42 U.S. gallons (306 pounds of oil, or 5.78 million Btu).

British Thermal Unit (Btu) - The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit; equal to 252 calories.

Cord (of Wood) - A stack of wood 4 feet by 4 feet by 8 feet.

Gigawatt (GW) - A unit of power equal to 1 billion Watts; 1 million kilowatts, or 1,000 megawatts.

Hertz - A measure of the number of cycles or wavelengths of electrical energy per second; U.S. electricity supply has a standard frequency of 60 hertz.

Horsepower (hp) - A measure of time rate of mechanical energy output; usually applied to electric motors as the maximum output; 1 electrical hp is equal to 0.746 kilowatts or 2,545 Btu per hour.

Kilowatt (kW) - A standard unit of electrical power equal to one thousand watts, or to the energy consumption at a rate of 1000 Joules per second.

Kilowatt-hour (kWh) - A common measurement of electricity equivalent to one kilowatt of power generated or consumed over the period of one hour; equivalent to 3,413 Btu.

Megawatt (MW) - One thousand kilowatts, or 1 million watts; standard measure of electric power plant generating capacity.

Megawatt-hour (MWh) - One thousand kilowatt-hours or 1 million watt-hours.

Mill - A common monetary measure equal to one-thousandth of a dollar or a tenth of a cent.

Quad - One quadrillion Btu. (1,000,000,000,000,000 Btu)

Therm - A unit of heat containing 100,000 British thermal units (Btu).

Terawatt (TW) - A unit of electrical power equal to one trillion watts or one million megawatts.

Tonne - A unit of mass equal to 1,000 kilograms or 2,204.6 pounds, also known as a metric ton.

Volt (V) - A unit of electrical force equal to that amount of electromotive force that will cause a steady current of one ampere to flow through a resistance of one ohm.

Voltage - The amount of electromotive force, measured in volts, that exists between two points.

Watt (W) - Instantaneous measure of power, equivalent to one ampere under an electrical pressure of one volt. One watt equals 1/746 horsepower, or one joule per second. It is the product of Voltage and Current (amperage).

Watt-hour - A unit of electricity consumption of one Watt over the period of one hour.

Watts per Square Meter (W/m^2) - Unit used to measure wind power density, measured in Watts per square meter of blade swept area.

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Data Sources

References

Common Map Layers
(1) Communities: State of Alaska Department of Commerce, Community, and Economic Development. Community Database Online.
www.commerce.state.ak.us/dca/commdb/CF_COMDB.htm

(2) Lakes, Streams, and Glaciers: State of Alaska Department of Natural Resources (ADNR).
www.asgdc.state.ak.us/metadata/vector/physical/hydro/lk2mil.html

(3) Grayscale Elevation Hillshade Image: Resource Data Inc.
The elevation image was developed using a 300 meter digital elevation model from U.S. Geological Survey EROS Alaska Field Office.
www.asgdc.state.ak.us/metadata/raster/elev/elev300m.html

(4) Canada and Russia: State of Alaska Department of Natural Resources.
www.asgdc.state.ak.us/metadata/vector/physical/coast/canada.html
www.asgdc.state.ak.us/metadata/vector/physical/coast/russia.html

Infrastructure
Average generation from Alaska Electric Power Statistics (with Alaska Energy Balance) 1960-2001, University of Alaska Anchorage Institute of Social and Economic Research, 2003. www.iser.uaa.alaska.edu/Publications/akelectricpowerfinal.pdf

Pie chart from Alaska Electric Power Statistics 1960-2001, and AEA estimates for non-hydro renewables.

(5) Coal, Gas Turbine, and Diesel sites*: Institute of Social and Economic Research (ISER). Alaska Electric Power Statistics (with Alaska Energy Balance) 1960-2001.

(6) Existing Utility Hydroelectric sites: Alaska Energy Authority hydroelectric database. Spatial location and attribute data updated by HDR Alaska Inc. in 2006.

(7) Wind, Solar, Geothermal, and Biomass sites*: Alaska Energy Authority.

(8) Electrical Interties: Interties aggregated from data provided by Alaska Electric Light & Power Company, Alaska Power & Telephone Company, Alaska Village Electric Cooperative, Chugach Electric Association, City of Sitka Electric Department, Copper Valley Electric Association, Four Dam Pool Association, Golden Valley Electric Association, Homer Electric Association, Naknek Electric Association, and Nushagak Cooperative.

(9) Natural Gas Pipelines: ENSTAR Natural Gas Company.

(10) Electric Service Areas: Chugach Electric Association.

(11) Trans-Alaska Pipeline: State of Alaska Department of Natural Resources.
www.asgdc.state.ak.us/metadata/vector/trans/pipeline.html

(12) Railroad: State of Alaska Department of Natural Resources.
www.asgdc.state.ak.us/metadata/vector/trans/rail2mil.html

(13) Roads: State of Alaska Department of Natural Resources & State of Alaska Department of Transportation.
www.asgdc.state.ak.us/metadata/vector/trans/road2mil.html
www.asgdc.state.ak.us/metadata/vector/othermet/akhwysy.html

Biomass
(14) Forested Areas: U.S. Forest Service, U.S. Geological Survey, and State of Alaska Division of Forestry Forest Health Monitoring Clearinghouse.
http://agdc.usgs.gov/data/projects/fhm/index.html#G
http://agdcftp1.wr.usgs.gov/pub/projects/fhm/vegcls.txt

Vegetation classes for the map selected from source dataset classes as follows:
Open forest and tall shrub: Class 10, 15
Mixed spruce and broadleaf: Class 11, 12, 14, 16, 18
Closed spruce: Class 13, 17, 19

(15) Fish Processing Plants*: Alaska Energy Authority.
Plant locations are a subset of a fish biodiesel database.

(16) Class I Landfills*: State of Alaska Department of Environmental Conservation.

(17) Sawmills*: Alaska Wood Products Manufacturers Directory, September 2004. Juneau Economic Development Council Wood Products Development Service.
www.jedc.org/wood/index.htm

(18) Agricultural Lands: State of Alaska Department of Natural Resources, Division of Agriculture (ADNR). Agricultural lands classified by ADNR from land use plans and private land patented for agricultural use.

Geothermal
(19) Volcanoes: Alaska Volcano Observatory. The locations depicted represent volcanoes without regard to recency of activity.
http://www.avo.alaska.edu/volcanoes/latlong.php

(20) Wells and Springs by Temperature: Geo-Heat Center State Geothermal Database CD, Geo-Heat Center, Oregon Institute of Technology.
http://geoheat.oit.edu/database.htm

(21) Potential Geothermal Resources: Idaho National Laboratory.
The areas depicted represent regions favorable for the discovery (at shallow depth, less than 1000m) of thermal water of sufficient temperature for direct-heat applications. It is probable that only small areas of the regions are truly underlain by such thermal water; the regions represent that part of the state that deserves exploration for thermal areas. The regions are defined on the basis of various geothermal and tectonic phenomena such as locations of thermal wells and springs, above-normal heat flow, youthful volcanism, mineralization, and seismicity.
http://geothermal.id.doe.gov/maps/index.shtml
http://geothermal.id.doe.gov/maps/ak_metadata.htm

Hydroelectric
(22) Existing and Potential Hydroelectric sites: Alaska Energy Authority hydroelectric database. Spatial location and attribute data updated by HDR Alaska Inc. in 2006.

Ocean
(25) Tidal Electric Generation Potential: Brian Polagye, 2007. Tidal resource was quantified for 35 transects across tidal channels, perpendicular to the flow. The analysis used NOAA time series of currents and tidal range, as well as bathymetric data. Due to map scale each study site is depicted as a point location rather than a linear transect.

(26) Wave Power Potential: Mirko Previsic (re vision consulting LLC), 2007. Primary resource potential in average megawatts was derived from analysis of nine representative NOAA moored ocean buoys. The linear length of the approximate outer coast represented by each buoy was used to calculate the kilowatts per meter depicted on the map as a buffered area. Wave energy resource is not shown for the coastline north of the Yukon River delta due to seasonal pack ice and relatively low wave energy resources.

Solar
(23) Solar Insolation: U.S. Department of Energy, National Renewable Energy Laboratory, 1999. The data layer provides annual average daily total solar resource averaged over surface cells of approximately 40 km by 40 km in size.
www.nrel.gov/gis/data_analysis.html

Wind
(24) Wind Power: AWS Truewind, 2006 & U.S. Department of Energy, National Renewable Energy Laboratory (NREL), 1986.

Three separate datasets were merged to create the wind power layer. In order of display priority these were 1) AWS Truewind 2006 final data for the core of Alaska (200m resolution), 2) AWS Truewind 2006 final data for the Southeastern Panhandle (200m resolution), and 3) NREL 1987 data for the remaining locations. All datasets were clipped to the coastline to remove offshore locations.
www.nrel.gov/gis/data_analysis.html
www.awstruewind.com/inner/windmaps/UnitedStates.htm

*For data sources with descriptive point locations the spatial positions were derived by matching the descriptive location to the community location in (1), or were geocoded using the U.S. Geological Survey Geographic Names Information System database.

For More Information

Alaska
Alaska Energy Authority
www.akenergyauthority.org
Renewable energy resource maps, reports, programs, planning, and financing information.

Alaska Housing Finance Corporation
www.ahfc.state.ak.us
Residential energy efficiency and energy resources library, programs, and financing information.

Renewable Energy Alaska Project
www.alaskarenewableenergy.org
Alaska utilities, businesses, conservation and consumer groups, and Alaska Native organizations with a goal of increasing the production of renewable energy in Alaska.

University of Alaska Fairbanks
Arctic Energy Technology Development Laboratory
www.uaf.edu/aetdl
Promotes research, development and deployment (RD&D) of energy technologies in Arctic regions.

Cooperative Extension Service
www.uaf.edu/coop-ext/faculty/seifert/energy.html
Provides housing technology information to Alaskan homeowners and builders.

Nationwide and Regional
National Renewable Energy Laboratory
www.nrel.gov
USDOE's premier renewable energy research and development lab.

US Department of Energy's Office of Energy Efficiency and Renewable Energy
www.eere.energy.gov
Provides information on federal programs relating to renewable energy and energy efficiency.

Western Governors Association
www.westgov.org/wga/initiatives/cdeac/index.htm
Maintains an advisory committee on clean and diversified energy.

Policies Supporting Renewable Energy
Database of State Incentives for Renewable Energy
www.dsireusa.org
Information on tax incentives, rebate programs, portfolio standards, green power programs and other policies.

Clean Energy States Alliance
www.cleanenergystates.org
Works with clean energy funds across the country to build and expand clean energy markets in the United States.

Biomass
National Biodiesel Board
www.biodiesel.org
National trade association represents the biodiesel industry.

National Biomass Energy Program
www1.eere.energy.gov/biomass
USDOE's biomass energy program.

Pacific Regional Biomass Energy Partnership
www.pacificbiomass.org
Promotes bioenergy development in Alaska, Hawaii, and the Northwest.

Geothermal
Geothermal Resources Council
www.geothermal.org
International association for geothermal education including industry, researchers, and government.

National Geothermal Energy Program
www1.eere.energy.gov/geothermal
USDOE's geothermal energy program.

Hydroelectric
National Hydropower Association
www.hydro.org
Information on conventional hydro and tidal wave technologies.

Ocean
Electric Power Research Institute
http://www.epri.com/oceanenergy/
Ocean energy webpage for independent, nonprofit energy research center.

Solar
Alaska Sun
www.alaskasun.org
Alaskans supporting solar energy with link to Solar Design Manual for Alaska.

American Solar Energy Society
www.ases.org
National association dedicated to advancing the use of solar energy.

National Solar Energy Program
www1.eere.energy.gov/solar
USDOE's solar energy website.

Wind
Wind Powering America
www.eren.doe.gov/windpoweringamerica
USDOE's wind energy program.

American Wind Energy Association
www.awea.org
National trade association promoting the development of wind power.

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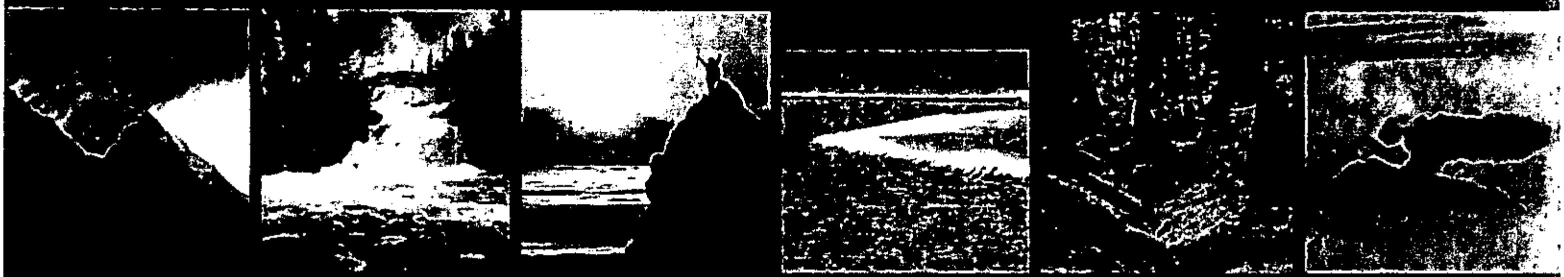
RENEWABLE ENERGY ATLAS OF ALASKA

A Guide to Alaska's Clean, Local and Inexhaustible Energy Resources

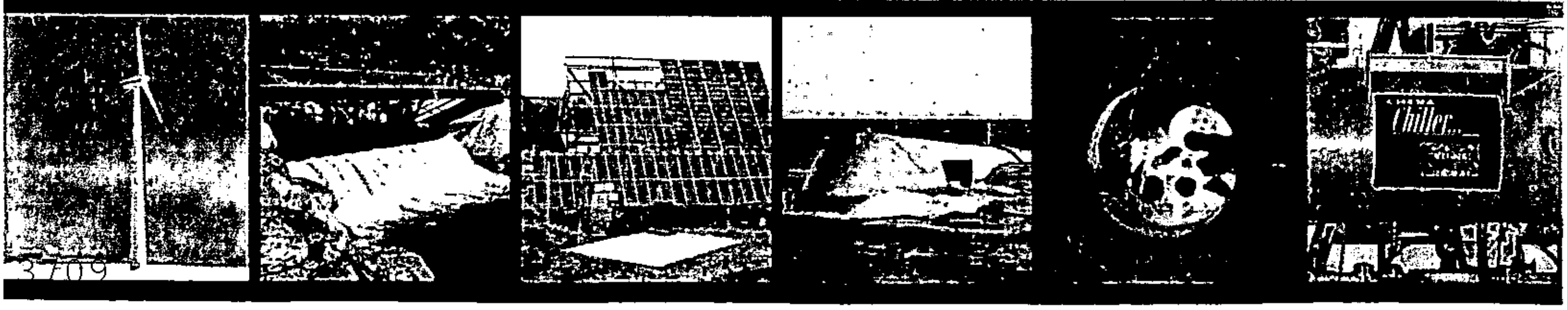


ALASKA ENERGY AUTHORITY

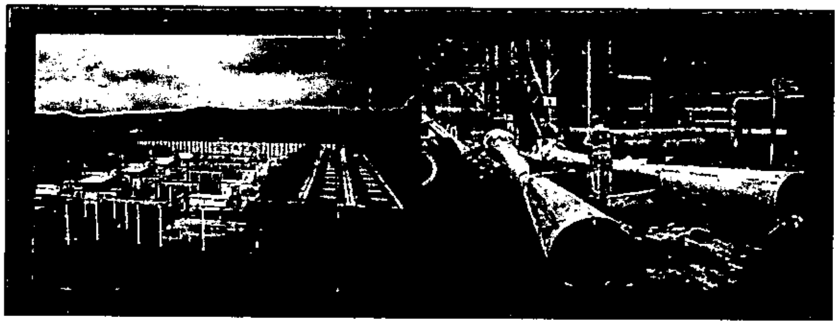
Alaska Energy Authority
813 West Northern Lights Blvd. Anchorage, Alaska 99503
Phone (907) 269-3000
Toll Free in Alaska (888) 300-8534
Fax (907) 269-3044
www.akenergyauthority.org

REAP

Renewable Energy Alaska Project (REAP)
308 G Street, Suite 218, Anchorage, Alaska 99501
Phone and Fax (907) 929-7770
www.alaskarenewableenergy.org



A Handbook on the Externalities, Employment, and Economics of Geothermal Energy



Puna geothermal power plant (source: Ormat), workers at The Geysers (source: U.S. DOE EERE)

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Summary

Geothermal energy is defined as heat from the Earth. It is one among only a few energy sources that is renewable, sustainable, and reliable over the long term. The United States, with a capacity of 2828.25 MW, continues to be the world leader in online capacity of geothermal power.

A. Externalities

Geothermal energy development, like any development, produces a series of effects. These effects, both positive and negative, include not only standard components such as the cost of building a power plant and generating power, but also effects that are sometimes difficult to quantify. Effects that are typically not taken into account in establishing the market price of goods or materials are known in economic circles as "externalities." In assessing the viability of an electricity source, externalities that should be considered include:

- average number of hours a facility can produce power in a 24 hour day
- ability of a facility to generate power during peak hours
- ability of a facility to increase/decrease generation, or be brought on line or shut down at the request of a utility's system operator
- the expected capacity factor of a facility (roughly defined as the reliability of a system)
- air emissions, other potential environmental effects, and related public health issues
- visibility and other aesthetic concerns
- water and waste disposal
- offsite fuel and transportation
- land usage, including the extent and impact of land use and zoning
- water usage
- employment

Geothermal power plants, like most types of power plants, promote economic growth. One of the unique external benefits of geothermal power, unlike many traditional types of power, is sustainable development. Geothermal development is sustainable because it is environmentally friendly and lasts for generations. Geothermal plants provide long-term, stable, well-paying jobs (typically in rural areas), produce nearly zero air emissions and associated health impacts, and supply billions of dollars to local, state, and federal economies through decades of reliable, secure, domestic, renewable energy production. In addition, geothermal plants can help states meet renewable portfolio standards (RPSs), ensuring that renewable power is available on a consistent, rather than intermittent, basis.

B. Employment

A geothermal power plant provides significantly more jobs than a comparative natural gas-fired power plant, according to the Department of Energy (DOE).[1] Geothermal jobs are quality, long term, and diverse. According to the Environmental Impact Statement/Environmental Impact Report (EIS/EIR) for the proposed Telephone Flat geothermal development project located in the Glass Mountain Known Geothermal Resource Area (KGRA) in California, the average wage at the facility will be more than double the average wage in the surrounding counties. GEA's employment survey found that the overwhelming majority of geothermal jobs (95%) are permanent, and most are also full-time.

In 2004 the geothermal industry supplied about 4,583 direct power plant related jobs. The total direct, indirect, and induced[2] employment impact of the industry in 2004 was 11,460 full-time jobs.[3] Looking to the future, geothermal employment should expand significantly. In 2005 alone, GEA has verified over 2000 MW of geothermal projects under development, which would increase geothermal capacity, and subsequently geothermal employment, by over 70%. Within the next ten years, the Western Governors' Association (WGA) estimates that over 5600 MW could be produced in eleven U.S. states, the economic effect of which is detailed in the table on page v.

Geothermal Development and Rural America

Rural areas that suffer from particularly high rates of unemployment can benefit from geothermal development. Because geothermal resources (hot water and steam) cannot be transported long distances and electricity is generated on-site, development facilities are located at the site of the resource. As a result, geothermal development and associated economic benefits occur in remote, rural areas. At the Mammoth Pacific Power Plant in Mammoth Lakes, California, the contested geothermal facility now produces substantial revenue, employment, and energy security for the small town in which it is located, while avoiding virtually all of the hydrologic and aesthetic concerns raised during the planning process. The plant is now considered a geothermal success story by industry and community members.

C. Economic Impacts

Geothermal's upfront costs, comprising mainly of exploration and development, make up the majority of costs accrued over the life of the plant. The operation and maintenance (O&M) phase accounts for a very small percentage of total costs, but can vary depending upon the location of the facility. O&M costs are low because geothermal relies on a

[1] U.S. DOE (Jan 2006). *Employment Benefits of Using Geothermal Energy*. Geothermal Technologies Program. Retrieved March 17, 2006 from http://www1.eere.energy.gov/geothermal/employ_benefits.html.
[2] See glossary for definitions
[3] Geothermal Energy Association (GEA) (September 7, 2005). *Expanding Geothermal Power Could Create 100,000 New Jobs*. Press Release. Retrieved June 16 2006 from www.geo-energy.org.

sustainable, environmentally friendly, low-maintenance fuel that is basically free once it is developed.

Most geothermal developers agree that the levelized cost[4] of power for new geothermal projects ranges from about 5.5 to 7.5 cents per kilowatthour (kWh). The following table displays the average cost figures for several phases of geothermal development.[5]

Selected Cost Parameters of a Geothermal Power Plant

PHASE	SUBPHASE (if applicable)	2004 Cost per kW	Cost for 50 MW Plant
Exploration		$150	$7.5 million
Site Development	Permitting	$20	$1 million
	Drilling	$750	$37.5 million
	Steam Gathering	$250	$12.5 million
	Power Plant equipment & construction	$1500	$75 million
	Transmission	$100	$5 million
Total		$2770	$138.5 million

It is important to note, when considering the figures in the table above, that actual cost figures vary considerably from site to site based upon a number of factors. These factors include:

- Type of project: expansion of an existing project will entail less exploration cost than a "greenfield" project (one that hasn't been previously drilled), where specific resource locations are unknown
- Plant size: the larger the plant, the less the cost per megawatt (economies of scale)
- Well characteristics: depth, diameter, productivity, subsurface geology, rock formation properties
- Site accessibility and location
- Time delays
- Ease with which the resource can be retrieved, influenced by permeability, depth of the reservoir, and pressure
- Characteristics of the geothermal fluid/steam, including chemistry and temperature

[4] See glossary for definitions
[5] All cost figures from Hance, Nathanael (2005). *Factors Affecting Cost of Geothermal Power Development*. Geothermal Energy Association (GEA) and represent 2004$. Geothermal Energy Association (2004). *Geothermal Energy Potential*. Retrieved March 23, 2006, from http://www.geo-energy.org/USGeoProv.pdf

- Fluctuations in the costs of certain materials or services, such as drilling, cementing, or steel for well casing
- Lease and permitting costs/issues
- Transmission costs
- Tax incentives, such as the production tax credit (PTC) included in the 2005 Energy Policy Act (EPAct)
- Financing: types of investors, interest rates, debt periods, rate of return
- Resource availability and quality
- Seasonal and weather variability

Geothermal facilities provide substantial contributions to the United States economy. The chart on page v indicates the economic output that would result if WGA's geothermal potential estimates are achieved.

The table below summarizes some of the economic benefits produced by an average, 50 MW facility over 30 years of operation on federal lands. While 30 years is the standard economic timeframe used to calculate costs at most energy facilities, geothermal plants typically last more than 30 years. Other socioeconomic benefits, including tax contributions, are not captured in this table.

Sample Economic Benefits at a 50 MW Geothermal Power Plant

Employment (direct, indirect, and induced)		212 fulltime jobs/800 person-years (p-*y)[6]
Economic Output (over 30 years, nominal)		$749 million
Royalties	Contribution to the Federal Government	$5.46 million
	Contribution to the State	$10.9 million
	Contribution to the County	$5.46 million

Besides the costs expended through the development and construction of a power plant, geothermal developers often make significant contributions to the communities in which they are located, as well as the local, state, and federal governments under whose jurisdiction they operate. Some contributions come as royalties or taxes, which are mandated by the government, while some come voluntarily from the geothermal company. In addition, wages paid to geothermal employees often circulate back through the community.

[6] Person year corresponds to the employment of one person during one year.

Summary of Western States' Near-Term Geothermal Potential and Resulting Employment and Economic Contribution

	New Power Capacity (MWs)	Direct and Indirect and Induced Employment (Power Plant Jobs/Construction & Manufacturing Employment)**	30 Year Economic Output (nominal)+
California	2,400	10,200 ft jobs/38,400 person*yrs	$36 billion
Nevada	1,500	6,375 ft jobs/24,000 person*yrs	$22.5 billion
Oregon	380	1,615 ft jobs/6,080 person*yrs	$5.7 billion
Washington	50	212 ft jobs/800 person*yrs	$749 million
Alaska	25	106 ft jobs/400 person*yrs	$375 million
Arizona	20	85 ft jobs/320 person*yrs	$300 million
Colorado	20	85 ft jobs/320 person*yrs	$300 million
Hawaii	70	298 ft jobs/1,120 person*yrs	$1 billion
Idaho	860	3,655 ft jobs/13,760 person*yrs	$12.9 billion
New Mexico	80	340 ft jobs/1,280 person*yrs	$1.2 billion
Utah	230	978 ft jobs/3,680 person*yrs	$3.4 billion
Wyoming, Montana, Texas, Kansas, Nebraska, South Dakota, North Dakota	Potential Exists; Resource not studied in WGA Report	Not Studied	Not Studied
Total Western States (additional to current)	**5,635 MW**	**23,949 fulltime jobs/90,160 person*years of construction and manufacturing employment**	**84,410,046,000.00** **Almost 85 billion dollars to the U.S. economy over 30 years**

** Power plant jobs are the direct, indirect and induced full-time jobs (ft jobs) created by reaching the full power production capacity indicated. Construction and manufacturing jobs are the direct, indirect and induced jobs necessary to build and supply the power plants at the full power capacity indicated. Construction and manufacturing jobs are expressed as full-time positions for one year (person*years), however these jobs will be spread out over several years depending upon the development time frame for new projects. Direct employment results in 1.7 full time positions and 6.4 person*years per megawatt. Induced and indirect impacts were calculated assuming a 2.5% multiplier; for a total direct, indirect, and induced employment impact of 4.25 full time positions and 16 person*years per megawatt.

+Economic Output measures gross power sales over 30 years, assuming power sells at $.06/kWh and produces at a 95% capacity factor. Economic output is represented in nominal dollars, is not adjusted for inflation, and is rounded to the nearest million. Total economic output is not rounded.

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[7] Individual's affiliated companies listed for identification purposes only

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I. INTRODUCTION

A. Background

In 2004, the Geothermal Energy Association (GEA), in support of the U.S. Department of Energy (DOE) Geothermal Technologies Program, surveyed the existing U.S. based geothermal literature related to socioeconomics. Much of this information turned out to be old, incomplete, or inconsistent. In an effort to update and improve the available information, GEA produced two publications on the socioeconomics of geothermal energy: *Factors Affecting Cost of Geothermal Power Development* and *Geothermal Industry Employment Survey Results and Analysis*. However, even after these publications were released, GEA routinely received questions about the basic economic, social, and employment impacts related to geothermal energy. Drawing upon the existing GEA documents and additional sources, GEA has produced this *Handbook on the Externalities, Employment, and Economics of Geothermal Energy* to address these key questions. "Externalities," including social and environmental effects, are costs or benefits attributable to activities that are not reflected in the price of the goods or services produced.

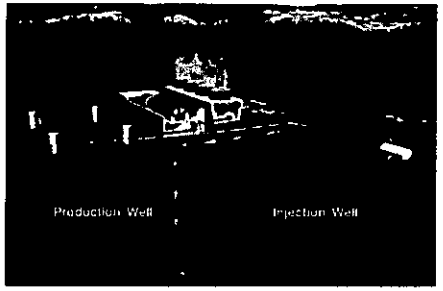
This handbook is divided into five sections. Some of the most common questions related to geothermal costs and benefits will be answered in each, including:

- *I. Introduction*: What is geothermal energy? How much geothermal energy is produced? What is geothermal potential?
- *II. Externalities*: What are the environmental implications of geothermal development? Is geothermal development sustainable?
- *III. Employment*: What types of jobs are created by the geothermal sector, and how long will they last? How many people currently work in the U.S. geothermal industry?
- *IV. Economic Impacts*: What is the cost of geothermal power or of a geothermal facility? Does the price of geothermal power fluctuate? What is the total estimated geothermal contribution to the U.S. economy?
- *V. Case Study Analysis (Mammoth Pacific Power Plants)*: Did the construction of the geothermal power plants at Mammoth impact tourism? After several decades, how have the power facilities affected the community?

B. Geothermal Basics

Geothermal energy is defined as heat from the Earth. It is considered a renewable resource because the heat emanating from the interior of the Earth, estimated to be equivalent to 42 million MW of power, is essentially limitless and continuously regenerates through natural geologic processes. The four main types of geothermal power plants are flash, binary, dry steam, and flash/binary combined cycle.

Figure 1: Basic Structure of a Geothermal Power Plant



Source: Geothermal Education Office (GEO)

To develop electricity from geothermal resources, wells are drilled into deep subsurface permeable regions containing natural hot water or steam, far below the shallow groundwater depth. The wells bring the hot fluids to the surface for use in generating electricity. Because hot geothermal fluids will cool if transported more than a few miles from the wellheads, geothermal power plants must be built at the site of the reservoir. If the deep resource contains hot compressed liquid water, it may be expanded to create steam or used to heat a secondary fluid that is converted to steam. The expanding steam is separated in a surface vessel (steam separator) and delivered to the spinning turbine, and the turbine powers a generator.[8] Flash, the most popular type, starts with hot water to produce electricity, while dry steam starts with hot steam to produce electricity. In the binary process, the geothermal water heats another liquid that boils at a lower temperature than water. The two liquids are kept completely separate through the use of a heat exchanger, so geothermal's already low emissions are reduced to zero. A combination of flash and binary technology, known as the flash/binary combined cycle, has been used effectively to take advantage of the benefits of both technologies.

Two cooling options are available: water or air cooling. The most popular type, water cooling, requires a continuous supply of cooling water and creates vapor plumes. Air cooled systems, in contrast to the relative stability and continuous efficiency of water cooled systems, can be extremely efficient in the winter months, but are less efficient in hotter seasons when the contrast between air and water temperature is reduced, so that air does not effectively cool the organic fluid. Air cooled systems are preferred in areas where the viewshed is particularly sensitive to the effects of vapor plumes, as vapor plumes are only emitted into the air by water cooling towers and not air cooling towers. Most geothermal air cooling is used in binary facilities.

While geothermal resources capable of power generation are only economically viable in the geologically active western states at this time, geothermal fluids and the heat they contain are currently used in 26 states for "direct uses" in spas, for space and district heating, and in industry, agriculture and aquaculture. Besides electricity production and

[8] Kagel, Alyssa et al. (2005). *Geothermal Energy and the Environment*. Geothermal Energy Association (GEA). Retrieved August 2, 2006, from www.geo-energy.org.

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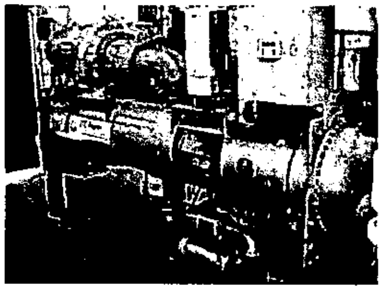
direct use, the third type of geothermal use, often called "geothermal heat pump" or "ground source heat pump" technology, does not require a geothermal reservoir. Rather, heat pumps make use of stable temperatures of approximately 65°F just a few feet underground, and can be used anywhere in the world. While this paper focuses on geothermal power production that takes place in the western U.S., widespread applications and uses of geothermal energy, such as through direct use or heat pump applications, span the entire country.

Figure 2: New Technology Using Low Temperature Resources at Chena Hot Springs in Alaska



Source: Chena Hot Springs, Alaska

Experts are exploring ways to produce geothermal energy in a variety of new ways: using oil and gas wells, hot dry rock (HDR) technology (an application that does not require liquid or steam), and low temperature resources, for example. Further advancements could make geothermal energy for direct use and power production economically viable throughout the U.S.

C. Current Generation

The United States continues to be the world leader in online capacity of geothermal energy. According to the Energy Information Administration (EIA), geothermal energy in 2005 generated approximately 16,010 Gigawatt hours (GWh) of electric generation or about 0.36% of U.S. annual electricity generation. U.S. capacity is rated at 2828.25 MW.

1. Developing Projects

Up to 1,500 MW of new geothermal power plant capacity are currently under development in the United States. 223 MWs are currently under construction in eight projects across the western United States. Unconfirmed projects (some of which are likely to be developed within the next few years) raise these numbers to over 2,000 MW of potential capacity currently under consideration.

D. Potential

Estimates for geothermal potential vary depending upon the study cited and the assumptions behind each study. A study considering only near-term potential, for example, will present vastly different numbers than a study considering long-term potential. Whether the timeframe considered is short or long, the potential for geothermal development is significantly greater than current geothermal output. With future technologies in geothermal engineering, geothermal output could exceed all the worldwide oil, gas and coal resources.

1. Short-Term Potential

In late 2005, the Western Governors' Association (WGA) estimated that nearly 6,000 MW of potential exist in eleven U.S. states at known, readily developable sites.[9] This resource base could produce electricity within 10 years without any technological advances. It is considered a short-term, limited potential estimate.

2. Long-Term Potential

The U.S. Geological Survey (USGS), in its Circular 790,[10] estimates a hydrothermal (liquid) resource base in each of two categories: an Identified Resources Base, which locates each of the sites included by latitude and longitude and presents specific information on each in the appendix, and an Undiscovered Resource Base, which is limited by depth, heat and location-related parameters. The potential, as assessed by USGS Circular 790, is as follows:

- Identified Resources Base (excluding National Parks): 23,000MW +/- 3,400 MW
- Undiscovered Resource Bases: 72,000-127,000MW
- Total Identified and Undiscovered Resource Base: 95,000-150,000MW

The USGS is currently working to revise these estimates using modern techniques that were not available during the study noted above and published in 1978.

[9] Western Governors' Association (WGA) (November 3, 2005). *Geothermal Task Force Near-Term Geothermal Resource Assessment*. Produced by WGA's Clean and Diversified Energy Advisory Committee (CDEAC). Accessed August 14, 2006, from http://www.geo-energy.org/information/developing/WGA%20GEOTHERMAL%20TASK%20FORCE%20RESOURCE%20ASSESSMENT%20NOV%203%202005I.pdf.
[10] USGS (1978). *Circular 790*. Retrieved October 3, 2006, from http://pubs.er.usgs.gov/usgspubs/cir/cir790#viewdoc.

II. EXTERNALITIES

Geothermal energy development, like any development, produces a series of effects. These effects, both positive and negative, include not only standard components such as the cost of building a power plant and generating power, but also effects that are sometimes difficult to quantify. Effects that are typically not taken into account in establishing the market price of goods or materials[11] are known in economic circles as "externalities." Notes one researcher, "the externality cost of fossil fuels...is not taken into account in the conventional analysis of electricity production cost per unit of energy produced."[12] Despite the fact that negative externalities such as pollution or land degradation, and positive externalities such as increased employment and reduced health risks, are rarely figured into conventional cost analysis, they should still be considered in assessing the viability of a resource. Numerous studies show that externalities significantly change costs – some studies even indicate that the externality costs of burning coal for electricity can be greater than the generation costs.[13]

Geothermal energy provides secure, low cost, reliable, environmentally friendly heat and electricity; supplies thousands of quality jobs; boosts rural economies; increases tax bases; stabilizes energy prices; provides baseload power; and diversifies the fuel supply. Each of these externalities benefits the U.S. economy in direct and indirect ways. Geothermal plants, for example, unlike coal and natural gas, incur no "hidden costs" such as offsite degradation of land and waterways, high air emissions, and health impacts to humans. Some of the factors to consider when choosing an energy source for a particular region are illustrated in table 1 on the following page.

[11] From Encarta online dictionary.
[12] Meidav, Tsvi and Joshua Meidav (October 1994). *Renewable Energy in Isolated Frontier Areas*. Geothermal Resources Council Transactions, Vol. 18.
[13] Ottinger, R L and M Jayne (2000) *Global climate change – Kyoto Protocol implementation: Legal frameworks for implementing clean energy solutions*, Pace University School of Law, White Plains, New York. Retrieved September 28, 2006, from http://www.solutions-site.org/special_reports/CleanEnergyFinal4.doc

Table 1: Power Technologies Comparison

Technology	Average Hours available out of 24 hours/day	Dispatchable[14]	Available During Peaking Hours[15]	Expected Capacity Factor (percent)
Coal	24	Y	Y	71
Nuclear	24	N	Y	90
Geothermal	24	N	Y	86-95
Wind	8-9*	N	N	25-40
Solar	6-7	N	Y	24-33
Natural Gas Combustion Turbine	24	Y	Y	30-35
Hydropower	24	Y	Y	30-35
Biomass	24	Y	Y	83

*The wind figure refers to full operation only; this figure increases if partial wind generation is considered.

Other externalities, besides those listed in the above table, include but are not limited to aesthetic concerns, resource availability and cost, environmental concerns, waste and water disposal, resource quality, transportation, land degradation, extent and impact of land use, zoning, water usage, and seasonal variability. The California Energy Commission (CEC) confirmed the importance of considering outside factors: "a more comprehensive analysis, which evaluates economic and environmental impacts, would be preferable to resource evaluation based on rate impacts alone."[16]

These outside factors influence all electricity sources. Nuclear plants, for example, use extensive land and water resources and have near and long-term spent fuel disposal concerns. Natural gas plants, in contrast to nuclear, suffer from considerable problems with fuel availability, a concern that has driven up the price of natural gas in recent years. Coal plants, while generally more economical than nuclear or natural gas facilities, use extensive land and water resources, suffer from significant environmental concerns such as air emissions and health impacts, and have mine tailings disposal problems. Solar and wind plants, with few water use issues, have land use, aesthetics, and resource availability problems. Geothermal is consistently available, but geothermal reservoirs must be managed properly in order to ensure sustainability, and thus, geothermal plants have potential resource availability concerns. Production from hydropower fluctuates with snow and rain fall and seasonal variability, and can be destructive if not managed carefully. Biomass plants also suffered fuel availability problems.

[14] A plant that is *Dispatchable* can increase or decrease generation, or be brought on line or shut down at the request of a utility's system operator.
[15] A plant that is capable of *Peaking* can be used to meet daily increases in electricity demand. Power demand tends to peak in late afternoon or early evening before gradually declining to its lowest point at night.
[16] Miller, Sanford A (Sept/Oct 1996). Incorporating Economic and Environmental Externalities of Geothermal and Natural Gas Generating Technologies. GRC Transactions; Vol 20. 187 – 193.

A. Meeting State RPS Requirements

Twenty states and the District of Columbia have Renewable Portfolio Standards (RPSs) which requires that a percentage of the electricity supplied by generators be derived from renewable sources. For many states, geothermal may be the preferred option to meet RPSs: geothermal is one of the only renewable energy sources that delivers reliable, baseload power. When geothermal is used in conjunction with other renewables such as wind and solar to meet RPSs, geothermal helps ensure that renewable power is available on a consistent, rather than intermittent, basis.

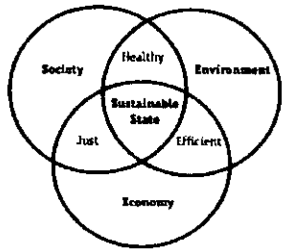
B. Promoting Sustainable Development

Sustainability is defined by the USGS as "economic development that takes full account of the environmental consequences of economic activity and is based on the use of resources that can be replaced or renewed and therefore are not depleted." A resource that is naturally renewable, such as geothermal energy, must still be properly managed to ensure sustainability. Geothermal energy is managed through the use of a geothermal reservoir: wells are drilled into the reservoir, and the hot liquid or steam is brought up to the surface and used to produce power. If the fluid in the reservoir is extracted at a faster rate than the rate at which it naturally regenerates, the reservoir will not be sustainable. Geothermal engineers must determine the rate at which geothermal energy (heat) can be extracted from the reservoir so that maximum electricity can be produced and the longevity of the reservoir can be preserved. Obtaining sustainability also depends upon the rate of injection of the resource (see *Steam Gathering System*, page 27, for more information about injection). While *sustainability* describes how a resource is used, *renewability* describes a property of a resource.[17] Geothermal is one among only a few energy sources that is both renewable and, if properly managed, sustainable over the long term.

Development fuels economies and grows communities. But development can sometimes produce negative externalities, including pollution from industrial activity, or short-term economic booms followed by long-term busts. *Sustainable development* is a type of development that is successful only when social, economic, and environmental consequences are considered over a longer timeframe. According to the International Institute for Sustainable Development (IISD), sustainable development must integrate environmental stewardship, economic development and the well-being of all people—not just for today but for countless generations to come.[18]

[17] Stefansson, Valgardur (2000). *The Renewability of Geothermal Energy*. Reykjavik – Iceland: Proceedings World Geothermal Congress 2000. pgs. 883-888.
[18] IISD. *About*. Retrieved April 6, 2006, from http://www.iisd.org/about/.

Figure 3: Three Spheres of Sustainable Development



Source: The Official Website of the state of New Jersey

Geothermal plants facilitate sustainable development. They provide long-term, stable, well-paying jobs (see *Employment* for more information), produce nearly zero air emissions and associated health impacts, and supply hundreds of thousands of dollars to local, state, and federal economies through decades of reliable, renewable, consistent energy production. The three spheres necessary for sustainable development are illustrated in the figure to the left, and discussed in more detail in the following sections.

1. Economy

Geothermal projects generate revenue for small, rural communities. Taxes and royalties paid by developers help support and grow underserved areas. The economic benefits of geothermal extend beyond just the community or sector in which they are located: for every dollar invested in geothermal energy, at least 2.5 dollars are invested back into the economy.[19] Over time, geothermal's economic benefits are even greater. Geothermal use throughout the U.S. helps stabilize volatile energy markets, and brings diversity and security to the economy (see *Direct Payments* for more information).

2. Environment

Development of any kind may cause environmental impacts. Any energy source, renewable or not, will require land and manmade materials, but renewable energy sources create far fewer environmental impacts than traditional fossil fuel sources. Geothermal, in particular, is unique in its ability to produce few environmental impacts, while also ensuring a high level of dependability.

[19] Hance, Nathanael (2005). *Factors Affecting Cost of Geothermal Power Development.* Geothermal Energy Association (GEA) and represent 2004$. Geothermal Energy Association (2004). *Geothermal Energy Potential.* Retrieved November 10, 2004, from http://www.geo-energy.org/USGeoProv.pdf.

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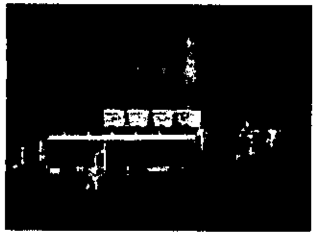
a) Air Emissions

Geothermal produces significantly less air pollution per unit of energy produced than traditional fossil fuel sources, resulting in fewer respiratory health problems for the U.S. population. The American Lung Association estimates that power plant emissions, primarily from coal plants, result in over 30,000 yearly deaths.[20] Greater use of geothermal power can decrease air emissions as compared to a greater use of fossil-fuel generation. This is certainly the case for Lake County, California, downwind of the world's largest geothermal field known as "The Geysers." Lake County is the only air district in California that has been in compliance with all state and federal air quality standards for over 17 years.

Figure 4: West Ford Flat Power Plant at The Geysers



Source: Calpine Corporation

Because fossil fuel health impacts are difficult to monetize, it is difficult to approximate the cost savings produced by renewable electricity options. One way to approximate positive geothermal externalities is to examine the economic values received for air emissions in existing emissions trading systems.

An article published in the *Electricity Journal* by GEA attempts to monetize the cost savings of geothermal power. GEA calculated geothermal's emissions savings compared with coal if examined within emissions trading markets. The study found that the positive externality benefits of geothermal from avoided air emissions—considering only carbon dioxide, sulfur dioxides, nitrogen oxides, and particulate matter—is $255.4 million per year.[21] In contrast, a 1995 study estimates that costs of power generation would increase 17% for natural gas and 25% for coal if environmental costs were included.[22] These additional costs include land degradation, potentially hazardous air emissions, forced extinction and destruction of animals and plants, and health impacts to humans.

[20] Garcia, Staci (Aug 2001). *Air Pollution Impacts and Reduction Strategies* Retrieved September 24, 2004, from http://www.nrel.gov/docs/gen/fy01/NN0060.pdf.
[21] Kagel, Alyssa et al (2005). *Promoting Geothermal: Air Emissions Comparison and Externality Analysis*. Electricity Journal: Volume 18, Issue 7, August-September 2005, Pages 90-99. Accessed March 13, 2006, from http://authors.elsevier.com/sd/article/S1040619005000862.
[22] Haberle and Flynn (1995). *Comparative Economics and Benefits of Electricity Produced from Geothermal Resources in the State of Nevada*. Univ. of Nevada, Las Vegas.

Recent studies show that both air quality and renewable technologies would benefit from stricter emissions control. An analysis of emissions legislation including "four pollutants,"—mercury, carbon dioxide, sulfur dioxides, and nitrogen oxides—as opposed to only "three pollutants"—mercury, sulfur dioxides, and nitrogen oxides— show that renewables energy sources such as geothermal increase most significantly under a four pollutant plan that includes regulations to reduce CO_2 emissions.[23]

Today's U.S. Geothermal output offsets harmful pollutants and greenhouse gases that would otherwise be generated by coal facilities each year, including 16 million tons of carbon dioxide (CO_2), 78 thousand tons of sulfur dioxides (SO_2), 32 thousand tons of nitrogen oxides(NO_x) and 17 thousand tons of particulate matter (PM).[24]

b) Public Health

Health impacts deliver an unfair burden to people living in the areas where fossil fuel plants are developed, as well as areas downwind of polluting plants where emissions travel. When a community's health is affected, its pocketbook is affected as well. According to one study, "health care is the single largest and fastest growing segment in numerous state and city budgets.[25]"

A 2004 study by Abt Associates, a consulting firm regularly employed by the Environmental Protection Agency (EPA), attempted to quantify costs associated with fossil fuel pollution.[26] The study found that health impacts associated with particulate matter emissions[27] from coal power plants alone subtracts billions of dollars each year in the form of healthcare costs from the U.S. economy. According to the report, the health care costs resulting from emissions at coal facilities, in 1999 $ by 2010, would be:

- $150 billion: mortality
- $5.5 billion: chronic bronchitis
- $3.3 billion: heart attacks
- $187 million: respiratory hospital admissions
- $206 million: cardiovascular hospital admissions

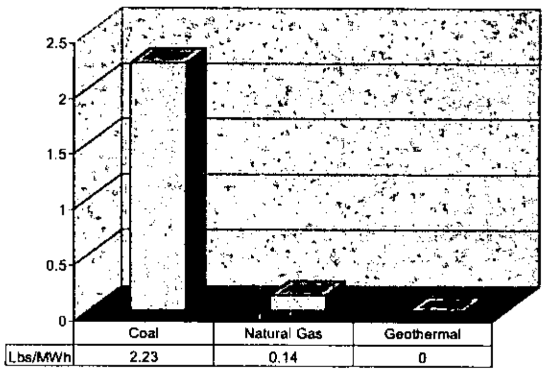
[23] Palmer, Karen and Dallas Burtraw (Jan 2005). *Cost-Effectiveness of Renewable Electricity Policies*. Discussion Paper 05-01: Resources for the Future (RFF).
[24] Based on average EIA estimate of yearly geothermal generation, 1990-2004, available at http://www.eia.doe.gov/cneaf/aer/txt/ptb0802c.html, and using percentages of each type of generation based on gross capacity listed at GEA website, available at http://www.geo-energy.org/Existing.htm.
[25] J. Peter Lynch. (Nov 2003). Renewableenergystocks.com Features: *The Real Costs of Fossil Fuels*. Retrieved April 3, 2006, from http://www.investorideas.com/Companies/RenewableEnergy/News/FossilFuels1110,03.asp.
[26] Schneider, Conrad, Project Manager of Abt Associates Team of Researchers (June 2004). *Power Plant Emissions: Particulate Matter-Related Health Damages and the Benefits of Alternative Emission Reduction Scenarios. Prepared for Clean Air Task Force*. Retrieved April 10, 2006, from http://www.cleartheair.org/dirtypower/docs/abt_powerplant_whitepaper.pdf.
[27] Particulate matter (PM) is a broad term for a range of substances that exist as discrete particles. Particulate matter includes liquid droplets or particles from smoke, dust, or fly ash.

- $7 million: emergency room visits for asthma
- $13 million: acute bronchitis
- $16 million: upper and lower respiratory symptoms
- $367 million: work loss days
- $956 million: minor restricted days

These costs total almost $160 billion, and place a substantial burden on hospitals, health care professionals, health insurers, taxpayers, company productivity, not to mention the individuals inflicted with these ailments.

If other emissions besides particulate matter were considered—including NOx, SO_2, CO_2, or mercury—or if fossil fuel sources other than coal were considered, the health care cost estimates would increase. The figure below compares particulate matter emissions from coal, natural gas, and geothermal power plants.

Figure 5: Particulate Matter Comparison



Comparing pulverized coal boiler, natural gas combined cycle, and average existing power plant, geothermal.

Source: Antares Group, Inc.

c) Environmental Implications of Baseload Power

Geothermal energy is a baseload resource: it is available 24 hours a day, 365 days a year. Not only does baseload power contribute to power stability, it also contributes to environmental stability. An intermittent peaking plant—one that is available only part of the day, or only during peaking hours—usually works in conjunction with a more reliable energy source. This means that an intermittent plant—even if it is renewable and emissions free—supplies consistent power only if paired with a baseload plant—usually a polluting fossil fuel plant such as a coal facility. When two plants are necessary, more land is required, and greater environmental impacts, such as air emissions, are produced. Geothermal is one of only a few resources that is clean, renewable—and also baseload.

3. Society

Geothermal provides a much needed source of employment to rural communities. Geothermal jobs are typically stable, long term, diverse, and high quality (see *Employment* for more information). Property taxes and royalty revenues are typically allocated to schools and roads. In counties with geothermal power projects on federal leases, a provision of the 2005 Energy Policy Act (EPAct) requires that 25% of the federally imposed royalty is returned to the county of origin, 25% to the federal government, and 50% to the state (previously royalties were equally shared by the state and federal government). Most developers hire locally and donate additional funds to local schools, museums and community centers.

a) Increasing National Security

Of the renewable options usually considered, geothermal is one of the few that provides baseload power while at the same time lowering homeland security risks. Geothermal plants do not rely upon unstable international energy sources. Also, geothermal facilities are local, and smaller than large fossil or nuclear plants. Geothermal plants are therefore important regional energy sources that are less likely to be used as terrorist targets. Finally, geothermal plants are not significantly impacted by scheduled outages.

b) Producing Power at Home

By producing power at home, jobs and revenue are generated in the U.S., rather than transported overseas. In addition, transportation over long distances in not required. Geothermal energy can displace natural gas in the electric power sector, which is increasingly imported from overseas sources.

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III. EMPLOYMENT

A. Current Employment

Geothermal provides more jobs per MW than natural gas, according to the DOE, as shown in Table 2 below.[28] While the figures in table 2 are not consistent with GEA's most recent employment data, the information is included for comparison purposes only.

Table 2: Comparative Job Creation

Power Source	Construction Employment (jobs/MW)	O&M Employment (jobs/MW)	Total Employment for 500 MW Capacity (person-years)
Geothermal	4.0	1.7	27,050
Natural Gas	1.0	0.1	2,460

Source: U.S. DOE[29]

In 2004 alone, the geothermal industry supplied about 4,583 direct power plant related jobs. The total direct, indirect, and induced impact[30] of the industry in 2004 was 11,460 full-time jobs.[31] Employment is expected to increase in coming years as geothermal plant development and research expands.

B. Job Quality

Not only does geothermal provide more jobs than a traditional power plant, it also provides quality, long-term jobs. According to the proposed Telephone Flat geothermal development project EIS/EIR located in the Glass Mountain Known Geothermal Resource Area, the average wage at the facility will be more than double the average wage in surrounding counties. According to the California census bureau, the average

[28] U.S. DOE (Jan 2006). *Employment Benefits of Using Geothermal Energy*, Geothermal Technologies Program. Retrieved March 17, 2006 from http://www1.eere.energy.gov/geothermal/employ_benefits.html.
[29] This table is included for comparative purposes only. While these geothermal employment numbers are not consistent with GEA's updated employment information, GEA chose to include this table, endorsed by US DOE, in order to show how geothermal's employment figures compare with natural gas'. GEA has chosen to include these slightly outdated figures because they allow an even comparison between natural gas and geothermal. As we do not have updated natural gas figures, we cannot update only the geothermal figures for the purpose of comparison.
[30] See glossary for definitions
[31] GEA Press Release (2005). *Expanding Geothermal Power Could Create 100,000 New Jobs*. Retrieved May 17, 2006, from http://www.geo-energy.org/publications/pressReleases/Expanding%20Geothermal%20Power%20Could%20Create%20100,000%20New%20Jobs%20September%207%202005.pdf.

per capita income in 1998 in the closest counties was around $20,000, with the average California per capita income nearly $8,000 higher.[32] The average projected wage related to operation at the Telephone Flat facility would be higher than both the county and state averages, totaling between $40,000 and $50,000 (1998 $).[33]

GEA's employment survey found that the overwhelming majority of geothermal jobs are permanent (95%), and most are also full-time. At The Geysers in California, 425 full-time and 225 part-time residents of the community are employed.[34]

1. Geothermal Employment and Rural America

Geothermal resources tend to be located in rural areas with few employment opportunities. Because geothermal energy must be developed where the resource is located, geothermal power plants tend to benefit these economically depressed areas by providing jobs, stability, and revenue. Geothermal developers, who typically negotiate 10 to 30 year agreements with purchasers (see *Financing* for more information), provide jobs that can be guaranteed for decades, presuming plants are not sold or do not suffer from financial problems.

Rural communities face many unique challenges. Lack of stable, secure, long-term jobs in rural communities leads many young adults with "the most education and the greatest earning potential" to emigrate, leaving a poorer, older, and smaller population.[35] Many rural communities, including those in which geothermal facilities tend to be located, suffer from significantly higher unemployment rates than the general population. In 2004, California's unemployment rate was 6.2%, while Siskiyou County, one of the areas closest to the proposed Telephone Flat proposed geothermal power plant, had an unemployment rate more than one-third higher than the California average, at 9.3%.[36] The Center for Mental Health Services (CMHS), found that "many rural Americans are at or below the national poverty level," which can result in physical and psychological harm.[37] Unemployment in rural communities makes residents particularly susceptible to high levels of social and health related problems—more so than their urban counterparts.[38]

[32] Bureau of Economic Analysis (BEA). *Table 3.—Personal Income and Per Capita Personal Income by County*. Retrieved September 6, 2006, from www.bea.gov/bea/regional/articles/0700lap/tab3b.html.
[33] Calpine Corporation (February 1999). *Telephone Flat Geothermal Development Project Final Environmental Impact Statement Environmental Impact Report*. California State Clearinghouse Number 97052078. pg 3.12-16.
[34] National Geothermal Collaborative (NGC). *Geothermal Energy and Economic Development*. Retrieved March 14, 2006, from http://www.geocollaborative.org/publications/Geothermal_Energy_and_Economic_Development.pdf.
[35] Fitchen, Janet M. (1991). "A Time of Change in Rural Communities: Implications for Rural Mental Health." *Rural Community Mental Health*, Vol. 18, No. 3. Retrieved April 5, 2006, from http://www.narmh.org/pages/culttwo.html.
[36] Employment Development Department (EDD) (2005). *Siskiyou County, Snapshot*. State of California. Retrieved June 30, 2006, from http://www.calmis.cahwnet.gov/file/cosnaps/siskiSnap.pdf.
[37] CMHS (1993). *Taking Rural Into Account: Report on the National Public Forum*.
[38] Jackson, Glenn & Charles Cook, Substance Abuse and Mental Health Services Administration

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Rural communities tend to focus on a single source of revenue, such as manufacturing or agriculture, and this can contribute to unemployment and economic instability. Geothermal offers an important means of diversifying the economic base and simultaneously adopting an "innovative income-generating [strategy] to build on...assets, diversify...economies, attract new businesses, and sustain... successes.[39]" Such diversification, according to the Sonoran Institute, is a direct indicator of economic stability.[40] The jobs within at a geothermal facility cover a broad spectrum of skills, and draw from a diverse selection of applicants.

2. Types of Jobs Created

Geothermal provides long-term income for people with a diversity of job skills. People employed by the sector include welders; mechanics; pipe fitters; plumbers; machinists; electricians; carpenters; construction and drilling equipment operators and excavators; surveyors; architects and designers; geologists; hydrologists; electrical, mechanical, and structural engineers; HVAC technicians; food processing specialists; aquaculture and horticulture specialists; managers; attorneys; regulatory and environmental consultants; accountants; computer techs; resort managers; spa developers; researchers; and government employees.

C. Projected Employment

Looking to the future, geothermal employment should expand significantly. In 2005 alone, GEA has verified over 2000 MWs of geothermal projects under development. If only half of this development comes online within the next few years (a conservative estimate), these new facilities will support 6400 person-year (p-*y) manufacturing and construction jobs and 740 power plant O&M jobs. If these 1000 MW last 30 years – another conservative estimate – new production will create 28,600 p*-y jobs. This employment estimate increases if the additional jobs brought on by research, direct use applications, and other geothermal activities are considered. The number also excludes indirect employment impacts.

(1999). "Crisis Counseling Programs for the Rural Community," from *Disaster Mental Health: Crisis Counseling Programs for the Rural Community*. DHHS Publication No. SMA 99-3378. Retrieved April 6, 2006, from http://www.mentalhealth.samhsa.gov/publications/allpubs/SMA99-3378/crisiscounseling_ch2.asp.

[39] Whitener, Leslie and David McGranahan (February 2003). *Rural America: Opportunities and Challenges*. AmberWaves, United States Department of Agriculture, Economic Research Service. Retrieved April 6, 2006, from http://www.ers.usda.gov/Amberwaves/Feb03/features/ruralamerica.htm.

[40] Sonoran Institute (2005). "A socioeconomic profile, Josephine County, Oregon." *Economic profile system (EPS)*. Sonoran Institute. Tuscan, Arizona.

Figure 6: Power Plant Workers

Source: EERE Geothermal Technologies Program

Take just one example of a developing project in Imperial County, California, at the Salton Sea Unit 6, where all permits have been secured for a 215 MW plant. Once this power plant produces electricity, it will be one of the largest renewable energy projects in the United States. According to congressional testimony, the plant will employ 550 construction workers, eventually leading to more than 60 "high paid, fulltime positions." Testimony concludes that the plant will represent "the single largest capital investment in Imperial County, which is the most economically disadvantaged area in the state."[41]

1. California Potential

Geothermal provides 5% of California's electricity, only a small percentage of the known, developable potential. This potential could contribute much-needed electricity to areas where the population is on the rise and blackouts have already occurred. In California, geothermal is expected to contribute more jobs to the state than any other renewable sector. The table on the following page shows the number of both construction and operational person-years that will likely be generated over the lifetimes of the plants built in California, producing electricity for California, from 2003-2017:[42]

[41] Statement of Vince Signorotti, Vice President, CalEnergy Operating Corporation, Brawley, California. (March 2006). *Testimony Before the Subcommittee on Select Revenue Measures of the House Committee on Ways and Means*. Retrieved March 14, 2006, from http://waysandmeans.house.gov/hearings.asp?formmode=view&id=2698.

[42] Source: Heavner, Brad and Bernadette Del Chiaro (July 2003). *Renewable Energy and Jobs: Employment Impacts of Developing Markets for Renewables in California*. Environment California Research and Policy Center. Accessed March 17, 2006, from http://www.environmentcalifornia.org/uploads/OW/aa/OWaa2RacdlfHwQOWbxKd5w/Renewable_Energy_and_Jobs.pdf.

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Table 3: Projected California Renewable Energy Job Opportunities, 2003-2017

Technology	Total CA Employment Growth for CA Electricity Production (person*years)
Geothermal	60,260
Biomass	38,610
Wind	20,420
Solar PV	2660
Solar Thermal	940

Source: Environment California Research and Policy Center

2. Direct and Indirect Potential, Western States

Most industries measure employment through both direct and indirect employment impacts. While indirect impacts are somewhat difficult to quantify, they help capture an industry's overall employment. According to a report by the Western Governors' Association (WGA),[43] development of the near-term geothermal potential of 5,600 MW of geothermal energy would result in the creation of almost 100,000 new power plant, manufacturing and construction jobs. If the USGS estimate of 125,000 MW of geothermal potential is developed, millions of quality jobs will be created. The table on the following page shows employment and resulting economic output estimates based on WGA's near-term estimates.

[43] Western Governors' Association (WGA) (2005). *CDEAC - Geothermal Task Force*. Retrieved March 14, 2006, from http://www.westgov.org/wga/initiatives/cdeac/geothermal.htm.

Table 4: Summary of Western States' Near-Term Geothermal Potential and Resulting Employment and Economic Contribution

	New Power Capacity (MWs)	Direct and Indirect and Induced Employment (Power Plant Jobs/Construction & Manufacturing Employment)**	30 Year Economic Output (nominal)+
California	2,400	10,200 ft jobs/38,400 person*yrs	$36 billion
Nevada	1,500	6,375 ft jobs/24,000 person*yrs	$22.5 billion
Oregon	380	1,615 ft jobs/6,080 person*yrs	$5.7 billion
Washington	50	212 ft jobs/800 person*yrs	$749 million
Alaska	25	106 ft jobs/400 person*yrs	$375 million
Arizona	20	85 ft jobs/320 person*yrs	$300 million
Colorado	20	85 ft jobs/320 person*yrs	$300 million
Hawaii	70	298 ft jobs/1,120 person*yrs	$1 billion
Idaho	860	3,655 ft jobs/13,760 person*yrs	$12.9 billion
New Mexico	80	340 ft jobs/1,280 person*yrs	$1.2 billion
Utah	230	978 ft jobs/3,680 person*yrs	$3.4 billion
Wyoming, Montana, Texas, Kansas, Nebraska, South Dakota, North Dakota	Potential Exists; Resource not studied in WGA Report	Not Studied	Not Studied
Total Western States (additional to current)	**5,635 MW**	**23,949 fulltime jobs/90,160 person*years of construction and manufacturing employment**	**84,410,046,000.00** **Almost 85 billion dollars to the U.S. economy over 30 years!**

** Power plant jobs are the direct, indirect and induced full-time jobs (ft jobs) created by reaching the full power production capacity indicated. Construction and manufacturing jobs are the direct, indirect and induced jobs necessary to build and supply the power plants at the full power capacity indicated. Construction and manufacturing jobs are expressed as full-time positions for one year (person*years), however these jobs will be spread out over several years depending upon the development time frame for new projects. Direct employment results in 1.7 full time positions and 6.4 person*years per megawatt. Induced and indirect impacts were calculated assuming a 2.5% multiplier; for a total direct, indirect, and induced employment impact of 4.25 full time positions and 16 person*years per megawatt.

+Economic Output measures gross power sales over 30 years, assuming power sells at $.06/kWh and produces at a 95% capacity factor. Economic output is represented in nominal dollars, is not adjusted for inflation, and is rounded to the nearest million. Total economic output is not rounded.

II. COSTS AND PAYMENTS

Geothermal's upfront costs, made up of exploration, resource confirmation and characterization (drilling and well testing), and site development (facility construction), comprise the majority of costs accrued over the life of the plant. In 2001, the Electric Power Research Institute (EPRI) estimated that capital reimbursement and associated interest account for 65% of the total cost of geothermal power, while the cost of fuel and operation account for only 35%. In contrast, fossil fuel facilities typically spend 65% on fuel, and only 35% on upfront costs.[44] Geothermal's high upfront costs and low O&M costs, while challenging to developers and investors, help stabilize the power market. Since the cost of fuel at a geothermal plant is so low compared to the initial cost of planning for and building the plant, the operational cost is less likely to fluctuate.

The following sections highlight cost information for each phase of development: exploration, confirmation, site development, financing, and O&M costs. Each phase also includes a set of sub-phases, and where appropriate or applicable, cost figures are sited for each sub-phase. These figures are unique and not cumulative unless otherwise noted. All cost figures are derived from GEA's 2005 Employment Study and represent 2004 $.[45]

A. Exploration

The first phase, exploration, during which resources are defined, can be divided into three sub-phases: regional reconnaissance, district exploration, and prospect valuation. Exploration for commercially viable projects costs between \$100/kW - \$200/kW.[46] At a typical, 50 MW plant, exploration costs will total an average of \$7.5 million, including all sub-phases (regional reconnaissance, district exploration, and prospect evaluation).

*1. **Regional Reconnaissance*** identifies resource areas at the least specific level, at around 1000 km^2. The price for regional reconnaissance has been estimated at roughly \$7.70 per kW[47] installed. For the typical geothermal plant, a 50 MW facility, this amounts to \$385,000 in total regional reconnaissance costs.[48]

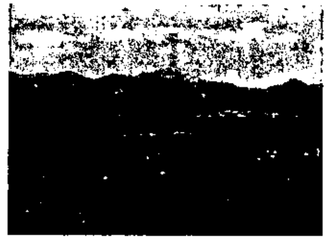
[44] Capital cost of a combined cycle natural gas power plant only represents about 22 percent of the levelized cost of electricity produced from the plant whereas the fossil fuel cost accounts for 67 percent. (Source: Source: "An Assessment of the Economics of Future Electric Power Generation Options and the Implications for Fusion", Oak Ridge National Laboratory, 1999)., Oak Ridge National Laboratory, 1999).

[45] Hance, Nathanael (2005). *Factors Affecting Cost of Geothermal Power Development*. Geothermal Energy Association (GEA) and represent 2004$. Geothermal Energy Association (2004). *Geothermal Energy Potential*. Retrieved November 10, 2004, from http://www.geo-energy.org/USGeoProv.pdf.

[46] The average confirmation costs of projects considered as "cost competitive" by GeothermEx (2004) *(i.e. capital investment ≤ 2400$/kW)* is 153$/kW. Inflated confirmation cost estimates published in EPRI 1997 correspond to 140.35 $/kW.

[47] Nielson D (1989), *Competitive economics of Geothermal Energy: The Exploration and Development Perspective*, University of Utah, estimated this exploration phase to cost \$500,000 for a 100 MW

Figure 7: Geothermal Surface Manifestation, Indicating Possible Underground Resources: Steam Vent in Central Nevada



Source: Daniel Fleischmann, GEA

Regional reconnaissance costs are influenced by the amount of resource information already available and by the accessibility of prospective areas. Government agencies, international development institutions, or multilateral aid programs typically subsidize or even fully finance such activities (through national geologic mapping or satellite imagery, for example).

The USGS completed a geothermal resource survey in 1978, Circular 790. However, when the assessment was conducted, relatively few geothermal power plants existed. That 1978 survey, which considered mostly resources with visible surface manifestations, identified 125,000 MW of geothermal potential throughout the U.S. Currently only 2825 MW of that potential is utilized—a mere fraction of the known potential. EPAct requires the USGS to update its 1978 survey by 2008. That update will incorporate data developed by federal agencies, states, and private entities; will consider the additional knowledge brought by increased geothermal power generation; and will take into account the technological advances that have emerged since 1978.

*2. **District Exploration*** identifies resources within more precise regions of around 100 km^2 with the intent of securing reservoirs for further exploration. Geophysical and geochemical surveys are completed and, if encouraging, exploration wells are drilled. Usually, in a greenfield prospect, temperature gradient holes will be drilled or cored. If those are encouraging (they indicate high enough temperature gradients), then a larger well, capable of testing a reservoir, may be drilled. Two types of geothermal exploration wells are generally used: either production-size (or full-size) exploration wells, or smaller and less expensive slim holes. A slim hole typically cannot be used during actual geothermal production, and so developers often opt to drill a production-sized well. However, if drilling a production well does not locate a usable resource, the money lost will be twice as great as if a slim well had been used. A slim well costs an average of \$22.50 per kW. District exploration cost varies depending upon geology and resource depth. Wells drilled during this phase are called "wildcats" and have an average success rate of 20-25%. Oil and gas exploration, which relies on wildcat drilling, has a similar

geothermal power project. The \$500,000 value has been inflated according to the U.S. BLS inflation calculator in order to represent 2004 dollar values. The inflation index for the 1989-2004 period is 1.54.

[48] All cost figures for "typical 50 MW plants" are drawn from: Hance, Nathanael (2005) [See footnote #5].

one in five success rate.[49] Drilling costs are escalating rapidly as the cost of steel and cement increases, so the cost figures cited above may be lower than the current average.

3. Prospect Evaluation is the most costly and specific phase of exploration. This phase costs about $77.00 per kW. For an average, 50 MW geothermal power plant, the total cost for prospect evaluation amounts to $3.85 million. This phase (which overlaps with the district exploration phase) seeks to locate the best sites to drill production wells with fluid temperatures and flow rates at levels that can produce electricity.

4. Geothermal and Oil and Gas Exploration: A Comparison

Because of technological constraints, geothermal resources below depths of 4 km are typically not considered economically viable. By improving technology and increasing the depth at which resources can be considered economical by only 2 km, to a total depth of 6 km, the potential for developable geothermal resources expands significantly. Increasing the geothermal drilling depth by only one kilometer—to 5 km depths, as is the current practice in Iceland—could dramatically expand the number of developable geothermal resources. Though the drilling techniques and procedures for geothermal wells are similar to those used in the oil and gas industry, the latter is remarkably farther along in its exploration capabilities when compared to geothermal. The depth record for a gas well is in the Gulf of Mexico. It was drilled in January 2004 by Shell Oil Company to a depth of 33,200 feet, or over 10 km.[50] Because many gas wells have elevated temperatures, work is being conducted to determine if these existing wells can be utilized for geothermal power generation.

5. Factors Affecting Exploration Costs

Financing costs can significantly increase the cost of exploration. Because the risk factor for geothermal is so high (only 25% of wells drilled during exploration find a usable resource), companies seek equity investors to share in the risk by financing the project. Equity invested in geothermal yields an average annual rate of 17%.[51] This increases the total exploration costs considerably (see *Financing* for more information). In recent years, the increased cost of steel and cement materials required for drilling and well completion has significantly increased drilling costs—in some cases, nearly doubling the drilling cost.

[49] EIA. *Supply*. Retrieved September 6, 2006, from http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/oil_market_basics/supply_text.htm.

[50] Geothermal Energy Association (2004). *Geothermal Energy Potential*. Retrieved November 10, 2004, from http://www.geo-energy.org/USGeoProv.pdf.

[51] Owens, Brandon, Platts Consulting and Research (September 2002). *An Economic Valuation of a Geothermal Production Tax Credit*. Geothermal Resources Council Transactions, Vol. 26.

A number of other factors affect exploration costs:

- Expansion of an existing project will require lower exploration costs than greenfield projects, where a reservoir has not been previously drilled
- The larger the plant, the less the cost per MW (economies of scale)
- When costs of drilling materials, such as steel, fluctuate, so will the cost of drilling; also if the lithologies (properties of the rock formation) are more difficult to drill through, the cost of drilling will increase
- Lease costs and lag time in obtaining leases and permits increase the costs associated with exploration
- Site location and accessibility both influence exploration costs; costs tend to increase if the resource is located in a remote area
- Competition for drill rigs, as has occurred in Nevada over the past year as both gold and geothermal exploration have expanded
- Exploration techniques, including geophysics, chemistry, and number of slim holes needed
- Time delays (see following section)

Considering all of these factors, exploration is estimated to cost $100 – 200 / kWh. Exploration for the typical 50 MW geothermal power plant will thus cost between $5 and $10 million, with costs rising as the cost of steel increases.

a) Project Delays: Increasing the Total Cost

Project delays due to permitting, leasing, or other issues can significantly increase the exploration cost of a project. The table and chart on the following page show the cost increase of the expected value of a $100 (pink lower line) and $150 (blue upper line) capital investment when a 17% rate of return is considered. The vertical column represents the increase in exploration costs (in 2004 $) due to delays. As shown in the figure below, an initial investment of $100 translates into an investment of $2311 after twenty years; likewise, an initial investment of $150 will cost $3466 after twenty years.

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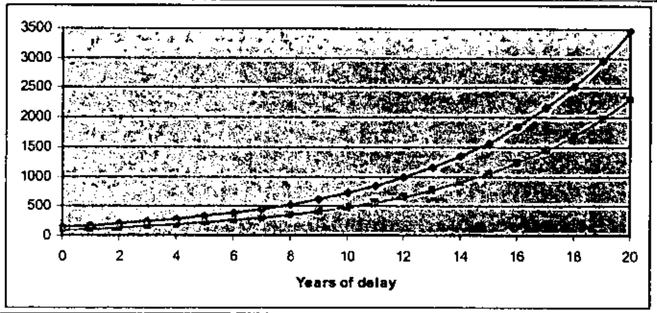
Figure 8: Typical Exploration Cost Increase Caused by Delays

Delay (years)	0	1	2	3	4	5	6	7	8	9	10
Exploration	100	117	137	160	187	219	257	300	351	411	481
Costs	150	176	205	240	281	329	385	450	527	616	721



Delay (years)	11	12	13	14	15	16	17	18	19	20
Exploration	562	658	770	901	1054	1233	1443	1688	1975	2311
Costs	844	987	1155	1351	1581	1850	2164	2532	2962	3466

Source: Hance, GEA

B. Confirmation

The confirmation phase seeks to confirm the energy potential of a resource by drilling production wells and testing their flow rates until around 25% of the resource capacity needed by the project is confirmed. Confirmation cost estimates for commercially viable projects average $150/kW.[52] At a typical, 50 MW plant, confirmation costs will total $7.5 million. The drilling success rate at the confirmation phase is 60%.[53]

A number of factors influence confirmation costs:

- The depth and diameter of the well
- The properties of the rock formation
- The number of wells drilled (determined by well productivity)
- Site accessibility
- Time delays

[52] The average confirmation costs of projects considered as "cost competitive" by GeothermEx (2004) *(i.e. capital investment ≤ 2400$/kW)* is 153$/kW. Inflated confirmation cost estimates published in EPRI 1997 correspond to 140.35 $/kW.

[53] GeothermEx (2004) estimates that a 60 percent success rate for production wells during the confirmation phase is reasonable, because confirmation drilling is based on very limited data about the deep resource, and the reservoir information gathered during confirmation later leads to the higher overall success rate."

- Rate of return on money invested

1. Confirmation Success Rate

GEA is often asked why the confirmation success rate is so low, especially considering that geothermal power plants have been operating for decades. Although the operating procedures for geothermal plants are mature and developed, the exploration and confirmation procedures are not nearly as advanced as operation. Often, geothermal resource areas have been found inadvertently in locations without any surface manifestation whatsoever. Even areas with surface manifestation do not always produce resources when drilled. If exploration shows the existence of a resource, confirmation is still needed to prove whether or not the resource is suitable for electricity production. All of these uncertainties accounts for the 60% confirmation success rate. As time goes on, it is expected that research activities will improve the confirmation success rate.

C. Site Development

The site development phase covers all the remaining activities that bring a power plant on line: drilling, project permitting, liquid and steam gathering system, and power plant design and construction. Site development costs at a 50 MW geothermal facility will average $131 million,[54] with site development costs varying considerably from project to project.

1. Drilling

The success rate for drilling production wells during site development averages 70 to 80%. The size of the well and the depth to the geothermal reservoir are the most important factors in determining the drilling cost. Inexpensive wells could cost as little as $1 million while expensive wells could cost $8-9 million. An average well will probably cost between $2 and 5 million.[55] Inexpensive wells tend to be found in areas of shallow resources located in sedimentary rocks, while expensive wells tend to be found in deep reservoirs located in hard rock formations.

[54] EIA's geothermal capital costs are low compared to those referenced in GEA's recent report, *Factors Affecting Cost of Geothermal Power Development* (see footnote #5). GEA lists geothermal development costs at $2620 per kWh, while EIA information represented in Table 1 of this paper lists geothermal capital costs at $2100 per kWh. The increase in the cost of the former can be explained because of the inclusion of additional cost parameters: financing, developer's soft costs, transmission costs, and others. Few of these parameters are included in the EIA figures of Table 1. However, if the figure of $2620 per kWh had been used for geothermal in Table 1, while using EIA figures for the other technologies, the cost figure for geothermal would include a larger set of parameters than those included in the other technologies, and thus would not provide a fair comparison.

[55] A 2M$ cost figure is most likely applicable to low average cost figure (e.g. a shallow resource) while a 5M$ well would rather correspond to the high end of the "average" cost figure.

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The average drilling expenses for a known geothermal site with existing production wells is $648/kW,[56] excluding confirmation drilling costs. Interviews with geothermal developers revealed that total drilling costs—including confirmation and site development drilling—range from $600/kW to over $1200/kW with an average drilling cost of close to $1000/kW. A typical, 50 MW plant would accrue an average of $37.5 million in drilling costs. However, just as the cost of drilling during exploration has significantly increased due to rising steel prices, so too has the cost of drilling during site development. In some cases, drilling costs have doubled.

A number of factors influence drilling costs:

- Permeability of the rock (ability of fluid to flow through the rock)
- Depth of the reservoir
- Chemistry of the geothermal fluid
- Resource temperature and pressure
- Competition with the oil & gas industry for drilling equipment (escalating rig and equipment costs, particularly steel and cement)
- "Known" versus "unknown" fields: drilling costs are expected to average 37% less on "known" geothermal fields compared with "unknown" fields[57]
- Reservoir engineering

a) A Note about Drilling Costs

GEA has often been asked why drilling costs are so high relative to the total price of a constructing a geothermal power plant. Indeed, after power plant design and construction, drilling costs account for the second largest cost associated with geothermal power development, at almost 30% of total cost. There are a number of reasons for this comparatively high drilling cost. Drilling requires a considerable amount of costly materials, such as steel. The cost of steel has been increasing in recent years, which creates competition between the geothermal and oil and gas industries, because oil and gas producers can generally afford to buy more of these costly materials. Additionally, competition for drill rigs drives up the costs. Geothermal drilling technology continues to require refinement if costs are to be reduced and accuracy is to be improved. Compared to geothermal's low operation and fuel costs, the cost of drilling looks particularly high; however, the levelized cost of geothermal power looks much more reasonable, and often, even cost-competitive with other available technologies.

2. Project Leasing and Permitting

Like all power projects, geothermal power projects must comply with a series of legislated requirements related to environmental concerns and construction criteria. Laws

[56] Hance, Nathanael (2005). *Factors Affecting Cost of Geothermal Power Development.* Geothermal Energy Association (GEA) and represent 2004$. Geothermal Energy Association (2004). *Geothermal Energy Potential.* Retrieved November 10, 2004, from http://www.geo-energy.org/USGeoProv.pdf
[57] Stefansson V (2002). *Investment cost for geothermal power plants*, Geothermics 31, pp 263-272.

and regulations vary significantly from state to state and, to some extent, depend on the land ownership. While procedures for approving construction of coal and natural gas facilities are generally standardized and transparent, those for permitting and leasing geothermal lands – before construction can even begin – can be arduous and unclear. Respondents to a recent survey about the barriers of new developing geothermal projects listed up to two decades of delay, with an average of 2 years, due primarily to difficulties in obtaining leases and permits for their projects.

During project development, leases are issued, site exploration for which permits are required takes place, and construction permits are issued. Overlapping jurisdiction, lack of funds, and lack of personnel has lead to leasing backlogs in many states, where applicants have been forced to wait decades for lease approval. EPAct's recent amendments to leasing laws seek to streamline the leasing process and facilitate the issuance of more leases. Because the new law has not yet been implemented, at this time its impact is unclear.

Most phases of project development must comply with a series of land use requirements. National Environmental Policy Act (NEPA) review costs are a subset of permitting costs, i.e., there are other permitting costs to consider besides NEPA compliance. Both permitting and leasing will require some sort of environmental documentation, whether it be the detailed Environmental Impact Statement (EIS), or the Environmental Assessment (EA).

One estimate places an EIS related to NEPA requirements at an average cost of $600,000, with an average time of up to two years. [58] Total permitting costs vary significantly for each project, often falling well above or below the average. While permitting a small project may only cost about $200,000 and take less than one year (best case scenario), permitting a large project may cost over a million dollars and take more than three years.

Even though geothermal plants are some of the most environmentally benign that exist today, the permitting requirements associated with geothermal development can be overwhelming. At the Mammoth Pacific plant, located in California, a five-year struggle for expansion permits resulted in approval with a 22-page "conditional use permit," with over 100 conditions that had to be met in order for the expansion to move forward (see *Mammoth Pacific Case Study* for more information).

3. Steam Gathering System

The liquid and steam gathering systems are the network of pipes connecting the power plant with production and injection wells. Production wells bring the geothermal fluid to the surface to be used for power generation, while injection wells return most of the used fluid back into the geothermal system to be used again. Injection helps ensure that geothermal systems are sustainable and that the resource is not depleted.

[58] National Geothermal Collaborative (November 2004). Geothermal Leasing Panel. Accessed March 23, 2006, at http://www.geocollaborative.org/publications/default.htm.

A number of factors influence the cost of the steam gathering system:

- Site topography
- Slope stability
- Average well productivity and thus, pipeline sizes
- Size and spread of the steam field
- Characteristics of the geothermal fluid (temperature, pressure)
- Site accessibility (road construction needs and difficulties)
- Chemical characteristics of the geothermal fluid

Recent cost estimates provided by geothermal power developers average 250$/kW and, in some cases, exceeded $400/kW. At a typical 50 MW plant, the steam gathering system costs approximately $12.5 million.

a) Benefits of Injection

Benefits of injection include enhanced recovery of geothermal fluids, reduced subsidence, safe disposal of geothermal fluids, and an increased operational lifetime of the reservoir.[59] Geothermal plants can last for decades if managed properly. Because geothermal facilities rely on a constant source of fuel that can be recycled through the system, the cost of maintaining the geothermal facility is minimal once the drilling and exploration takes place, while the benefits of using a clean, stable energy source—including reduced air emissions, increased national security, energy stability, reduced dependence upon foreign oil—are substantial.

One geothermal complex, The Geysers in California, has realized unique benefits from its injection activities. At The Geysers, injection serves the dual purpose of environmentally responsible disposal of reclaimed water, which would otherwise be discharged onto fields or into local waterways, and rejuvenating geothermal reservoirs with additional water sources. Reclaimed water from Lake County is being injected deep into The Geysers reservoir at the rate of approximately 2.8 billion gallons annually. Additionally, about 4 billion gallons annually (11 million gallons of treated wastewater per day) is being pumped to The Geysers for injection from cities in Sonoma County. These projects have proven to be a great success.

4. Power Plant Design and Construction

In designing a power plant, developers must balance size and technology of plant materials with efficiency and cost effectiveness. The power plant design and construction depends upon the type of plant (flash, binary, dry steam, or flash/binary

[59] California Division of Oil, Gas, and Geothermal Resources (2004). *Geothermal Injection Wells*. Retrieved November 4, 2004, from http://www.consrv.ca.gov/DOG/geothermal/general_info/injection_wells.htm.

combined cycle), as well as the type of cooling cycle used (water or air cooling). See *Geothermal Basics* for more information about cooling systems and power plant types. Labor costs are estimated to account for 41% of total project construction costs while materials and "other" costs respectively represented the remaining 40% and 19%. Labor costs can increase by 10% if camps are needed to provide housing and meals to workers when a resource is remotely located.[60]

Figure 9: Soda Lake Binary Power Plant, Fallon, Nevada.

Source: Daniel Fleischmann, GEA

Besides the costs related to physically building a power plant, other power plant related costs include soft costs and land costs. *Soft costs* relate to project development and financial issues, including expenses such as engineering, legal, regulatory, documentation and reporting activities. Soft costs represent approximately 6 -10% of total costs.

Land costs can vary depending upon the type and ownership of land in question—desert vs. agricultural land; rural land vs. land close to cities, purchased vs. leased parcels. For steam geothermal systems,[61] land costs include subsurface mineral rights that correspond to roughly 10% of the value of steam.

a) Land Cost and Use Comparison

Although any development will impact land, fossil fuel site development and land use tends to be more destructive than geothermal development. Fossil fuel power plants impact both the site of the plant and the site of drilling (for natural gas), or mining (for coal). Transportation impacts for pipelines and coal shipments, usually via rail, can also be environmentally destructive. Coal mining can damage large swaths of land and degrade streams. Coal power use impacts and associated costs would be much higher if

[60] Bloomquist, Gordon (2002). "Economics and Financing," In *Geothermal Energy* (UNESCO), Chapter 9. M.H. Dickson and M. Fanelli.

[61] At a *dry steam geothermal power plant*, steam directly from the geothermal reservoir runs the turbines that power the generator, and no separation is necessary because wells only produce steam.

mining, processing, transport, construction, and reclamation were included. Nuclear costs increase due to the required safe maintenance of huge amounts of radioactive waste, and the cost of keeping waste safe is imposed on future generations. Nuclear also uses and discharges extensive water resources. Natural gas wells are drilled hundreds of miles from the plant site, and this means that the gas is transported by pipeline across considerable distances to be used at the power plant. In the future, much of our natural gas will likely be imported from other countries as liquefied natural gas.

With geothermal development, land use impacts are located at the power plant and transmission line site. There is no potential for disasters such as the 1989 Exxon Valdez oil spill in Prince William Sound, Alaska, where 15 million gallons of oil in transport were accidentally released into a pristine natural area. Over 30 years, the period of time commonly used to compare life cycle impacts of different power sources, geothermal uses less land than most other sources.[62] Geothermal plants can also be built upon multiple use land, where aquaculture operations, agricultural activities, and hunting can regularly take place on the same site as the power plant. Cascaded uses, where a power facility provides power and thermal heating needs for collocated businesses, are also common at geothermal power plants.

Geothermal facilities use less freshwater than other electricity sources. An analysis of a geothermal and a natural gas facility shows that a typical geothermal facility uses significantly less freshwater than a natural gas facility.[63] A binary geothermal plant with an air-cooling system uses virtually no freshwater at all.

b) Transmission Issues

Because geothermal resources cannot be transported distances over a few miles, geothermal power plants must be built at the site of the reservoir and must rely upon transmission systems to bring their power to the regional power grid. Sometimes transmission infrastructure does not exist where a geothermal resource is located, and additional power lines must be built, adding to project costs. Geothermal developers pay the direct costs to connect their plant to the grid, and in some cases incur additional transmission related costs. These additional costs could include the construction of new lines, upgrades to existing lines, or new transformers and substations.

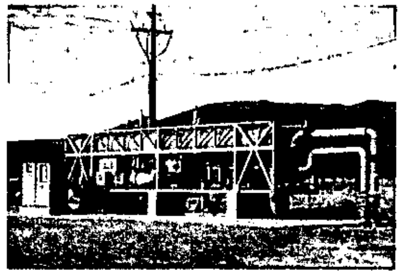
[62] Brophy, Paul (1997). Environmental Advantages to the Utilization of Geothermal Energy. *Renewable Energy*, Vol 10:2/3, Table 3, pp. 374.
[63] Telephone Flat Environmental Impact Statement 3.2-32, 3.2-34, 3.2-35; natural gas: Calpine Corporation Sutter Power Plant Project, Application for Certification (AFC) (Dec 1997). Table 2.2-1, *Estimated Average Daily Water Requirements*.
NOTE ON CALCULATIONS: Telephone Flat (geothermal)was proposed to produce 48 MW and use an average of 6.5 acre feet/year, Sutter (natural gas) was proposed to produce 500 MW and use an average 4,336,000 gals/day. Numbers based on the assumptions that one acre-foot = approximately 325,851 gallons, as reported by USGS (http://water.usgs.gov/pubs/circ/2004/circ1268/htdocs/text-conversion.html) and that the water usages are averaged over a 24 hour a day, 365 day a year time period.

Projects considered economically viable have transmission related costs ranging from $13 to $236 per kW with an average of $104/kW.[64]

A number of factors influence the transmission costs:

- existing lines
- topography of the area
- size of the plant – Considering a 10 MW and a 100 MW project with similar transmission requirements, transmissions costs for the larger project will be 10 times smaller than the cost for the smaller project, since the cost will be shared out over a much larger power output.

Figure 10: A Small Power Plant in Nevada, the Wabuska



Source: Ormat

c) Other Factors that Influence Design and Construction

A number of other factors besides transmission influence the cost of designing and constructing a power plant:

- The temperature of the resource: as the temperature increases, the efficiency of the power system increases and the specific cost of equipment decreases
- The depth to the reservoir
- The chemistry of the geothermal fluid
- Water availability, which will help determine the type of cooling system that will be used[65]
- Location, topography and geologic factors
- Power plant technology choices
- Larger projects will cost less per MW than smaller projects (economies of scale)
- Greenfield projects tend to cost 10 to 15% more than power plant expansions

[64] Sanyal S (2004). *Cost of Geothermal Power and Factors that affect it.* GeothermEx.
[65] Two different kinds of cooling systems exist: air-cooled or water-cooled. Water-cooled systems are generally considered to be less expensive to build and operate as long as water is inexpensive and readily available.

d) Geothermal Power Plants and Tourism

Most geothermal power plants will either not affect tourism or cause it to increase. Take the example of the power plant at Mammoth Lakes, California, a sight of heavy outdoor recreation and active fisheries. Although people initially opposed the project due to worries over tourism impacts, the project is now highly regarded among community members and visitors alike. Many people in the city do not even know the power plant exists because it was so expertly engineered to blend into the surrounding environment (See *Mammoth Pacific Case Study* for details). Tourism might increase when students, scientists, or interested individuals visit the site of the power plant, thereby bringing business to the local community, but rarely does geothermal development negatively impact tourism. Tourism has certainly increased near the Blue Lagoon in Iceland, a turquoise body of mineral rich water, which was actually created by geothermal water discharged from a power plant.[66]

5. The Production Tax Credit (PTC)

EPAct 2005 provides a production tax credit (PTC) for renewable technologies, including geothermal, through the end of 2007. This PTC provides a 1.9 cent tax credit for each KWh of power produced by an eligible facility (or $19 per MWh) as adjusted annually for inflation. The PTC was available only to wind and closed loop biomass in 1992, and resulted in the "increased installed capacity of wind turbines in the United States," according to the EIA, with "large amounts of capacity built in the year prior to the expiration of the PTC, and virtually no capacity built when the PTC [was] not available."[67] As of 2005, the PTC was expanded to include not only geothermal facilities, but also open-loop biomass, solar energy, small irrigation power, and municipal solid waste (MSW) power facilities. The value of the PTC is halved for open-loop biomass, MSW, landfill gas, small hydro and incremental hydro from efficiency improvements or capacity additions at existing hydro projects. Coal owned by or held in trust on behalf of an Indian tribe and refined coal are eligible as well, with the credit set at $4.375 per ton for refined coal and $1.50 for Indian coal.

a) Impact on Geothermal Cost

One analysis found that a PTC would decrease the levelized cost of geothermal power by 25 – 30% compared with the current policy environment.[68] For many developers, a PTC

[66] Geotimes, Dec. 2003. http://www.geotimes.org/dec03/Travels1203.html. Retrieved November 9, 2004.
[67] EIA, DOE. Policies to Promote Non-hydro Renewable Energy in the United States and Selected Countries (February 2005). Retrieved April 5, 2006, from http://www.eia.doe.gov/cneaf/solar.renewables/page/non_hydro/nonhydrorenewablespaper_final.pdf#2.
[68] Owens, Brandon, Platts Consulting and Research (September 2002). *An Economic Valuation of a Geothermal Production Tax Credit*. Geothermal Resources Council Transactions, Vol. 26, pgs 467 – 471.

can dictate whether or not a power purchase agreement (PPA) will be secured (see *Financing* for more information). Without a PTC, geothermal power will not likely be brought to the grid. Besides increasing geothermal and other renewable development, the PTC lowers the price customers must pay for renewable energy.[69]

Figure 111: Raft River Groundbreaking

Source: Dan Fleishmann, GEA

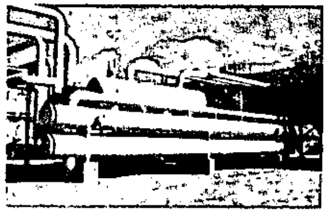
b) Impact on Geothermal Development

As of October 2005, one newly operating geothermal power plant, the Richard Burdette power plant located near Reno, Nevada, benefited from the production tax credit (see figure 12 below). About a half dozen other plants—of the three dozen or so under development—are set to come online in time to benefit from the credit. One of the plants that will likely benefit from the PTC is the Raft River geothermal power plant, which will be the first geothermal plant to produce power in the northwest (figure 11).

Other plants included in the 35 new projects under development as of 2006 may benefit from the credit, but timeframe issues make this uncertain. Many industry experts, including Ormat, the owner of the Richard Burdette plant, admit that "it is too early to assess the impact of provisions in EPAct, including the PTC, on the geothermal industry." Ormat stresses, however, on behalf of the geothermal industry, that the PTC will likely "enhance the ability of geothermal projects to compete with other fossil fuel technologies." Only in the next few years will the geothermal industry know for sure what the impact of the PTC will be. It is anticipated, however, that the PTC, especially if extended, will result in new geothermal development. In fact, industry leaders and the GEA, the industry trade group representing U.S. companies, identify the PTC is one of the most effective policy tools to expand geothermal development.

[69] Gale, Brent E., MidAmerican Energy Company (April 2005). "The Economics of Utility Ownership of Wind." Power point presentation at PUC Conference on *The State of America's Energy*. Retrieved July 21, 2006, from http://www.state.sd.us/puc/pucevents/Energy%20Conf%20Presentations/Brent%20Gale%20Economics%20of%20Wind.pdf.

Figure 122: Richard Burdett Plant



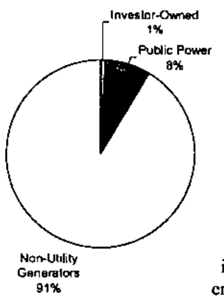
Source: Ormat

c) Geothermal Market Price

Even though the levelized cost of certain distributed renewable energy sources might be higher than the levelized cost of geothermal energy, geothermal still needs the PTC to remain competitive. The reason for this price difference can be explained, in part, by the power prices in the wholesale vs. the retail market. In general, for an energy source to compete in the wholesale market, it must cost less than the competitive cost in the retail power market. Geothermal is an energy source sold in the wholesale power market, while a source such as solar is typically sold in the retail power market.

It is true that geothermal prices are decreasing, and in fact are close to market price. While geothermal is one of the most cost-effective options of the renewable energy sources available, in many cases geothermal technology still struggles to compete with polluting fossil fuel sources. Geothermal developers hope that, with time, they will be able to compete in the wholesale power market without the PTC. But today's studies show that in order for geothermal to compete against highly subsidized fossil fuel energy sources, the PTC is necessary.

Figure 13: Public and Private Ownership of Geothermal



Source: American Public Power Association (APPA)

Power Plants, 2003d) Alternative for Independent Power Producers: CREBs

Clean Renewable Energy Bonds (CREBs) provide an incentive for electric co-ops and public power projects that cannot qualify for the PTC. A CREB is a special type of bond, known as a "tax credit bond," that offers cooperatives the equivalent of an interest-free loan for financing qualified energy projects for a limited term.[70] While the majority of geothermal power plants, designated as either private or utility-generators, benefit from the PTC, some geothermal power plants, such as the Northern California Power Agency (NCPA) facilities, are publicly owned. The breakdown of private/public ownership is shown in figure 13 on the preceding page.[71] Two NCPA units generate 220 MW of geothermal power at The Geysers. New publicly owned projects are in the works, including several on Indian land.

[70] National Rural Electric Cooperative Association (NRCA). *Clean Renewable Energy Bonds (CREBs)*. Retrieved August 11, 2006 from http://www.nreca.org/Documents/PublicPolicy/CleanRenewableEnergyBonds.pdf.

e) PTC Timeframe Challenges for the Geothermal Industry

EPAct specifies that a facility eligible for the PTC must be built by the end of 2007. This stipulation poses a challenge for many geothermal developers, because most new geothermal facilities cannot be constructed by that time. Most geothermal projects take 3 to 5 years to come online, without even considering permitting and leasing issues that can delay operation further. In one instance, a geothermal power company is only developing 25 of its contracted-for 215 MW, because only 25 MW can be developed within the timeframe set forth in the PTC. According to the largest geothermal power producer in the U.S., Calpine Corporation, without a facility qualifying for a PTC, even though "buyers have shown considerable interest in purchasing geothermal power because it is both renewable and extremely reliable...the utilities are likely to award power purchase contracts to plants that can be constructed in a shorter time frame and can offer more price certainty."[72]

Table 5 on the following page shows average leadtimes for selected alternative energy technologies.[73] As the table shows, several other technologies suffer from long leadtimes: geothermal, conventional hydropower, and biomass share the longest leadtimes. Many geothermal developers in California—the state with the most developed geothermal resources—complain of even longer leadtimes. Note that nuclear, with an EIA-projected six-year leadtime, benefits from long-term loan agreements, substantial R&D funding, and numerous other benefits.

[71] American Public Power Association (APPA). *2006-07 Annual Directory & Statistical Report.* "Renewable Capacity by Owner Type: Nameplate Capacity, in Megawatts." Retrieved August 14, 2006, from http://www.appanet.org/files/PDFs/renewablecapacity.pdf.
[72] Calpine Corporation (2006). *Statement on Calpine Plans for Geothermal Development.*
[73] Source: EIA (2006). *Assumptions to the Annual Energy Outlook 2006.* Retrieved March 17, 2006, http://www.eia.doe.gov/oiaf/aeo/assumption/index.html.

Table 5: Average Number of Years Required to Bring a Plant Online

Technology	Leadtime (years)
MSW[74] / Landfill Gas	3
Biomass	4
Wind	3
Geothermal	4
Fuel Cells	3
Conventional Hydropower	4
Solar Thermal	3
Photovoltaic (PV)	2

Source: EIA

6. Mitigation Measures

Despite the minimal impact of geothermal facilities compared to fossil fuel sources, geothermal development is accompanied by significant mitigation measures.

At most geothermal facilities, detailed site planning, facility design, materials selection, revegetation programs, and adjustment to transmission line routing are routine components of geothermal operations. One large geothermal company reduced the visual impacts of their power plant by painting all piping forest green to blend into the surrounding landscape. Another installed the first air-cooled geothermal power plant in order to eliminate the view of steam plumes that accompany the more standard water-cooled geothermal plant (for details, see *Mammoth Pacific Case Study*). Some companies utilize non-specular conductors, which reduce reflection and glare on transmission lines. Transplanting trees is also a common mitigation technique.

Several noise muffling techniques and equipment are available for geothermal facilities. During drilling, temporary noise shields can be constructed around portions of drilling rigs. Noise controls can be used on standard construction equipment, impact tools can be shielded, and exhaust muffling equipment can be installed where appropriate. Because turbine-generator buildings are usually designed to accommodate cold temperatures, they are typically well-insulated acoustically and thermally, and equipped with noise absorptive interior walls.

Mitigation also consists of monitoring activities. Ongoing monitoring activities could include but are not limited to well pressure, water chemistry, archeological, species, ecosystem, surface site, and deep temperature monitoring. Most mitigation measures are set forth in permitting conditions and in environmental documents that are available for public review.

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[74] Municipal Solid Waste

D. Financing

Two types of investors typically provide money for geothermal development: equity investors and debt investors. Early *equity investors* may recover the money they invest only if geothermal exploration proves the existence of a resource that results in an operating project or a sale. Because high risk is involved for equity investors, equity investors expect a high rate of return if a project is successful—16-20 percent or more.[75]

Debt investors are usually risk-averse lenders or commercial banks. Debt investors are among the first financial stakeholders to recover their money in case of project failure. Because comparatively lower risk is involved for debt investors, debt investors receive lower interest rates (about 6-8%). Debt investors usually will not lend money unless a certain percentage has already been invested by an equity investor. Today's geothermal projects are generally composed of 70% debt and 30% equity. As an added constraint, debt lenders (commercial banks) will require 25% of the resource capacity to be proven before lending any money. This means that all early phases of the project have to be financed by equity. So, while geothermal developers would prefer their projects were funded entirely by debt due to lower interest rates, at least part of the project, especially the upfront costs, must be funded by equity.

1. Interest Rates for Geothermal Developers

Different types of developers will be required to pay different rates of interest over various timeframes for their loans. For example, Independent Power Producers (IPPs),[76] which account for all but one geothermal power producer in the U.S., will pay an average interest rate of 10.7% over 15 years, while a municipal utility[77] will pay an average interest rate of 5.5% over 30 years.[78] This means that the cost of financing for an IPP could increase the levelized cost of power[79] by as much as 44% compared with the cost at a municipal utility.

2. Length of Debt

In order to secure the revenue flow of the project, commercial banks will require the developer to have a Power Purchase Agreement (PPA) that covers at least the length of the debt period. A PPA, negotiated with a utility, guarantees that a power plant will be able to deliver its power to the grid at a fixed or market-dependent price for a certain

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[75] Return on equity figures provided above are nominal. To obtain real interest rates, inflation has to be subtracted from nominal interest rates.

[76] An "IPP" is a private non-utility or utility-affiliated entity that generates electricity and sells it to other businesses including utilities.

[77] A "municipal utility" is one owned and operated by a town or city with an organized local government.

[78] U.S. DOE, EPRI (1997). Renewable Energy Technology Characterizations.

[79] "Levelized cost" is defined as the total capital, fuel, and operating and maintenance costs associated with the plant over its lifetime divided by the estimated output in kWh over its lifetime (expressed here in current dollars).

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period of time.[80] Geothermal power plants have a planned lifetime of at least 30 years and usually operate much longer, while power purchase agreements typically last 10 to 20 years. This means that the debt payback period of the project has to fit into the PPA timeframe. After a geothermal project pays back the debt incurred by a PPA, over ten years or more, costs may then fall by about 50% to cover just O&M costs for the remaining time during which a facility operates.

3. Long-term PPAs and Stability

Although obtaining a long-term PPA may be challenging for a developer, the agreement helps stabilize the electricity market. A geothermal PPA transfers any risk related to fuel from the market and/or consumer to the developer and/or operator. A PPA ensures a stable, long-term electricity price for decades. This price security means that geothermal energy can offset the U.S.'s dependence upon the highly volatile fossil fuel power market. Once a power project is built, most of its power production costs are known and predictable and, in many cases, few market parameters can modify them.

4. The True Capital Cost of Power: Considering Capacity Factor

At first glance, geothermal power plants seem to require higher upfront costs than most other renewable and fossil fuel technologies. A closer look, however, proves that this is not the case. Table 6 on the following page shows the weighted overnight costs[81] once capacity factor (CF) is considered.[82] CF measures the amount of power that a facility produces related to its rated capacity over time. Geothermal plants have the highest projected rated CF of any renewable facility, according to EIA. The overnight or capital costs increase dramatically for most technologies when capacity factor is considered, but stay relatively stable for geothermal. This means that geothermal's overnight costs based on generation—the number of MWs actually producing electricity—is competitive with other fuel sources.

[80] Power Purchase Agreements are long-term contracts that specify power prices and output for the period considered. They are usually the result of political commitment that aims to diversify the energy mix and promote alternative sources of energy (renewable energy) to stabilize long-term price projections but are not always available neither easy to obtain.

[81] Overnight costs for each technology are calculated as a function of regional construction parameters, project contingency, and technological optimism and learning factors, according to EIA.

[82] From EIA (2006). *Assumptions to the Annual Energy Outlook 2006.* Retrieved April 17, 2006, from http://www.eia.doe.gov/oiaf/aeo/assumption/index.html.

Table 6: Overnight or Capital Cost Comparison

Technology	Base Overnight Costs (2005, per MW)	2010 Capacity Factor (percent)	Weighted Overnight Costs[83]
MSW / Landfill Gas	1,443	90	1,603
Biomass	1,659	83	1,999
Wind	1,091	37	2,949
Geothermal	2,100	95	2,211
Conventional Hydro	1,320	64	2,063
Solar Thermal	2,589	31	8,352
Photovoltaic (PV)	3,981	21	18,957

Source: EIA

E. O&M Costs

Operation and Maintenance (O&M) costs consist of all costs incurred during the operational phase of the power plant. Operation costs include labor, spending for consumable goods, taxes, royalties, and other miscellaneous charges such as internal electricity uses. Maintenance costs include all expenses related to the upkeep and maintenance of the equipment and the continued sustainability of the resource through injection and other activities such as reservoir and environmental monitoring and reporting. Geothermal is one of few technologies with near zero fuel costs. This, combined with a high capacity factor, means that geothermal is one of the most reliable fuel sources available today.

1. Direct Payments (Government Taxes, Royalties and other Revenues)

Geothermal facilities make significant contributions to the U.S. economy. Some contributions come as royalties or taxes, which are mandated by the government, while some come voluntarily from the geothermal company. In many areas where geothermal resources are developed, the developer is considered a "good neighbor" because of substantial local contributions.

[83] In order to calculate the weighted overnight costs, we divided 100 by the projected 2010 capacity factor (CF) percent, and then multiplied the resulting number by the EIA listed base overnight cost. For example, to find geothermal weighted overnight cost, we divided 100 by 95, and then multiplied the resulting number (1.053) by 2,100. We chose to represent capacity factors projected for 2010 because the average new geothermal power plant will come online at or near 2010 if development begins today. Also, this is the earliest year capacity factor is rated in EIA's Assumptions to the Annual Energy Outlook 2006.

a) Royalties

Royalties are payments that power producers are required to make to the owners of the geothermal resource. Exact royalty values are difficult to provide since terms and conditions of geothermal leases vary according to the resource owner (private vs. government). Royalty values range from 0.5 to 5.5% of the price of power and typically account for 10 to 15% of O&M costs. Globally, the "average effective royalty rate" paid by geothermal power producers in 2004 for leases concerning resources located on federal land was 3.94%.[84]

Between 1970 and 1997, geothermal power plant operators had paid a total of nearly $500 million to the Federal Government in royalties.[85] In 2000, California alone supplied $14,373,308 in federal royalties from geothermal leases.[86]

Recent changes to royalty fees proposed by the Mineral Management Service (MMS) Royalty Advisory Committee would provide $4 million a year to local counties, according to the proposed rule. Assuming the newly proposed royalty schedule,[87] over 30 years, an average, 50 MW plant will supply a total of over $16 million to the federal government and the state and county where the resource is developed. The new rules require geothermal producers to pay a royalty of 1.75% of total annual income for the first 10 years, and 3.5% for every year thereafter. Of this amount, 25% goes directly to the county, 50% to the state, and 25% to the federal government. This means that for the first ten years of production, assuming an average price of 6 cents/kWh and 95% capacity factor, without adjusting for inflation, every year a 50 MW geothermal plant will contribute $218,453 to the state, $109,226 to the federal government, and $109,226 to the county government. From the eleventh year on, without adjusting for inflation, every year the plant will contribute $436,905 to the state, $218,452 to the county, and $218,452 to the federal government. Over 30 years, the power plant would contribute a nominal total of over $16 million to federal, state, and local governments.

b) Taxes

Geothermal power producers contribute to government budgets through different kinds of taxes:
- *Property taxes* are based on the estimated value of the company assets. Tax rules may be different from one jurisdiction to another.

[84] The royalty ranges provided above were provided by BLM and MMS to the Royalty Policy Committee for the "Geothermal Valuation Subcommittee Report" that was published in May 2005.
[85] National Geothermal Collaborative. *Geothermal Energy and Economic Development*. Retrieved March 13, 2006, from http://www.geocollaborative.org/publications/Geothermal_Energy_and_Economic_Development.pdf.
[86] Bureau of Land Management (December 2004). *Geothermal Leasing in California*. Retrieved July 12, 2006, from http://www.blm.gov/ca/pa/minerals/geothermal.html.
[87] Proposed rules were issued in August 2006. At publication, these rules had not been finalized.

- *Federal and State income taxes* are calculated upon the net revenue of the company. Rules may vary from one state to another and the amount will vary according to the company structure and annual profits.
- *Sales taxes* paid on consumables and services will depend on the amount and value of goods needed for O&M (which varies with the technologies used) and will also vary from one state to another.

Besides companies' tax contributions, local employees will pay income, property, municipal, county, and sales taxes.

In many counties where geothermal power plants exist, the plant is one of the largest taxpayers. In 2003, The Geysers paid property taxes to two counties totaling more than $11 million. CalEnergy, the largest geothermal company in the region, is the single largest taxpayer in Imperial County, supplying 25% of the tax base.[88] At the geothermal power plants located in Inyo County, California, plant owners pay approximately $6 million annually, of which roughly two-thirds is used to fund schools.

c) Voluntary Payments

Besides royalty and tax payments, geothermal companies often provide voluntary funds to the communities in which they are located. The Mammoth Pacific power plant, for example, has been designated a "good neighbor" by many locals for making donations to local groups in the area and building a new community center from the proceeds of the power plant (see *Mammoth Pacific Case Study* for details).

d) Projected Payments

Achieving the 2001 goals of the DOE Geothermal Energy Strategic Plan could result in payment of over $7 billion in royalties to the Federal Government by 2050, and income tax revenues of over $52 billion (1998 $).[89] From just the state share in these royalties, alone, that would mean an additional investment of $3.5 billion in schools and local government facilities in the western states (1998 $).[90]

Renewable Northwest Project reports that a 100 MW project in Eastern Oregon could create over a $1 million (1990 $) of additional local income each year, and would pay $4 million-$6 million (1990 $) in local and state fees, royalties and taxes, according to the Oregon Department of Energy. In contrast, a similarly-sized natural gas project sends

[88] Center for Energy Efficiency and Renewable Energy (CEERT). *Geothermal Power*. Accessed March 13, 2006, from http://www.ceert.org/ip/geothermal.html.
[89] Princeton Energy Research Inc (December 15, 1998). Review of Federal Geothermal Royalties and Taxes. Volume I, page 17. March 14, 2006, from http://waysandmeans.house.gov/hearings.asp?formmode=view&id=4069#_ftn4#_ftn4
[90] Ibid

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$11-24 million (1990 $) out of the region every year for fuel costs alone.[91]

The construction of two new geothermal plants by Calpine Corporation in Siskiyou County, California would result in a total economic benefit of almost $114 million over 30 years (2002 $), with a yearly average increase of almost $4 million. Property taxes and royalty revenues for the two projects totals $956,286, and the 30-year total is $28,688,581 (2002 $).[92] The new royalty laws would provide even more money to the local community in which the plants are located. This money will generate jobs, improve community living, and boost educational standards throughout the region.

Two plants in the planning stages, the Fourmile Hill and Salton Sea Unit 6 Geothermal Power Plant projects, would together have a total economic benefit of $866 million, or $29 million per year.[93]

2. Indirect and Induced Payments

For every dollar invested in geothermal energy, the resulting growth of output to the economy is $2.50 or more. This means that the investment required to bring 1000 MWs of new geothermal power online within the next three years as projected, the associated $2.8 billion investment[94] will bring an economic output of at least $7 billion nationwide, and even more over several years.

F. The Levelized Cost of Geothermal Power

The California Energy Commission (CEC) estimates the levelized generation costs from new geothermal plants at 4.5 to 7.3 cents per kWh, which over the lifetime of the plant can be competitive with a variety of technologies. Recent EIA analysis places geothermal energy at a lower levelized cost than natural gas combined-cycle, wind, open-loop biomass, nuclear, solar thermal, and photovoltaic (with costs increasing in the order in which they are listed).[95] However, two points should be considered regarding these estimates. First, it is important to keep in mind the different prices associated with

[91] Sifford, Alex and Kasi Beale (Dec 1991). Economic Impacts of Geothermal Development in Deschutes County, OR. Prepared for the Bonneville Power Administration under Agreement No. DE-BI79-90BP07 129. Oregon Department of Energy, Salem, Oregon.
[92] Gallo, David E. (June 2002). The Economic Impact of Calpine's Geothermal Development Projects, Siskiyou County, California. Prepared for Calpine Corporation. Center for Economic Development: California State University, Chico. Accessed March 23, 2006, from http://www.csuchico.edu/cedp/pdf/esp.calpine.pdf
[93] Battocletti, Liz, and Marilyn Nemzer (February 2006). *Measuring the Economic, Environmental, and Social Benefits of Nine Geothermal Heating System and Power Generation Projects*. Prepared for California Energy Commission Geothermal Program. Contract No. MFS-04-002.
[94] Assuming that average capital investment of a geothermal project is $2800/kW.
[95] Howard Gruenspecht, Administrator, Energy Information Administration, U.S. DOE (May 2005). Statement Before the Subcommittee on Select Revenue Measures., Committee on Ways and Means, U.S. House of Representatives. Table 1. Accessed March 23, 2006, from http://www.eia.doe.gov/neic/speeches/howard052405.pdf.

competitiveness in different markets (wholesale vs. retail). Second, the lower-end price figures cited for geothermal likely rely on lower than average upfront financing agreements (see *Financing*), or consider only new projects that are built as expansions of existing projects. Expansion projects typically forgo many of the construction, resource risk, and transmission costs associated with new plants.

In fact, most geothermal developers contend that the cost for new projects is more accurately reflected in a range of 5.5 to 7.5 cents per kWh. Even so, the current price for geothermal expansion projects can be competitive with coal-fired plants, and greenfield projects can be competitive with natural gas.[96] At current fossil fuel market prices, natural gas costs the equivalent of 8 to 9 cents per kWh (2005 $).[97]

Figure 14 on the following page shows that developing and defining the geothermal resource costs almost as much as building the power plant. For geothermal, a full one quarter of total costs are attributed to drilling alone, and almost half of all levelized costs are spent before the plant goes online.

[96] Comparative Cost of California Central Station Electricity Generation Technologies, Final Staff Report, March 16, 2006, from http://www.energy.ca.gov/reports/2003-06-06_100-03-001F.PDF.
[97] Energy Information Administration (EIA) (2005). Natural Gas Weekly Update. Accessed March 23, 2006, from http://tonto.eia.doe.gov/oog/info/ngw/ngupdate.asp.

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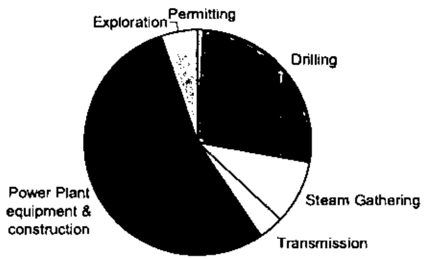
Figure 14: Typical Cost for Geothermal Power Plant



Source: Hance, GEA

1. Geothermal and Fossil Fuels: Comparing True Levelized Costs

While it is important to compare the costs of various components of power production across technologies, it is perhaps more important to consider other factors, not necessarily apparent at first, that directly impact the levelized cost of power over the long and short term.

a) Subsidies

According to the nonpartisan *Taxpayers for Common Sense*, the fossil fuel industry receives billions of dollars in subsidies from the U.S. government[98]—almost 80% of the subsidies supplied to the energy industry.[99] *Taxpayers* estimates that removing subsidies could reduce U.S. carbon emissions by 65-70 million metric tons. These U.S. subsidies amount to as high as $18.3 billion a year ($ 2000).[100] The removal of fossil fuel subsidies has been advocated by World Bank as the first order of priority in instituting economic policies to protect local and global environments that could also help spur new renewable development. [101] Further, a report by the New Economics Foundation says that

[98] Taxpayers for Common Sense. *Fuels Fact Sheet*. Retrieved March 13, 2006 from http://www.taxpayer.net/TCS/fuelsubfact.htm.
[99] Aulisi, Andrew (October 2004). *Emissions Market Designs and Implications for Renewable Energy*. World Resources Institute: Tenth National Green Power Marketing Conference: Austin, TX. Retrieved March 13, 2006, from http://www.eere.energy.gov/greenpower/conference/10gpmc05/aulisi.pdf.
[100] Ottinger, R L and M Jayne (2000) *Global climate change – Kyoto Protocol implementation: Legal frameworks for implementing clean energy solutions*, Pace University School of Law, White Plains, New York. Retrieved September 28, 2006, from http://www.solutions-site.org/special_reports/CleanEnergyFinal4.doc
[101] Larsen, Bjorn and Anwar Shah (1992). *World Fossil Fuel Subsidies and Global Carbon Emissions*. The World Bank, Office of the President. Retrieved March 13, 2006, from http://info.worldbank.org/etools/docs/library/206933/WorldFossilFuelSubsidiesandGlobalCarbonEmissions.pdf.

worldwide fossil fuel subsidies amount conservatively to about $235 billion a year ($ 2004),[102] while other sources put the figure closer to $250-300 billion (mid-1990s $), plus an estimated $100 or more per barrel necessary to secure the supply of oil imports.[103]

b) Trend in Cost of Power over Time

Geothermal costs have decreased considerably – by nearly 50 % over the past two decades. According to the National Renewable Energy Laboratory (NREL), costs neared 15 cents per kWh in 1980, with current prices decreasing to 7 cents per kWh. And while geothermal prices are expected to continue to decline, both coal and natural gas prices will likely increase, according to the EIA. Natural gas prices have increased recently, often experiencing boom and bust type cycles. Most industry experts agree that geothermal is one of only a few alternative technologies that could compete economically with polluting technologies in the near term—even without considering the ancillary benefits of geothermal production. Authors noted in one recent EIA publication, "In some regions and years, new geothermal...plants may be competitive with new coal-fired plants, but their development is limited by the availability of geothermal resources."[104]

c) Electricity Needs and Cost Savings

In the long run, renewable energy resources can help decrease costs by providing domestic, low-cost, low-pollution options to meet U.S. energy needs. An EPA study concludes that if all states were to implement "cost-effective energy efficiency and clean energy policies, the expected growth in demand for electricity could be cut in half by 2025, providing billions of dollars in customer savings, contributing to lower prices for natural gas, and substantially reducing greenhouse gas emissions."[105] Another study cites that increasing renewable energy generation to 20% could "reduce natural gas use by 6%, while saving consumers nearly $27 billion."[106] Geothermal, as a renewable technology, offers all of these benefits. In addition, geothermal's long-term, legally binding PPAs offset some of the volatility of other energy markets.

[102] Simms, Andrew (June 2004). *The price of power: Poverty, climate change, the coming energy crisis and the renewable revolution*. New Economics Foundation, isbn 1055254. *Retrieved September 28, 2006, from http://www.neweconomics.org/gen/uploads/3lskha55ejuveu45nvbftgmb18062004173646.pdf*.
[103] Ottinger, R L and M Jayne (2000) *Global climate change – Kyoto Protocol implementation: Legal frameworks for implementing clean energy solutions*, Pace University School of Law, White Plains, New York. Retrieved September 28, 2006, from http://www.solutions-site.org/special_reports/CleanEnergyFinal4.doc.
[104] EIA (2005). *Annual Energy Outlook 2005*. Retrieved March 16, 2006, from http://www.eia.doe.gov/oiaf/aeo/electricity.html.
[105] U.S. EPA. NREL (2004). *EPA-State Energy Efficiency and Renewable Energy Projects* Retrieved March 8, 2005, from http://www.epa.gov/cleanenergy/pdf/eere_factsheet.pdf.
[106] Retrieved March 14, 2006, from http://www.ucsusa.org/clean_energy/clean_energy_policies/renewable-energy-can-help-ease-natural-gas-crunch.html.

d) Investors' Perspective

Unfortunately, many investors tend to consider only the near term. They favor the electricity source—such as coal—that will require the lowest cost and risk upfront, without considering the higher costs associated with the fuel itself over the long term. With fossil fuel development, utility commissions usually permit the recovery of increased fuel costs through fuel-price adjustment clauses in power contracts, passing the increase in cost onto the consumer. Geothermal developers, on the other hand, bear all of the risks associated with fuel cost changes. This means that if costs increase, the developer loses money; if costs decrease, the developer makes money.

Investments in geothermal projects may take longer to recover because of exploration and drilling costs and risks, among other factors. The longer recovery time leads many lenders to invest in fossil fuel projects with smaller associated risks. While petroleum prospectors can usually get a full return on their investment in less than a year, geothermal prospectors can wait ten years or more for a full return on their investment.[107]

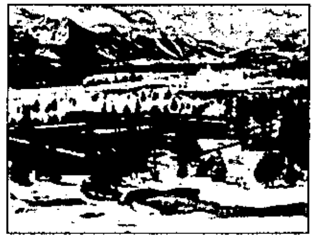
e) Addressing Shortages and Concerns Over Increasing Fossil Fuel Prices

Natural gas prices have soared recently, and our oil reserves are continually being depleted. In the mean time, our energy needs are increasing. The development of renewables, in conjunction with improved efficiency, provides one of the only solutions to our increasing energy needs that is both readily available and environmentally friendly. Drilling in Alaskan National Wildlife Refuge (ANWR), nuclear development, and new advanced coal facilities are examples of projects that will likely require 10 years or longer. Research into other energy sources such as fusion or hydrogen is not expected to provide any new energy in the near term. The good news is that many megawatts of geothermal potential, along with potential from other renewable sources, exist throughout the United States that are developable today.

[107] Hook, John W. (Nov/Dec 2005). *Geothermal Energy from the Cascades*. GRC Bulletin, pgs 263-265. Retrieved May 2, 2006, from http://www.geothermal.org/articles/Cascades.pdf.

IV. CASE STUDY: MAMMOTH PACIFIC POWER PLANT

Figure 15: View of Mammoth Pacific II



Source: Ormat

The following section offers a firsthand account of the development process for a geothermal power plant. It reveals what took place behind the scenes to bring a power plant online near a small, California community, as indicated by the people who were involved in that process—both within and outside the developing company. This case study documents one plant's transformation from one of the most hotly contested to one of the most locally and internationally appreciated power plants in the United States.

A. Setting

Travel guides advertise Mono County, California, as "a land of fire and ice" with "extraordinary features [that] attest to the region's active geologic past."[108] The largest city within Mono County, the Town of Mammoth Lakes, is a recreation area, where regular activities include skiing, mountain climbing, hiking, fishing, and is a land that one local described as Los Angeles' playground. At the time the Mammoth Pacific power plants were developed near the Town of Mammoth Lakes, the type of geothermal technology used[109] was relatively new and unexplored. The effects of such a plant, especially upon such a prime recreation area prized for its natural beauty, were uncertain.

[108] Official Website for Mammoth Lakes (2004). Retrieved October 7, 2005 from http://www.visitmammoth.com/areainfo/geology.html.

[109] At a *binary geothermal power plant*, the type developed at Mammoth, electricity is produced using lower temperature geothermal resources, at 100° C (212° F) to 165° C (330° F). In the binary process, the geothermal water heats another liquid that boils at a lower temperature than the geothermal water. The two liquids are kept completely separate through the use of heat exchangers used to transfer the heat energy from the geothermal water to the "working-fluid." The secondary fluid vaporizes into gaseous vapor and (like steam) the force of the expanding vapor turns the turbines that power the generators. The vapor is then condensed back to a liquid and reused over and over.

B. Plans for Development

The first unit at the Mammoth Pacific Complex, the 10-MW MP-I power plant that came online in 1984, was relatively unknown by constituents of Mono County. But the 1990 expansion, which added two 15 MW units to the Mammoth Pacific Complex, bringing the total capacity at the complex to 40 MW, met substantial public scrutiny. These two new facilities, one on private land, known as MP-II, and one on federal land (Inyo National Forest), known as PLES I, were proposed by Mammoth Pacific, L.P. (MPLP) as expansion projects.

C. Public Reaction and Company Response

Once plans for the expansion began, a full five years before permits were issued in 1989, people began voicing concerns related primarily to tourism and environmental impact. With guidance from Mono County Economic Development Director Dan Lyster, the county established the Long Valley Hydrologic Advisory Committee (LVHAC) in 1986 in response to those concerns. Members of LVHAC included regulatory agencies such as Mono County; the Bureau of Land Management (BLM) the U.S. Forest Service (USFS); California Dept. of Fish and Game; California Division of Oil, Gas, and Geothermal Resources; and Mammoth Community Water District; as well as the developer. The meetings were open to the public and were regularly attended by technical groups, representatives from USGS, and local organizations such as the Sierra Club.

At the same time that the LVHAC was formed, MPLP (through it managing partner, initially Pacific Energy and currently Ormat) responded to the concerns voiced by constituents. According to Claude Harvey, Pacific Energy's Senior Vice President in charge of geothermal at the time, without a timely and comprehensive response to peoples' concerns, the expansion would never have been permitted.

"When a project is going to be controversial, you've got to get in there and talk to the people directly," notes Harvey. "You've got to knock on doors, show up at town meetings, respond to letters in the local paper. Explain the benefits of a geothermal power plant and the benign nature of the plant. That's what we [Pacific Energy] did, and, if we hadn't done so, the plant simply would not have come online, because we wouldn't have had the necessary public support."

Dwight Carey, an environmental consultant who worked with MPLP during the expansion, notes that MPLP's efforts to integrate itself into the community have been ongoing, and continue to this day under the efforts of Bob Sullivan, plant manager: "MPLP has made it a point to be a true member of the community - making presentations, inviting tours, sponsoring community events - and generally making sure that people in the community at all levels (both in the economic and environmental community) know what is going on. As a result, the community trusts MPLP, and is not willing to immediately believe the worst if issues or concerns are brought up."

D. Permitting

Though the permitting process began in 1986, only after a five-year struggle to obtain permits was permission finally granted for construction. The MP-II expansion project, located on private land, was approved by Mono County with a "conditional use permit," a 22-page document that contained over 100 conditions that had to be met in order for the project to move forward. The PLES I project, located on public land managed by the Inyo National Forest, was approved with a similar extensive list of conditions. Each project was required to pay for its own detailed study (an Environmental Impact Report [EIR] for the MP-II project and an EIS for the PLES I project) that assessed all potential environmental impacts of each project and the potential cumulative impacts of all of the projects.

According to Lyster, these two projects were the most highly conditioned power plant projects in California, with a laundry list of water monitoring activities developed by LVHAC and required by the respective permits. Water monitoring activities, including quality, flow, and temperature monitoring of geothermal resource wells, hot and cold water springs, groundwater wells, and surface waters, were initially conducted by USGS, but subsequently some of those have been transferred to the power company. Additional permit conditions required transplanting pine trees, extensive revegetation of disturbed areas, archeological surveys and monitoring, and painting structures with specific colors approved by the agencies.

E. Construction

The expansion construction followed a breathtaking pace—the shortest amount of time Harvey had ever seen—so that the plants could reap the benefit of an investment tax credit. The company that designed the power plant, started by Harvey and Ben Holt, provided much of the financial backing for the project. Efficient, state-of-the art facilities were operating in December 1990, just a year after construction began. Today, 15 years later, the plants continue to produce power with few hydrologic impacts, and minimal emissions or aesthetic impacts.

Notes Harvey, "you'd never find a hotel that blended so well into this pristine environment." A hotel wouldn't contribute as much money to the economy, and it certainly wouldn't provide electricity to the grid, he adds.

MPLP took steps that showed their willingness to integrate into the community. For example, they paid special attention to preserving and adding to the bicycle paths, they utilized costly and efficient technology to minimize noise, and they ensured that roads were accessible in the wintertime.

Harvey, who, before his tenure with Pacific Energy had built many power plants—including coal, natural gas, and nuclear facilities—says that the Mammoth Plants "involved the longest, biggest, and most arduous permitting process" he's ever gone through. "I never got into [a project] as hot and controversial as Mammoth during my 40 years of experience, and that's ironic because the Mammoth plant was the most environmentally benign I've ever worked on."

Richard Campbell, one of the primary engineers for the units at Mammoth, helped design a power plant that is not only environmentally benign, but also unobtrusive. He and the company he worked for, Ben Holt Company, designed low-lying, camouflaged facilities that are difficult to spot even from a major highway overlooking the plant. The company also put silencers in place to limit noise.

Based on Campbell's design, the MP-I plant became the first of its kind to utilize air-cooled technology, rather than the water-cooled technology used by geothermal power plants before it. While water-cooled units emit generally harmless but noticeable steam plumes, air-cooled units have no visible emissions and minimal operating losses of geothermal fluid or gases. Besides reducing the aesthetic impact, air-cooled binary cycle technology requires no cooling water—a particularly important consideration in the Mammoth area where water availability is limited.

F. Results of Monitoring Activity

After years of monitoring, with the Mammoth power plants continually pumping at 12,500 gallons of hot water per minute, there have been few adverse impacts attributed to plant development. Even so, all monitoring efforts continue on a regular basis, and are made available once a quarter to any interested parties. With continued efficient management practices, the plant will likely stay online many years into the future.

Carey measures the success of the plant based on the minimal impact over the last 15 years of operations: "none of the dire predictions about the worst case impacts of the expansion projects came true. The projects aren't that visible; no adverse impacts to the hot springs in Hot Creek or the hatchery or the Owens tui chub have been documented; deer are grazing amongst the wells; no spills have adversely affected the creeks; and tourism is doing well." People slowly but surely began to realize that not only did the Mammoth Plants produce no negative impacts, it actually produced community benefits.

G. Economic Benefits

One such benefit is employment. Construction of the plant required a few hundred workers; current operation requires 21 full-time employees, with additional seasonal employees. The plants provide some of the best jobs in the Town of Mammoth Lakes, with a population of around 7,000. Both the original managing partner, Pacific Energy, and the current managing partner, Ormat Nevada, Inc., have made a commitment to hiring locally, with most full-time employees entering the geothermal field from a variety of backgrounds. Jobs histories of current Mammoth employees include positions as ski patrolmen, ex-miners, bartenders, and volunteer firemen. Ormat provides the

considerable training needed for these highly skilled positions, and workers are encouraged to stay with the company long term. Indeed, most of them do.

"A number of our employees have been with us for 20 years," says Sullivan. "I myself have been with the company for over almost 15 years."

Another benefit of the Mammoth Pacific geothermal plant is its low environmental impact. This type of plant produces minimal air emissions. A study showed that the pine trees surrounding the geothermal plants emit more greenhouse gases than the fugitive emissions from the power plants themselves. The effect on the deer population, which was one of the concerns of the California Department of Fish and Game when it sued Mono County to prevent the approval of the MP-II project, was found to be one half of one deer over the entire lifetime of the plant. Hawks have flocked to the area near the plants, and can be seen using the thermal currents to assist in soaring. In 1991, the California State Assembly passed a resolution commending the MPLP on the start-up of two of its geothermal power facilities in Mono County, recognizing its use of clean energy without "environmentally damaging emissions." In addition, for four consecutive years (2000-2004), MPLP received from the California Department of Conservation an award for its outstanding environmental record at its Mono County geothermal facilities.[110]

Another significant benefit has been the financial contributions of the power plant. MPLP has been designated a "good neighbor," by many locals, including Lyster, for making donations to local groups in the area. MPLP built a new community center from the proceeds of the power plants. According to Sullivan, MPLP is one of the largest taxpayers in the county, supplying over half a million dollars last year alone.

H. MP: A Success Story

The Mammoth Pacific Complex, which supplies power enough for approximately 40,000 homes, has provided many socioeconomic benefits. MPLP's involvement at all levels—including monitoring, individual responses to citizens' concerns, sponsorship of community events, funding of community centers, and construction of aesthetically pleasing facilities—demonstrates its commitment to Mono County. Despite initial challenges, MPLP has emerged as a true success story for the geothermal community.

[110] DOE EERE Geothermal Technologies Program (Update Jan 2005). *The Award-Winning Environmental Performance of Geothermal Power in California*. Retrieved October 14, 2005, from http://www.eere.energy.gov/geothermal/geopower_calif_awards.html.

Glossary[111]

Aquaculture:[112] farming of organisms that live in water, such as fish, shellfish, and algae.

Baseload Capacity: The generating equipment normally operated to serve loads on an around-the-clock basis.

Baseload Plant: A plant, usually housing high-efficiency steam-electric units, which is normally operated to take all or part of the minimum load of a system, and which consequently produces electricity at an essentially constant rate and runs continuously. These units are operated to maximize system mechanical and thermal efficiency and minimize system operating costs.

Baseload: The minimum amount of electric power delivered or required over a given period of time at a steady rate.

Binary-Cycle Plant: A geothermal electricity generating plant employing a closed-loop heat exchange system in which the heat of the geothermal fluid (the "primary fluid") is transferred to a lower-boiling-point fluid (the "secondary" or "working" fluid), which is thereby vaporized and used to drive a turbine/generator set.

Biomass: Energy resources derived from organic matter. These include wood, agricultural waste and other living-cell material that can be burned to produce heat energy. They also include algae, sewage and other organic substances that may be used to make energy through chemical processes.

Capability: The maximum load that a generating unit, generating station, or other electrical apparatus can carry under specified conditions for a given period of time without exceeding approved limits of temperature and stress.

Capacity Factor: a measure of the amount of real time during which a facility is used

Capacity: The amount of electric power delivered or required for which a generator, turbine, transformer, transmission circuit, station, or system is rated by the manufacturer.

Carbon Dioxide: A colorless, odorless, non-poisonous gas that is a normal part of the air. Carbon dioxide, also called CO_2, is exhaled by humans and animals and is absorbed by green growing things and by the sea.

Coal: A readily combustible black or brownish-black rock whose composition, including inherent moisture, consists of more than 50 percent by weight and more than 70 percent by volume of carbonaceous material. It is formed from plant remains that have been compacted, hardened, chemically altered, and metamorphosed by heat and pressure over geologic time.

Combined Cycle: An electric generating technology in which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. This process increases the efficiency of the electric generating unit.

Condensate: Water formed by condensation of steam.

Consumption (Fuel): The amount of fuel used for gross generation, providing standby service, start-up and/or flame stabilization.

Cooling tower: A cooling tower is the structure associated with water-cooled heat extraction systems. Hot water is spayed from the top of the structure and cascades against an upwards airflow that cools the water (mainly through evaporation).

Cost: The amount paid to acquire resources, such as plant and equipment, fuel, or labor services.

Crust: Earth's outer layer of rock. Also called the lithosphere.

Debt: An amount owed to a person or organization for funds borrowed. Debt can be represented by a loan note, bond, mortgage or other form stating repayment terms and, if applicable, interest requirements. These different forms all imply intent to pay back an amount owed by a specific date, which is set forth in the repayment terms.

Demand (Electric): The rate at which electric energy is delivered to or by a system, part of a system, or piece of equipment, at a given instant or averaged over any designated period of time.

Demand (Utility): The level at which electricity or natural gas is delivered to users at a given point in time. Electric demand is expressed in kilowatts.

Direct impacts: All expenditures associated with construction and maintenance of geothermal power plants. During the construction phase, it corresponds to the total investment associated with the power plant construction. During the operation and maintenance phase, it relates to all expenditures in goods and services associated with power plant operation and maintenance.

Direct Use: Use of geothermal heat without first converting it to electricity, such as for space heating and cooling, food preparation, industrial processes, etc.

Dispatch: The operating control of an integrated electric system to: Assign generation to specific generating plants and other sources of supply to effect the most reliable and economical supply as the total of the significant area loads rises or falls. Control operations and maintenance of high-voltage lines, substations and equipment, including administration of safety procedures. Operate the interconnection. Schedule energy transactions with other interconnected electric utilities.

Distribution: The delivery of electricity to retail customers (including homes, businesses, etc.).

[111] All terms from Energy Information Administration [EIA] (2002) *Glossary of Electricity Terms*, Retrieved August 1, 2006, from http://www.eia.doe.gov/cneaf/electricity/epav1/glossary.html; California Energy Commission [CEC] (2004), *Glossary of Energy Terms*, Retrieved August 1, 2006, from http://www.energy.ca.gov/glossary/; U.S. DOE Energy Efficiency and Renewable Energy Geothermal Technologies Program. *Geothermal Glossary*. Retrieved August 1, 2006, from http://www.eere.energy.gov/geothermal/glossary.html; from Hance (2005) (see footnote #5); or from the *Investing Glossary* accessible at www.investorwords.com unless otherwise noted.
[112] Source: USGS

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Drilling: Boring into the Earth to access geothermal resources, usually with oil and gas drilling equipment that has been modified to meet geothermal requirements.

Dry Steam: Very hot steam that doesn't occur with liquid.

Economics: The study of how the forces of supply and demand allocate scarce resources. Subdivided into microeconomics, which examines the behavior of firms, consumers and the role of government; and macroeconomics, which looks at inflation, unemployment, industrial production, and the role of government.

Economy of scale: Reduction in cost per unit resulting from increased production, realized through operational efficiencies. Economies of scale can be accomplished because as production increases, the cost of producing each additional unit falls.

Electric Plant (Physical): A facility containing prime movers, electric generators, and auxiliary equipment for converting mechanical, chemical, and/or fission energy into electric energy.

Electric Utility: A corporation, person, agency, authority, or other legal entity or instrumentality that owns and/or operates facilities within the United States, its territories, or Puerto Rico for the generation, transmission, distribution, or sale of electric energy primarily for use by the public and files forms listed in the Code of Federal Regulations, Title 18, Part 141. Facilities that qualify as cogenerators or small power producers under the Public Utility Regulatory Policies Act (PURPA) are not considered electric utilities.

Emissions Standard: The maximum amount of a pollutant legally permitted to be discharged from a single source.

Energy Policy Act 2005 (EPAct): (Public Law 109-58) is a statute which was passed by the United States Congress on July 29, 2005 and signed into law on August 8, 2005 at Sandia National Laboratories in Albuquerque, New Mexico. The Act, described by proponents as an attempt to combat growing energy problems, provides tax incentives and loan guarantees for energy production of various types.

Energy Source: The primary source that provides the power that is converted to electricity through chemical, mechanical, or other means. Energy sources include coal, petroleum and petroleum products, gas, water, uranium, wind, sunlight, geothermal, and other sources.

Energy: The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. Electrical energy is usually measured in kilowatthours, while heat energy is usually measured in British thermal units.

Environmental Impact Study: A document required by federal and state laws to accompany proposals for projects and programs that may have an impact on the surrounding area.
equity: Ownership interest in a corporation in the form of common stock or preferred stock. It is the risk-bearing part of the company's capital and contrasts with debt capital which is usually

secured and has priority over shareholders if the company becomes insolvent and its assets are distributed.

Facility: An existing or planned location or site at which prime movers, electric generators, and/or equipment for converting mechanical, chemical, and/or nuclear energy into electric energy are situated, or will be situated. A facility may contain more than one generator of either the same or different prime mover type. For a cogenerator, the facility includes the industrial or commercial process.

Flash Steam: Steam produced when the pressure on a geothermal liquid is reduced. Also called flashing.

Fossil Fuel: Any naturally occurring organic fuel, such as petroleum, coal, and natural gas.

Fossil-Fuel Plant: A plant using coal, petroleum, or gas as its source of energy.

Fuel: Any substance that can be burned to produce heat; also, materials that can be fissioned in a chain reaction to produce heat.

Generating Unit: Any combination of physically connected generator(s), reactor(s), boiler(s), combustion turbine(s), or other prime mover(s) operated together to produce electric power.

Generation (Electricity): The process of producing electric energy by transforming other forms of energy; also, the amount of electric energy produced, expressed in watthours (Wh).

Geology: Study of the planet Earth, its composition, structure, natural processes, and history.

Geophysical survey: Geophysical methodologies used during the exploration and drilling phases to locate the resource and identify the best suited sites to drill production wells. These may include gravity surveys, ground magnetic surveys, magnetotelluric surveys, electrical resistivity surveys, and seismic surveys.

Geothermal: Of or relating to the Earth's interior heat.

Geothermal Energy: Natural heat from within the Earth, captured for production of electric power, space heating or industrial steam.

Geothermal Heat Pumps: Devices that take advantage of the relatively constant temperature of the Earth's interior, using it as a source and sink of heat for both heating and cooling. When cooling, heat is extracted from the space and dissipated into the Earth; when heating, heat is extracted from the Earth and pumped into the space.

Geothermal Plant: A plant in which the prime mover is a steam turbine. The turbine is driven either by steam produced from hot water or by natural steam that derives its energy from heat found in rocks or fluids at various depths beneath the surface of the Earth. The energy is extracted by drilling and/or pumping.

Geothermal Steam: Steam drawn from deep within the Earth.

Geyser: A spring that shoots jets of hot water and steam into the air.

Geysers, The (note: "The" of "The Geysers" is always capitalized): A large geothermal steam field located north of San Francisco.

Greenfield project: A greenfield project (as opposed to a project expansion) is a project that is developed on a resource (area) that is not used by an existing power plant.

Greenhouse Effect: The increasing mean global surface temperature of the Earth caused by gases in the atmosphere (including carbon dioxide, methane, nitrous oxide, ozone, and chlorofluorocarbon). The greenhouse effect allows solar radiation to penetrate but absorbs the infrared radiation returning to space.

Grid: The layout of an electrical distribution system.

Gross Generation: The total amount of electric energy produced by the generating units at a generating station or stations, measured at the generator terminals.

Heat Exchanger: A device for transferring thermal energy from one fluid to another.

Heat Pumps: *See Geothermal Heat Pumps*

Hot Dry Rock: A geothermal resource created when impermeable, subsurface rock structures, typically granite rock 15,000 feet or more below the Earth's surface, are heated by geothermal energy. The resource is being investigated as a source of energy production.

Hydroelectric Plant: A plant in which the turbine generators are driven by falling water.

Independent Power Producers: Entities that are considered nonutility power producers in the United States. These facilities are wholesale electricity producers that operate within the franchised service territories of host utilities and are usually authorized to sell at market-based rates. Unlike traditional electric utilities, Independent Power Producers do not possess transmission

Indirect impacts: This correspond to the economic impact that affects all industries that provides goods and services to the industries directly involved in power plant construction or operation and maintenance. Indirect impacts thus quantify the impact of changes in power plant construction or O&M activities on the industries that supplies it.

Induced impacts: Industries that experience both direct and indirect impacts will often change their employment levels to meet the new level of demand. These employment changes induce changes in income that are spent in the region to purchase goods and services. This income effect is the source of induced impacts. Induced impacts leads to further rounds of indirect and induced impacts as the increased demand for goods and services purchased by workers leads to further increases in output in other industries.

Injection well: Injection wells inject the brine back into the reservoir after using it in the power production process.

Injection: The process of returning spent geothermal fluids to the subsurface. Sometimes referred to as reinjection.

Kilowatt (kW): One thousand watts.

Kilowatthour (kWh): One thousand watthours.

Known Geothermal Resource Area (KGRA): A region identified by the U.S. Geological Survey as containing geothermal resources.

Lead-time: The amount of time between the placing of an order and the receipt of the goods ordered.

Lease: A contract between a lessor and a lessee for the use of a vehicle or other property, subject to stated terms and limitations, for a specified period and at a specified payment.[111]

Levelized cost: The present value of the total cost of building and operating a generating plant over its economic life, converted to equal annual payments. Costs are levelized in real dollars (i.e., adjusted to remove the impact of inflation).

Lithologies: properties of a rock formation

Load (Electric): The amount of electric power delivered or required at any specific point or points on a system. The requirement originates at the energy-consuming equipment of the consumers.

Magma: The molten rock and elements that lie below the Earth's crust. The heat energy can approach 1,000 degrees Fahrenheit and is generated directly from a shallow molten magma resource and stored in adjacent rock structures. To extract energy from magma resources requires drilling near or directly into a magma chamber and circulating water down the well in a convection- type system. California has two areas that may be magma resource sites: the Mono-Long Valley Caldera and Coso Hot Springs Known Geothermal Resource Areas.

Mantle: The Earth's inner layer of molten rock, lying beneath the Earth's crust and above the Earth's core of liquid iron and nickel.

Megawatt (MW): One million watts.

megawatt hour (MWh): One million watthours.

Mitigation: Structural and non-structural measures undertaken to limit the adverse impact of natural hazards, environmental degradation and technological hazards

Municipal utility: Water or electric company over which the State Department of Public Utility Control does not have jurisdiction to regulate.

[111] Federal Reserve. *Glossary of Terms*. Retrieved August 1, 2006, from www.federalreserve.gov/pubs/leasing/glossary.htm.

Natural Gas Combined-Cycle: plants that generate electricity using two methods, the steam cycle and the gas cycle. In the steam cycle, fuel is burned to boil water and create steam which turns a steam turbine driving a generator to create electricity. In the gas cycle, gas is burned in a gas turbine which directly turns a generator to create electricity. Combined cycle power plants operate by combining the gas cycle and the steam cycle for higher efficiency.

Natural Gas: A naturally occurring mixture of hydrocarbon and nonhydrocarbon gases found in porous geological formations beneath the earth's surface, often in association with petroleum. The principal constituent is methane.

Net Capability: The maximum load-carrying ability of the equipment, exclusive of station use, under specified conditions for a given time interval, independent of the characteristics of the load. (Capability is determined by design characteristics, physical conditions, adequacy of prime mover, energy supply, and operating limitations such as cooling and circulating water supply and temperature, headwater and tailwater elevations, and electrical use.)

Net Generation: Gross generation less the electric energy consumed at the generating station for station use.

Nitrogen oxides (NOx): Oxides of nitrogen that are a chief component of air pollution that can be produced by the burning of fossil fuels. Also called nitrogen oxides.

Non-specular conductors: conductors treated to reduce the amount of light reflected, usually by dipping the conductor in an acid bath that takes the shine off thereby reducing visibility.

Nuclear Energy: Power obtained by splitting heavy atoms (fission) or joining light atoms (fusion). A nuclear energy plant uses a controlled atomic chain reaction to produce heat. The heat is used to make steam run conventional turbine generators.

Nuclear Power Plant: A facility in which heat produced in a reactor by the fissioning of nuclear fuel is used to drive a steam turbine.

Open-Loop Biomass: [114] any agricultural livestock waste nutrients; or, any solid, nonhazardous, cellulosic or lignin waste material or by product of wood
or paper mill operations, including lignin in pulping liquors, which is derived from

Outage: The period during which a generating unit, transmission line, or other facility is out of service.

Particulate Matter (PM): Unburned fuel particles that form smoke or soot and stick to lung tissue when inhaled. A chief component of exhaust emissions from heavy-duty diesel engines

Peak Demand: The maximum load during a specified period of time.

[114] American Forest & Paper Association (August 2005). *Senate Corrections Comments*. Retrieved August 1, 2006, from http://www.senate.gov/~finance/Technical%20Correction%2005/Comments%20on%20Tax%20Technical%20Corrections-%20Finance.pdf.

Peaking Capacity: Capacity of generating equipment normally reserved for operation during the hours of highest daily, weekly, or seasonal loads. Some generating equipment may be operated at certain times as peaking capacity and at other times to serve loads on an around-the-clock basis.

Permeability: The relative ease with which a porous medium can transmit a liquid under a hydraulic gradient. In hydrology, the capacity of rock, soil, or sediment to allow the passage of water.

Plant: A facility at which are located prime movers, electric generators, and auxiliary equipment for converting mechanical, chemical, and/or nuclear energy into electric energy. A plant may contain more than one type of prime mover. Electric utility plants exclude facilities that satisfy the definition of a qualifying facility under the Public Utility Regulatory Policies Act of 1978.

Pollution: Unwanted particles, mist or gases put into the atmosphere as a result of motor vehicle exhaust, the operation of industrial facilities or other human activity.
power purchase agreement: The off-take contract from a large customer to buy the electricity generated by a power plant.

Power: The rate at which energy is transferred. Electrical energy is usually measured in watts. Also used for a measurement of capacity.

Price: The amount of money or consideration-in-kind for which a service is bought, sold, or offered for sale.

Production well: A production well is a well drilled through a geothermal resource that produces geothermal brine.

Profit: The income remaining after all business expenses are paid.

Qualifying Facility (QF): A cogeneration or small power production facility that meets certain ownership, operating, and efficiency criteria established by the Federal Energy Regulatory Commission (FERC) pursuant to the Public Utility Regulatory Policies Act (PURPA).

Rate of return: The annual rate of return on an investment, expressed as a percentage of the total amount invested. also called return

Reconnaissance:[115] A method of gathering data, often associated with surface surveys, in which archaeological remains are systematically identified and plotted on a map.

Regulation: The governmental function of controlling or directing economic entities through the process of rulemaking and adjudication.

Reliability: Electric system reliability has two components--adequacy and security. Adequacy is the ability of the electric system to supply to aggregate electrical demand and energy requirements of the customers at all times, taking into account scheduled and unscheduled outages of system facilities. Security is the ability of the electric system to withstand sudden disturbances, such as electric short circuits or unanticipated loss of system facilities. The degree

[115] Archeological Institute of America (2006). *Glossary*. Retrieved August 1, 2006, from http://www.archaeological.org/webinfo.php?page=10299.

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of reliability may be measured by the frequency, duration, and magnitude of adverse effects on consumer services.

Renewable energy: Resources that constantly renew themselves or that are regarded as practically inexhaustible. These include solar, wind, geothermal, hydro and wood. Although particular geothermal formations can be depleted, the natural heat in the earth is a virtually inexhaustible reserve of potential energy. Renewable resources also include some experimental or less-developed sources such as tidal power, sea currents and ocean thermal gradients.

Renewable Resources: Naturally, but flow-limited resources that can be replenished. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Some (such as geothermal and biomass) may be stock-limited in that stocks are depleted by use, but on a time scale of decades, or perhaps centuries, they can probably be replenished. Renewable energy resources include: biomass, hydro, geothermal, solar and wind. In the future, they could also include the use of ocean thermal, wave, and tidal action technologies. Utility renewable resource applications include bulk electricity generation, on-site electricity generation, distributed electricity generation, non-grid-connected generation, and demand-reduction (energy efficiency) technologies.

Reservoir: A natural underground container of liquids, such as water or steam (or, in the petroleum context, oil or gas).

Revegetation:[116] Regrowing native plants, mainly trees and shrubs, by active restoration, natural process restoration, or both.

Revenue: The total amount of money received by a firm from sales of its products and/or services, gains from the sales or exchange of assets, interest and dividends earned on investments, and other increases in the owner's equity except those arising from capital adjustments.

Royalty: A payment made for the use of property, especially a patent, copyrighted work, franchise, or natural resource. The amount is usually a percentage of revenues obtained through its use.

Sales: The amount of kilowatthours sold in a given period of time; usually grouped by classes of service, such as residential, commercial, industrial, and other. Other sales include public street and highway lighting, other sales to public authorities and railways, and interdepartmental sales.

Slim-hole: Slim-holes are small diameter wells drilled during the exploration phase in order to verify the existence of a productive geothermal resource and provide information about the geologic structure of the site. Such holes are sometimes preferred to "full-diameter production wells" since they are significantly less expensive.

Socioeconomics:[117] Research into the effects of both social and economic factors on individuals and communities. Socioeconomics begins with the assumption that economics is not a self-contained system, but is embedded in society, polity, and culture.

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[116] The Nature Conservancy. Retrieved August 1, 2006, from www.tnccalifornia.org/glossary/.
[117] Harvard University (http://www.researchmatters.harvard.edu/topic.php?topic_id=260) and Society for the Advancement of Socio-Economics (SASE)

Solar Energy: Heat and light radiated from the sun.

Stability: The property of a system or element by virtue of which its output will ultimately attain a steady state. The amount of power that can be transferred from one machine to another following a disturbance. The stability of a power system is its ability to develop restoring forces equal to or greater than the disturbing forces so as to maintain a state of equilibrium.

Standby Service: Support service that is available, as needed, to supplement a consumer, a utility system, or to another utility if a schedule or an agreement authorizes the transaction. The service is not regularly used.

Subsidence: A sinking of an area of the Earth's crust due to fluid withdrawal and pressure decline

Sulfur oxides: Compounds containing sulfur and oxygen, such as sulfur dioxide (SO2) and sulfur trioxide (SO3).

Sustainablility:[118] Economic development that takes full account of the environmental consequences of economic activity and is based on the use of resources that can be replaced or renewed and therefore are not depleted.

System (Electric): Physically connected generation, transmission, and distribution facilities operated as an integrated unit under one central management, or operating supervision.

Temperature gradient hole: A temperature gradient hole is a relatively slim and shallow hole (50-600 feet deep) that aims to estimate the rate of increase of ground temperature with depth.

Transmission System (Electric): An interconnected group of electric transmission lines and associated equipment for moving or transferring electric energy in bulk between points of supply and points at which it is transformed for delivery over the distribution system lines to consumers, or is delivered to other electric systems.

Transmission: The movement or transfer of electric energy over an interconnected group of lines and associated equipment between points of supply and points at which it is transformed for delivery to consumers, or is delivered to other electric systems. Transmission is considered to end when the energy is transformed for distribution to the consumer.

Turbine: A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two.

Utility: A regulated entity which exhibits the characteristics of a natural monopoly. For the purposes of electric industry restructuring, "utility" refers to the regulated, vertically-integrated electric company. "Transmission utility" refers to the regulated owner/operator of the transmission system only. "Distribution utility" refers to the regulated owner/operator of the distribution system which serves retail customers.

(http://www.sase.org/index.php?option=com_content&task=blogsection&id=5&Itemid=43). Retrieved August 1, 2006, 2006.
[118] USGS. *Glossary*. Retrieved August 1, 2006, from http://biology.usgs.gov/s+t/SNT/noframe/zy198.htm.

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Watt: The electrical unit of power. The rate of energy transfer equivalent to 1 ampere flowing under a pressure of 1 volt at unity power factor.

Watthour (Wh): An electrical energy unit of measure equal to 1 watt of power supplied to, or taken from, an electric circuit steadily for 1 hour.

Index

Strategic Information for the Climate Change Industry

CLIMATE CHANGE BUSINESS JOURNAL®

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Global Geothermal Industry Balances Short-Term Development With Long-Term Investment in EGS

If the Low-Carbon & Renewable Power segment of the Climate Change Industry were a baseball team, geothermal energy would be the underrated veteran shortstop who doesn't hit many homers but fields consistently, rarely strikes out and scores runs on a regular basis. Let the stars like wind turbines and solar photovoltaic (PV) panels get the headlines; let the sports writers pump up the egos of rookies like thin-film PV, cellulosic biofuels and solar thermal power. Geothermal will be there to rack up solid stats and deliver for the team and the fans year after year.

Geothermal power's workmanlike quality stems from the fact that it offers something that wind and solar cannot provide: reliable baseload power that can be counted on to deliver megawatt-hours 24 hours a day, 365 days a year. In fact, for a utility or regional transmission organization, a geothermal power plant shows up on a resource plan grid like a conventional power plant.

In a broad context there are really three ways to look at geothermal energy:

1) Traditional steam-generated electricity generation, or hydrothermal, as it is often known, is site-dependent and has rather limited potential of perhaps 30,000 MW in the United States;

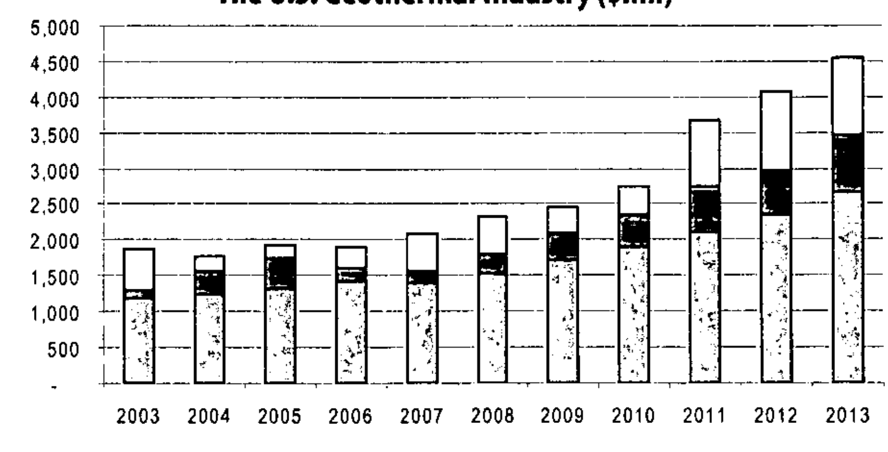
2) Enhanced geothermal systems (EGS) allow electricity generation from hot dry rock, thus opening up the map and the potential for geothermal power. But it is still early stages for EGS; and

3) Direct use geothermal encompasses space heating, hot water, process heat, pools, greenhouses and aquaculture. Direct use is exploited in more countries than electricity generation (see box on page 5), but CCBJ classifies it as an energy efficiency application in that it replaces conventional sources of energy. The main growth in direct use during the last decade has been geothermal or ground-source heat pumps for space heating.

The Geothermal Energy Industry

Geothermal energy was a $6.8 billion global industry in 2008, generating 66,000 GWh of electricity worth close to $4.8 billion, $1.1 billion in equipment sales and $900 million in service revenues. The United States market is the world's largest at $2.3 billion, and forecasts are for high growth as a strong pipeline of projects are developed in the next few years when carbon regulations are expected to drive a subsequent wave of growth.

The U.S. Geothermal Industry ($mil)



Source: Climate Change Business Journal from a market model dervied from a variety of sources including Geothermal Energy Assn., International Geothermal Assn., Emerging Energy Research, New Energy Finance and company, government and academic sources. Services include exploration & resource assessment, well field drilling & development, plant design & construction.

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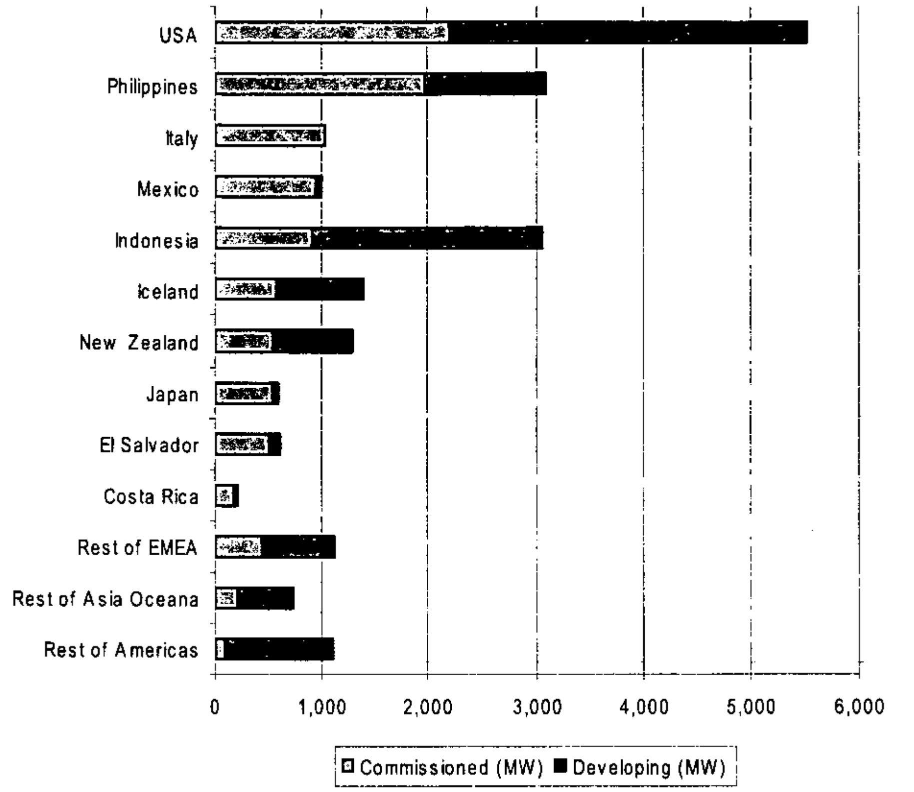
Global Geothermal Capacity and Development Pipeline (MW)



Source: New Energy Finance, Mark Taylor presentation, April 2009. Commissioned total is 10,162 MW in 2009 with 10,663 MW in development. EMEA is Europe, Middle East and Africa

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Hence the focus of this review on electricity generation and its tie in with the power sector. Geothermal electricity "bridges both the conventional feedstock and renewable energy options for electric power generation rather uniquely," wrote **Deloitte** in a February 2008 report for the **U.S. Department of Energy (DOE)**. Geothermal's baseload characteristics allow "it to compete with other baseload feedstocks such as coal, natural gas and nuclear. At the same time, geothermal energy is a clean, renewable resource that competes with other renewable energy options such as wind and solar [making] it an attractive option for reliable and scalable generation while satisfying renewable energy voluntary or mandatory portfolio standards."

Yet, geothermal both in the United States and the rest of the world is not being deployed at a particularly brisk pace. At the end of 2008, cumulative worldwide installed capacity was between 9,900 and 10,500 MW, including 2,200 MW in operating capacity in the United States, according to estimates from **New Energy Finance** (NEF) and **Emerging Energy Research**. (Some 400-500 MW of capacity at the 1,400-MW Geysers project in California is on standby.)

Globally the pipeline of hydrothermal electricity projects currently in development exceeds the installed capacity by about 500 MW (see chart on page 2). The United States, Indonesia, the Philippines, Iceland and New Zealand account for 77% of the 10.7-MW pipeline, according to NEF estimates as of April 2009.

How Geothermal Stacks Up Against Other Renewables

Not only is geothermal's 10,000 MW in current global capacity easily less than 10% of the comparable capacity figure for wind power (121 GW worldwide) and less than two thirds of solar PV's installed capacity (15 GW), but geothermal electricity generation represents a comparatively anemic growth rate. At the end of 2003, global geothermal capacity was at 8,400 MW, meaning average annual growth from 2003-2008 was about 3.4%. Not bad if you're in the soup business, but in the clean energy business that kind of growth doesn't generate much excitement. By contrast, PV's 5.95-GW jump in 2008 as tallied by **SolarBuzz** represented one year growth of 110%. Wind power's leap forward in 2008 as tallied by the **Global Wind Energy Council** was 29%.

Even with the recent growth in wind and solar, renewable sources remain fairly insignificant in the 19 million GWh global electricity picture. In terms of electricity production, however, geothermal's superior capacity factor makes its contribution to global electricity generation more substantial than solar and close to half that of wind—at least in 2006, the most recent year for which the International Energy Agency publishes data. According to the IEA, geothermal electricity accounted for 59,200 GWh or 0.31% of global electricity generated, with wind at 0.7% and solar 0.2% in the same year. Coal (41%), gas (20%), hydro (16%), nuclear (15%) and oil (6%) made up 98% in 2006, according to IEA. Of course, lumping geothermal with the other renewables does de-emphasize its higher capacity factor (see table at right) and predictable baseload contribution valued by utilities.

As a business segment, CCBJ estimates the U.S. geothermal industry accounted for $2.3 billion in revenues in 2008, or 34% of the $6.8 billion global total. The $7 billion figure for the global geothermal industry compares to $56 billion for wind and $28 billion for solar (See dedicated CCBJ editions from 2008).

CCBJ defines the geothermal industry in three subsegments: electricity generation; equipment sales; and services. The latter includes exploration & resource assessment, well field drilling & development and plant design & construction. Electricity represents about 70% of the global total, but the ramping up of growth until the 2008 financial meltdown had corresponding investments in site evaluation, drilling, etc. that tilted the share of revenues more to services in growing mar-

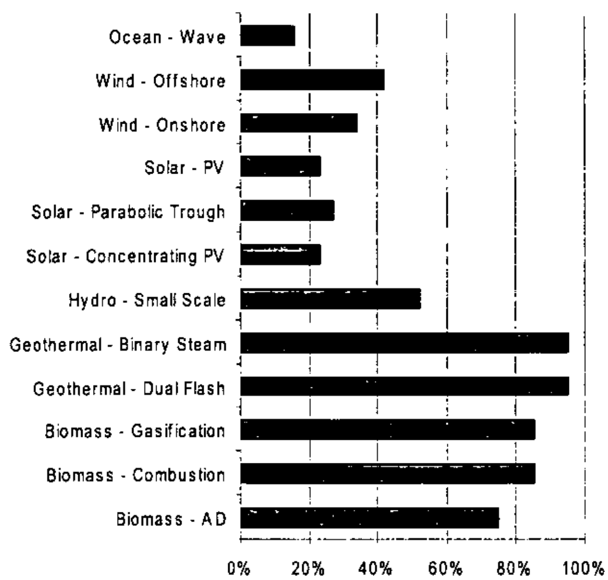
Typical Market Drivers for Renewable Energy

Driver	Developed markets	Emerging markets
Power prices	+	++
Demand growth	++	+++
Reliance on energy imports	+++	++++
Environment	++++	+

Note: Each + indicates relative importance of market driver; Drivers are the same worldwide, but priorities vary.

Source: Ormat Technologies, Inc., presentation by Rahm Orenstein at Greenpower Conferences' March 2009 Geothermal Innovation and Investment conference

Capacity Factors for Selected Renewables (Average Net Capacity %)



Source: Presentation by Raser Technologies
Original Source: Glitner Geothermal Report, September 2007

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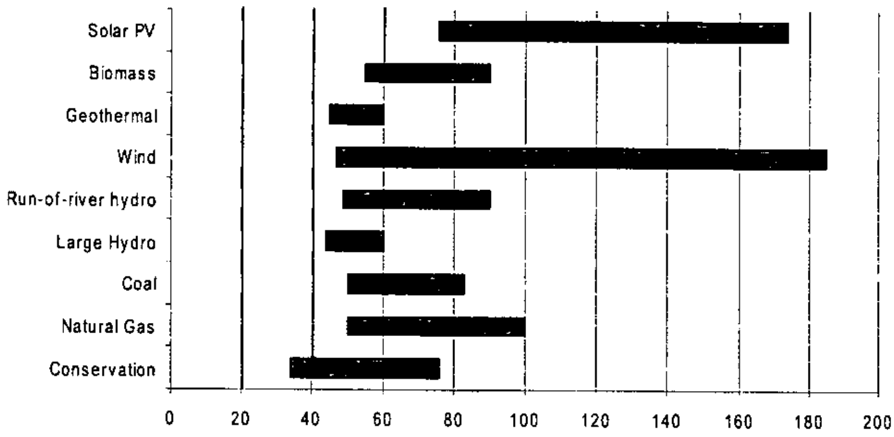
Levelized Costs: Generation Cost Range ($/MWh)



Source: Pathway to Accelerated Commercialization by Raser Technologies. Original Source: B.C. Hydro - Challenges & Choices (2006); Jacob & Company Securities estimates. Levelized cost is the present value of the total cost of building and operating a generating plant over its economic life, converted to equal annual payments.

kets, the U.S. included. CCBJ forecasts indicate that following a delay resulting from the freezing of credit and financing, the geothermal market will resume a growth trajectory and reach $5 billion in the U.S. and $16 billion globally by 2014.

Revenues available to specialist consulting & engineering firms could arguably be the total service amounts of roughly $1 billion globally the past few years, with a jump to $2-3 billion provided nothing further curtails the current pipeline or forecasted growth trajectory. A significant portion of these revenues, however, would be drilling or construction, meaning pure C&E project revenue would likely be closer to half these figures.

According to a variety of analysts and CCBJ interviews with industry leaders and experts, the growth of geothermal has historically been hampered by several constraints and challenges. In the first place, without a technological revolution like that promised by enhanced geothermal systems (EGS, also known as hot dry rock technology; see EGS/HDR feature on pages 29-31), geothermal power can only be developed in countries with suitable underground geothermal resources. Most geothermal resources are located along the seismically active Ring of Fire that roughly follows the coasts of the Pacific Ocean. Other resource areas include Eastern China and the Himalayan Belt, the Caribbean, Iceland, The Azores, Canary Islands, Italy, parts of Northern and Eastern Europe, the Eastern and Southern Mediterranean and Kenya, Tanzania and other countries is the East Africa Rift zone.

Investors prefer to buy geothermal companies or their operating power plants rather than invest in new projects.

In the second place, geothermal development is to a certain degree a speculative enterprise. Like wildcatters in the oil industry, geothermal developers must spend millions of dollars drilling for underground resources that they're not sure are present—or present in the quantities that will lead to their expected return on investment. "Geothermal projects have distinctly different challenges than other, more traditional, renewable technologies such as wind, solar, and biomass," notes the DOE's office of **Energy Efficiency and Renewable Energy (EERE)** in its *Geothermal Tomorrow* report. "Geothermal projects require subsurface exploration and well field development and have greater upfront risk because the geothermal resource is not confirmed without drilling."

Geothermal developers at **Greenpower Conferences'** March 2009 Geothermal Innovation and Investment conference in San Francisco said that typically 20% to 30% of the wells they drill—wells costing from $1.5 million to $10 million—end up hitting "dryholes." While not always physically dry, these dryholes are of sub-commercial enthalpy (heat energy). Compounding this dryhole risk is the fact that in the United States and some other regions, many of the best and most easily accessible geothermal resources—those with surface expressions like hot springs and fumaroles—have already been developed. To tap undeveloped resources for new power plants, developers must take on more risk in their drilling and development efforts.

As described in the developers roundtable article that follows this overview on page 9, as recently as the summer of 2008 developers could obtain debt financing to finance some of this resource and wellfield development work. Today the pendulum has swung the other way. Those lenders willing to finance geothermal projects require that developers sink wells and have proven resources—"steam behind the pipe" as they call it—before they will finance power plant construction. Separately with the depressed market caps of publicly held geothermal developers, private equity funders would rather buy companies or their assets than invest in new projects. Financial institutions in the market for tax credits are few and far between. And except for companies with a technology play in the emerging EGS segment, venture capitalists aren't interested in geothermal companies because of the lack of upside potential.

In this difficult environment, geothermal developers are urging the U.S.

Geothermal Energy: Opportunity and Challenge

Advantages from Utility Perspective

- Firm 24x7, not an intermittent resource
- Competitive cost
- Small physical footprint with minimal environmental impact
- 20-40 MW size does not require EHV transmission
- Credibility from years of success
- Recognized as a well-established industry

Some Development Challenges

- Financing uncertainty & heightened risk aversion
- Resource uncertainty
- Consolidating site control
- Prospecting/drilling cost on front-end
- Permitting
- Long lead-time
- Supply curve: progression to lower quality prospects

Challenges for Utilities

- Increasing RPS requirements puts pressure on utilities to turn to big projects
- Greenfield project failure an issue
- Uncertainties regarding amount, timing, and cost at odds with competitive resource procurement
- Operating plant/resource performance predictability an issue
- Few players in geothermal industry have the financial strength to go the distance

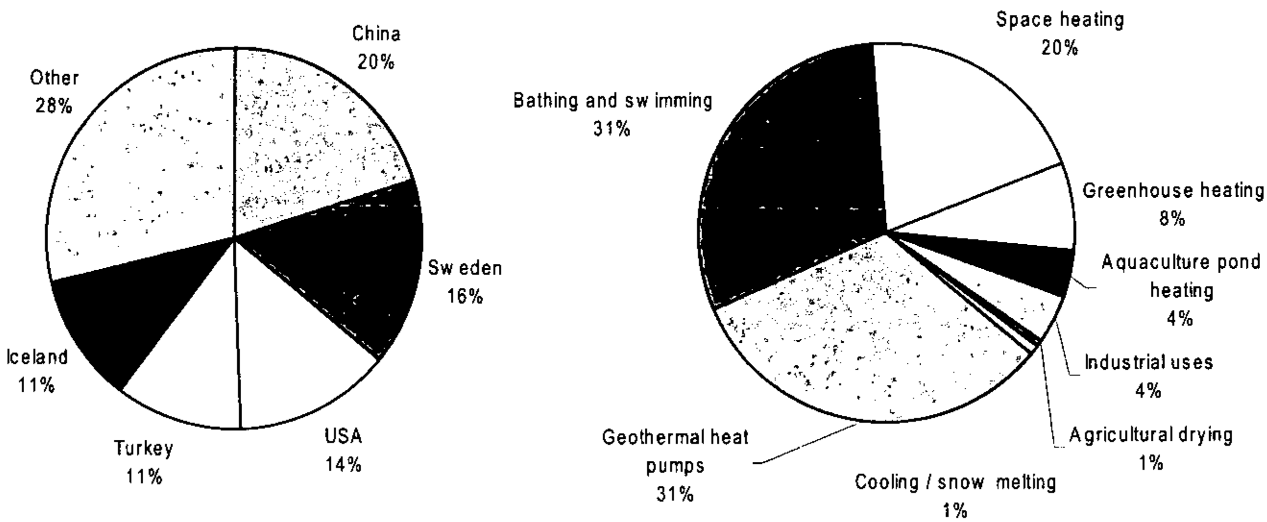
Source: NV Energy, March 2009 presentation by Thomas R. Fair, Vice President Renewable Energy

Direct Use Geothermal and Impacts on Climate Change

Electricity is produced from geothermal sources in 24 countries. Direct application of geothermal energy has been reported by 72 countries. In 2005, the worldwide use of geothermal energy was 57 TWh/yr of electricity and direct use was 76 TWh/yr, as reported by the **Intergovernmental Panel on Climate Change** (IPCC), a scientific intergovernmental body set up by the World Meteorological Organization and by the United Nations Environment Programme. Six developing countries are in the top 15 countries in direct use, with China at the top of the list. Direct use utilizes low-enthalphy geothermal fields that don't produce hot water at temperatures sufficient to generate power. While many firms engaged in geothermal electricity also work on direct-use projects, the segment is more driven by utilities, governments or companies using the heat directly. (Note: IPCC has released forecasts for geothermal electricity with global capacity reaching 24 GW in 2020, 46 GW in 2030, 90 GW in 2040 and 140 GW in 2050)

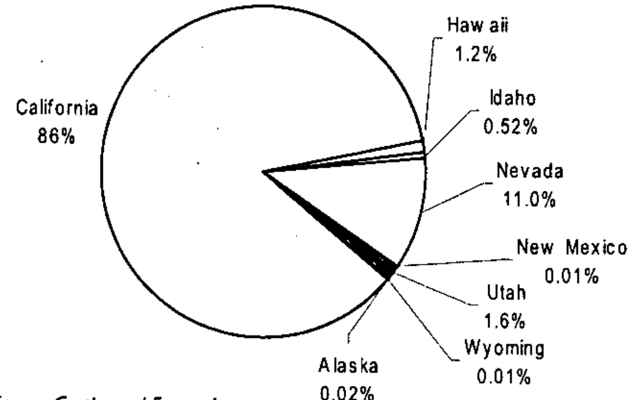
Direct Use Applications: Direct applications of geothermal energy are for space heating 52%, hot water (bathing and swimming) 30%, horticulture (greenhouses and soil heating) 8%, industry 4%, and aquaculture (mainly fish farming) 4%, according to John Lund in his paper *World-Wide Direct Uses of Geothermal Energy 2005.* Ground-source heat pumps are growing due to their ability to utilise groundwater or ground-coupled temperatures. According to IPCC, scenarios for future development show only a moderate increase in traditional direct use applications, but an exponential increase in heat pumps, as geothermal heat pumps can be used for heating and/or cooling in most parts of the world. In addition, geothermal heat pumps driven by fossil-fuel electricity reduce CO2 emissions by at least 50% compared with fossil-fuel fired boilers. If the electricity that drives the geothermal heat pump is produced from a renewable energy source like hydropower or geothermal energy the CO2 emission savings are up to 100%. The total CO2 emission reduction potential of geothermal heat pumps has been estimated to be 1.2 billion tonnes per year or about 6% of global CO2 emissions. Geothermal heat pumps will be covered in CCBJ's upcoming edition on energy efficiency and demand response.

Geographic and Application Breakdown of Direct Use Geothermal



Source: Lund, Freeston, and Boyd, World-Wide Direct Uses of Geothermal Energy 2005, published in Proceedings of the World Geothermal Congress 2005

2009 U.S. Geothermal Power Capacity On-Line



Source: Geothermal Energy Assn.

Department of Energy to use some of its ARRA funding—$400 million for geothermal and $6 billion for innovative technology loan guarantees—to subsidize drilling. As of May 2009, DOE had not issued guidance on this question. In international developments, the recession's impact on Icelandic geothermal firms has been amplified by the collapse of Iceland's currency. With the krona almost worthless on the international market, Icelandic geothermal developers that had set their sights on developing projects in foreign markets have scaled back to focus on the significant potential in their homeland.

Western States' Near-Term New Geothermal Power Capacity

	Capacity MW	Number of Sites
Alaska	20	3
Arizona	20	2
Colorado	20	9
California	2,400	25
Hawaii	70	3
Idaho	860	6
Nevada	1,500	63
New Mexico	80	6
Oregon	380	11
Utah	230	5
Washington	50	5
Total	**5,630**	**138**

Source: Western Governors' Association, Geothermal Task Force of the Clean and Diversified Energy Initiative. The task force concluded that Western States have a capacity of 13,000 MW that can be developed on specific sites within a reasonable timeframe, of these, 5,600 MW are considered viable for commercial development by 2015.

Long-Term Market Drivers Look Solid

The phrase "when the economy recovers" is becoming a cliché of analysts and commentators looking at virtually all industries, but there's really no other way to say: When the economy recovers, and when the prices of oil and gas resume their inevitable rise into the $100-plus territory, the geothermal power industry's prospects will improve. The CCBJ global market forecast, not that dissimilar from the base-case capacity-growth scenario of Emerging Energy Research (EER), has 2011-2014 annual growth in the high teens, with double-digit growth persisting to 2020.

Market drivers for geothermal power are fundamentally sound: In the developed world, renewable energy standards and greenhouse gas caps are pushing utilities toward low-carbon generation, and geothermal's baseload qualities give it advantages over solar and wind. As outlined in the chart on page 3, energy supply and security are also drivers, as is power price in regions such as the Caribbean and parts of South Asia that are highly dependent on imported diesel oil for power supply. Some developing country markets are using feed-in tariffs popularized mostly for other renewables in Germany and other developed nations.

With renewed growth, however, the geothermal power segment will have to contend with a couple of looming challenges. One is lack of access to drilling rigs. When oil prices were in the stratosphere and demand was outstripping supply, geothermal developers had a difficult time contracting for rigs and crews. With the drop in prices and demand, that has gotten easier; but rising prices and demand will inevitably cause drilling demand to rise. Another challenge will be recruiting and training staff. "The professional staff available in geothermal is minute," said Doug Glaspey, CEO of **U.S. Geothermal**, at the March conference. "In order to grow, you have to have skilled professionals, and that's a very difficult thing to accomplish in this business today." Investment capital is also required, and although the flow of venture money into cleantech businesses was tallied at over $8 billion in 2008, geothermal is not the sexiest category.

EER states that geothermal power plant investment could reach $13-20 billion by 2020, representing cumulative investment in geothermal exploration, drilling, and power plant construction. In comparison with EER's broader power generation forecasts, geothermal is the fourth-largest market for cumulative renewable power generation investment between 2009 and 2020, behind onshore wind, solar PV, and biomass, but ahead of offshore wind, CSP, and small hydro globally by 2020.

EER's base-case growth scenario forecasts 20 GW of geothermal installed during the 2010s, with their high-growth scenario at about 1.5 times that or about 30 GW. The vast majority of growth in both scenarios is North America and Southeast Asia, although the rest of the world accounts for as much as 25-30% of growth in some years of EER's forecast. A few new markets are expected to see sustained growth, led by Chile, Turkey, Russia, East Africa, and Central America. Established markets in Iceland, Mexico, and New Zealand are also expected to

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Regions Where Geothermal Companies Expect to Increase Their Work in 2009-2011

United States	69%
Europe	31%
Indonesia	31%
Central America	23%
Australia	15%
Africa	12%
China	12%
New Zealand	12%
Philippines	12%
Rest of Asia	12%
Canada	12%
Italy	8%
Japan	8%
Mexico	8%
India	8%
Chile	8%
Iceland	4%

Source: CCBJ 2009 Geothermal Survey conducted in April 2009. Question was: What countries or regions are you expecting to increase your work in over the next three years? n=26

continue to tap their potential. Australia is what EER calls the largest region of uncertainty, as its substantial goal of bringing online over 2 GW of geothermal by 2020 remains contingent on successful deployment of unproven EGS.

As mentioned, the United States leads the world in online capacity of geothermal energy and continues to be one of the principal countries to increase its geothermal growth. Geothermal electric power generation is centered in eight U.S. states: Alaska, California, Hawaii, Idaho, Nevada, New Mexico, Utah and Wyoming with Oregon and Colorado coming on line. Total U.S. installed capacity was 3,040 MW as of March 2009, according to GEA's *U.S. Geothermal Power Production and Development Update* that includes some units on standby. With a pipeline of now more than 4.4 GW of confirmed projects, the U.S. geothermal market is poised to more than double existing capacity over the next five years, says EER, with U.S. carbon legislation and national

Geothermal Industry Gameboard Not Too Crowded

The geothermal power industry consists of project developers that identify, finance and build geothermal power plants; consulting engineering and technical firms that identify and quantify geothermal resources, conduct environmental analyses, design, operate and maintain projects; drilling firms that drill wells for exploration and production; engineering, procurement and construction (EPC) firms that build geothermal power plants; manufacturers of turbine generator sets, heat exchangers and other equipment; and other specialty firms. Some firms perform multiple roles, for example, manufacturers sometimes develop their own projects and EPC firms often provide multiple technical services with in-house staff. Exploring for and developing geothermal power resources requires specialized expertise that is concentrated in a few countries including Japan, Iceland, the United States, Canada, New Zealand, Australia and the Philippines.

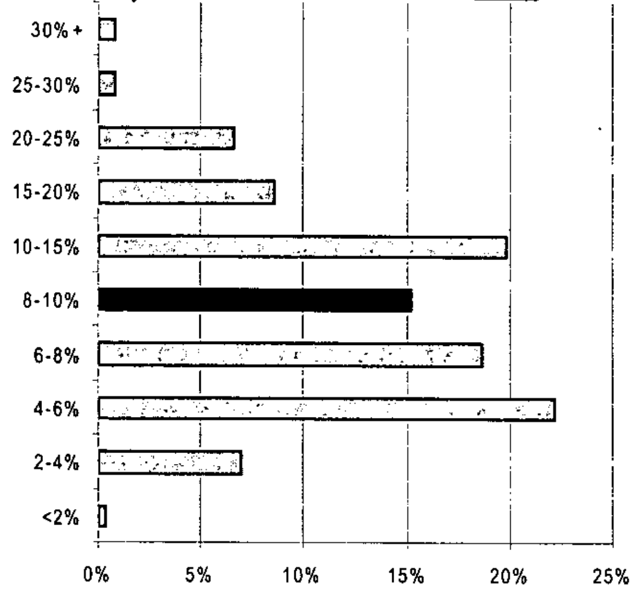
The number of firms in the industry is very small compared to other energy sectors. There are 11 manufacturers of geothermal turbine generator sets and related power plant components. They include: Alstom (France), Ansaldo (Italy), Fuji Electric (Japan), GE Energy (United States), Mitsubishi Heavy Industries (Japan), OAO Kalugo Energo (Russia), Ormat Technologies (United States), Siemens (Germany), Turboden (Italy), Toshiba (Japan) and UTC/Pratt & Whitney (United States). At the most recent international trade show of the **Geothermal Energy Association** in the United States, there were fewer than 100 exhibitors.

Geothermal project developers and power plant owners can be divided into two categories: 1) major independent power producers (IPPs) and utilities and 2) pure-play geothermal developers. The former category includes (U.S. companies unless stated): ArcLight Capital Partners/Terra-Gen Power, Calpine, Chevron, ENEL (Italy), EnBW (Germany), Geysir Green Energy (Iceland), LaGeo (El Salvador), Mid-American/CalEnergy, Ormat Technologies and PNOC EDC (The Philippines). Unocal and Chevron had historically been active developers of geothermal power in Southeast Asia. In 2005, Chevron acquired Unocal, and Chevron today is the world's largest private owner of geothermal power plants with combined capacity of 1,273 MW in the Philippines and Indonesia. Pure-play developers include: Magma Energy (Canada), Nevada Geothermal Power (Canada), Polaris Geothermal (Canada), Ram Power, Raser Technologies, Sierra Geothermal (Canada), U.S. Geothermal, Vulcan Power and Western GeoPower (Canada).

Enhanced geothermal systems (EGS) firms include AltaRock, Green Rock Energy (Australia), Panax Geothermal (Australia), Petratherm (Australia) and Potter Drilling. Leading technical and engineering consultancies and EPC contractors include AMEC, Enex (Iceland), GeothermEx, Geothermal Development Associates, Geothermal Resource Group, Horizon Well Logging, Hot Dry Rocks (Australia), Mannvit Engineering (Iceland), Ormat Technologies, Power Engineers, SAIC, SKM Consulting (Australia), West Japan Engineering Co. and Wood Group (United Kingdom)

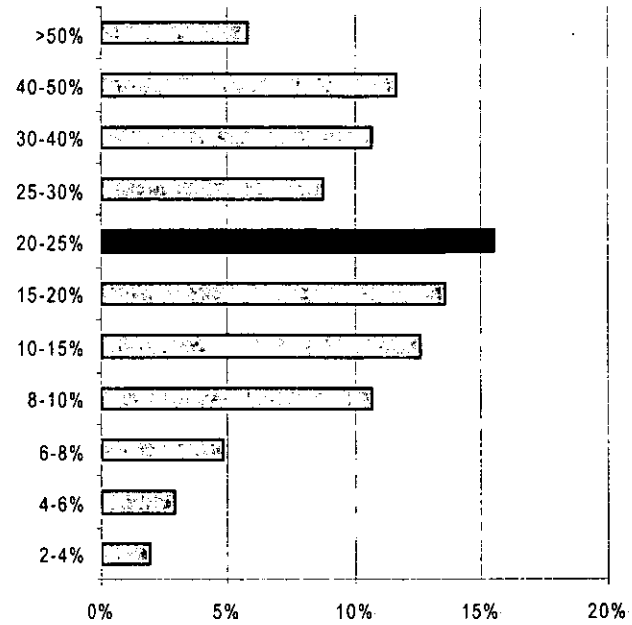
Leading drilling and drilling services companies include Baker Hughes, (United States), B.J. Services (United States), Boart Longyear (United States), Halliburton (United States), Iceland Drilling (Wales), Schlumberger (France, United States and The Netherlands), Thermasource (United States) and Weatherford (United States).

Percentage of U.S. Electricity Generation From Non-Hydro Renewable Sources in 2020



Source: Multiple CCBJ surveys with the same question conducted in 2008 and 2009 on the following topics: wind energy, CCS, snapshot and geothermal. Black bar indicates median range. Question was: U.S. DOE's Energy Information Administration says non-hydro renewable sources were responsible for 2.4% of U.S. electricity generation in 2006. What percentage of U.S. electricity generation do you believe non-hydro renewable sources will represent in 2020? (includes wood, municipal solid waste, landfill gas, sludge, biomass, geothermal, solar and wind).

Percentage of U.S. Electricity Generation From Non-Hydro Renewable Sources in 2050



Source: Multiple CCBJ surveys with the same question conducted in 2008 and 2009 on the following topics: wind energy, CCS and geothermal. The black bar indicates median range.

RPS expected to drive sustained growth from 2015-2020.

The global geothermal pipeline now exceeds 10 MW of projects under development, which if completed would almost double the installed global geothermal capacity of 10.5 GW built up over the past 30 years.

Currently, there are over 215 commercial geothermal electricity projects operating in 24 countries. The largest dry steam field in the world is The Geysers, 116 km north of San Francisco. The Geysers began in 1960 and has 1360 MW of installed capacity. **Calpine Corp.** now owns 19 of the 21 plants in The Geysers and is currently the United States' largest producer of geothermal energy. The other two plants are owned jointly by the Northern California Power Agency and the City of Santa Clara's municipal Electric Utility (now called Silicon Valley Power). Since the activities of one geothermal plant affects those nearby, the consolidation plant ownership at The Geysers has been beneficial because the plants operate cooperatively instead of in their own short-term interest. The Geysers is now recharged by injecting treated sewage effluent from the City of Santa Rosa and the Lake County sewage treatment plant. This sewage effluent used to be dumped into rivers and streams and is now piped to the geothermal field where it replenishes the steam produced for power generation.

Another major geothermal area is located in south central California, on the southeast side of the Salton Sea, near the cities of Niland and Calipatria, Calif. There were 15 geothermal plants producing electricity in the area. CalEnergy owns about half of them and the rest are owned by various companies. Combined the plants have a capacity of about 570 MW. The Basin and Range geologic province in Nevada, southeastern Oregon, southwestern Idaho, Arizona and western Utah is an area of rapid geothermal development. Several small power plants were built during the late 1980s during times of high power prices. Plants in Nevada at Steamboat near Reno, Brady/Desert Peak, now produce about 240 MW. As indicated on the chart on page 24, Nevada and Utah account for 86% of the new leases granted by the U.S. government in 2007-2008.

While geothermal electricity using existing technology indeed has good short-term prospects, the best sites are already snapped up. If geothermal is to make a big dent in renewables' inevitable penetration of the U.S. electricity business, EGS will have to play a role. Regardless, the manufacturers, consulting engineers, investors and policymakers in the CCBJ community believe that non-hydro renewables will account for roughly 8-10% of electricity by 2020 and 20-25% by 2050, according to compiled results of CCBJ surveys that incorporated the identical question (see charts above). How America reaches these thresholds remains to be seen, but it seems certain that there will be an ample supply of scientists, engineers, entrepreneurs, businessmen and corporations to chase the goal. ✪

Geothermal Developers Grapple With Financial Realities of 2009

For many geothermal power plant developers in North America, the worldwide economic free-fall that began in September 2008 has turned 2009 into a year of holding on, hunkering down and trying to survive. Despite holding leases to tens of thousands of acres of geothermal-rich land in the western United States, most developers lack risk capital to invest in the upfront geo-scientific work and exploratory drilling that is needed to verify the extent and quality of geothermal resources under the ground. (An exception to some degree is **Ormat Technologies,** which generated $252 million in revenues last year from its 505-MW portfolio of existing geothermal power plants; for more on Ormat see story on page 20.)

As recently as a year ago, developers could obtain debt financing before they had validated and drilled the production wells to tap geothermal resources—had "steam behind the pipe" in industry parlance. Not so today. "We've come out of a period in which there has been hyper-liquidity, a buyer's market for capital if you will. In the period we're in now, the pendulum has swung the other way," Ric Abel, Managing Director, Electric Finance Group, **Prudential Capital Group,** told CCBJ in April. "While in the past developers could get debt sooner in the life of a project and finance their drilling with a larger percentage of debt, today drilling and proving up the resource is seen as an equity risk."

Abel spoke at the March 2009 San Francisco Geothermal Innovation and Investment Forum sponsored by **Greenpower Conferences.** He was one of several representatives of lending institutions who discussed just how much financial conditions have tightened up for geothermal developers since the fall of 2008.

Investors had similarly bad news. Venture capitalists from **Google.org** and KPCB said they're only investing in technology firms with a strong upside potential, like those aiming to gain a position in the emerging enhanced geothermal systems (EGS) industry (also known as hot dry rock or HDR; for more, see feature on pages 29-31).

Private equity investors told the audience that because of the depressed market caps of publicly held geothermal developers, investors would prefer to buy geothermal companies or their operating power plants rather than invest in new geothermal projects. "Right now because of the large number of [geothermal] companies looking for financing as well as the significantly shrunken pool of available capital we expect that [development] deals will be few and far between going forward. The return hurdles and pre-requisites for successful private equity investment will be a lot higher," Paul Ho, managing director of **Hudson Clean Energy Partners,** told the audience.

New Wave of Developers

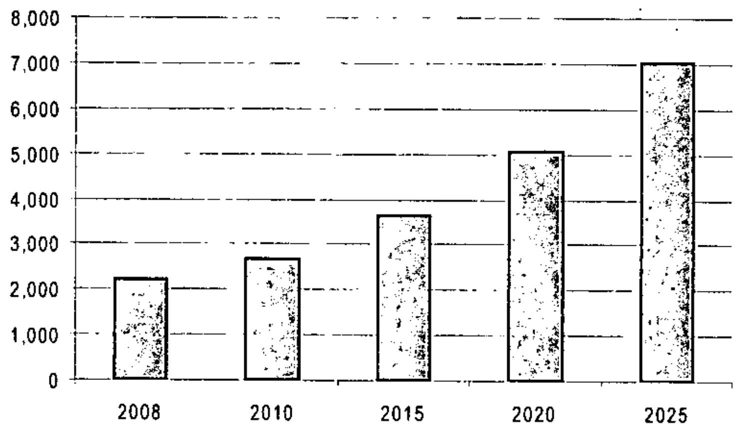
This was not news to the North American geothermal project developers who were in the audience, five of whom would later sit on a panel together representing their firms: **Magma Energy, US Geothermal, Ram Power, Nevada Geothermal Power** and **Sierra Geothermal Power.** These companies are part of a relatively new wave of pure-play geothermal project developers that emerged in this century, driven by the California energy crisis, the adoption of renewable energy standards in western states and the emergence of climate change and energy security concerns. Unlike Ormat and a handful of larger independent power producers and energy companies playing in U.S. geothermal project development—such as **CE Generation** and **Enel North America**—these firms are in the early stages of building their portfolios of geothermal projects. Tim Stephure, a geothermal expert at **Emerging Energy Research,** calls them "junior developers." Some have purchased existing plants with an eye toward expanding or repowering those facilities, but all are focused on new developments.

Hezy Ram, a longtime executive with Ormat who founded Ram Power last year, told an anecdote that while not literally true was nonetheless emblematic of the state of play for him and his counterparts. After leaving a meeting with an investor, he checked the visitor register at the front desk. Competing developer Doug Glaspey of U.S. Geothermal had been in just before him, while Brian Fairbank, CEO of developer **Nevada Geothermal Power** had just arrived for his appointment. (Both Glaspey and Fairbank were on the conference panel.) "We all go to the same private equity funds and financial institutions and talk to the same people," he said. "We need development capital. And as you know capital is very scarce today."

Development capital—lots of it—is needed for the upfront work that developers must do not only to verify that adequate geothermal resources lie under the ground they've leased or purchased, but also to sink wells accurately enough to tap those resources. In this economic environment, until they've got "steam behind the pipe," they can't access private equity funding, tax-credit equity or project-finance debt. And even when they can meet the risk requirements of such funders, funding is harder and more expensive to obtain than any time in recent memory.

As Abel pointed out, prior to the recession, developers could often obtain debt financing for some of this risky resource development activity. Not only is that no longer the case, but prospective equity investors are requiring more resource development work—more steam behind the pipe—before they'll invest in projects. And lenders are requiring higher levels of equity investment before they'll lend money for a project. One geothermal

Forecast of US Capacity for Conventional Hydrothermal Power



Source: CCBJ 2009 Geothermal Survey conducted in April 2009. Question was: Geothermal generating capacity in the United States was approximately 2,200 MW at the end of 2008. Given an economic revival by 2010 and adequate incentives, please estimate the US capacity for conventional hydrothermal power for 2010, 2015, 2020 and 2025. Result displayed is an average of the responses written in.

veteran who spoke to a CCBJ editor at the conference said: "The big economic problem affecting us now is the amount of debt you can get as part of your total project cost. This amount used to be 70-80%, and you'd only have to come up with 20-30% equity. First of all, nobody is really doing any deals right now. Banks don't have money they're willing to loan on such projects. But the numbers we're hearing tossed around [by lenders willing to lend] are more like 40-50% equity."

Panelists agreed that the last significant geothermal financing deal in the United States was Nevada Geothermal Power's $180 million line of credit to build a 50-MW project near Winnemucca, Nevada. But as CEO Brian Fairbank told CCBJ in an interview, the financing was much less favorable than what the company had anticipated. And in the current climate, the developer's success in getting steam behind the pipe for 50 MW has not led to any breakthroughs in financing an additional 50 MW at the same site. "Just at the time when we should have the light of success shining on us, we've run into the collapse in the credit market and a situation where the equity markets aren't working very well either." (For more on Nevada Geothermal Power, see page 28.)

Geothermal Land Rush

Before a developer worries about financing, however, it must have land leased for development, either from private owners, states or the federal Department of Interior, which controls through **the Bureau of Land Management** (BLM) millions of acres in the West. After May 2007, when the BLM finalized its rules for auctioning leases under the Energy Policy Act of 2005, there was a "land rush" as firms bid for favorable parcels. Auctions in 2007 brought in bids ranging from an historic high of $14,000 per acre for a 470-acre parcel adjacent to The Geysers in California to bids in the neighborhood of $300 to $500 per acre in Nevada, according to a BLM news release. Data compiled by Emerging Energy Research shows that since 2007 the three top lessees are Ormat, with about 150,000 acres; **Raser Power Systems** with some 75,000 acres; and Magma Energy with about 45,000 acres. These three are followed by some 20 developers with anywhere from a few hundred acres to 20,000-plus acres under lease. (See chart on page 24.)

The BLM has been paid more than $63 million for geothermal leases since 2007, according to Kermit Witherbee, national geothermal program manager for the agency. According to Witherbee, the perceived value of auctioned leases have dropped significantly. In the agency's last auction in December 2008, the average price was between $30 and $50 per acre.

For developers without existing leases or rights to private or federal lands, the prospects of gaining a toehold in geothermal development are increasingly slim. Most of the favorable geothermal sites—outside of off-limits areas like Yellowstone National Park—have already been developed or acquired. "Those of us who have been around for a few years kind of got the first pick on some of these prospects that that [already] had drilling [done] and had discoveries," said Doug Glaspey, CEO of **U.S. Geothermal.** "Those are the sites we went to first, and those are rapidly being consumed not only by ourselves but by new entrants in the market. So the quality of [geothermal site] prospects is going down. That means the risk to define and develop new resources is going higher and higher."

Drill, Baby, Drill (With DOE Money?)

While the output of wind, solar PV, biomass, hydropower and other renewable power plants can be predicted with a fair amount of certainty, geothermal developers face much more uncertainty as they search for steam supplies anywhere from 2,000 to 10,000 feet underground.

To find geothermal resources of sufficient enthalpy (heat energy) for power generation, they start with geological mapping that points to likely areas. They also consider distance to grid connections. Then they hire staff or consultants to perform geochemical analyses of hot springs and geophysical analyses such as seismic studies to refine models of likely resources. On many prospective geothermal properties, developers have the benefit of earlier explorations done by oil and gas companies that were investigating geothermal in a big way in the 1970s and 1980s.

Many of those prospective sites were not developed because the market drivers of that era diminished with the decline in oil prices. Additionally, the binary technology that can utilize lower-temperature geothermal resources was not available on a commercial scale at that time.

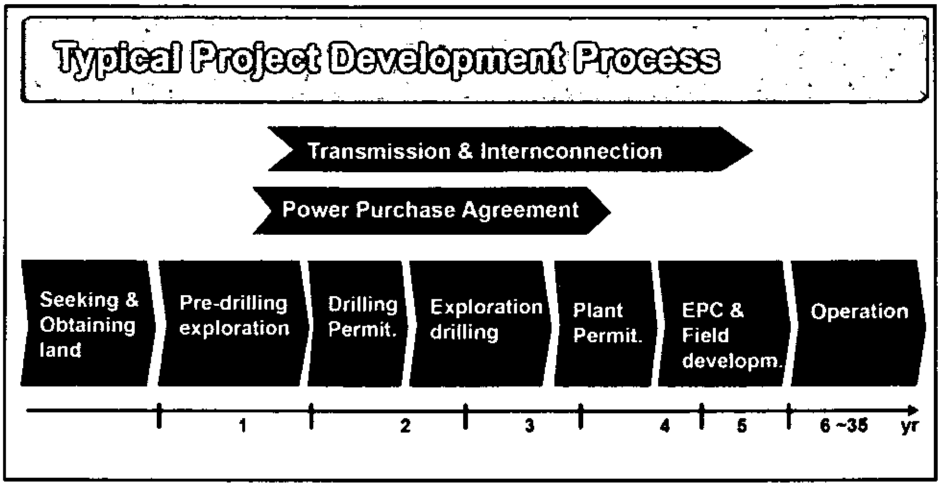
The costs for the geologic mapping, geochemical and geophysical work is generally in the hundreds of thousands of dollars for a 40 to 50 MW geothermal power project—add in permitting for the well drilling phase and you're looking at $2 million to $3 million, according to Brian Fairbank of Nevada Geothermal Power (see page 27).

Then the cash really starts to flow. Developers hire drilling contractors who come with rigs, equipment and personnel and charge $25,000 a day or more. Sometimes a drilling program start with slimhole test wells that can cost $2 million to $3 million each; in other cases developers and their contrators go straight to the production wells that can cost anywhere from $3 million to $10 million or more.

Like wildcat oil drillers, the geothermal prospectors are usually looking in areas without a history of geothermal production. They don't always hit paydirt, yet the drilling contractors must be paid. In fact, drilling "dry holes" is quite common. Developers estimated the risk at 20% to 30% on greenfield projects that haven't already been subjected to some exploratory drilling. "That scares a lot of people," said Glaspey.

"The drilling is really the wild card in geothermal," said Gary Thompson, CEO of Sierra Geothermal Power in response to a questions about average costs for developing a geothermal wellfield. "You have to have a fairly large contingency when you're talking about drilling because [the costs] are all over the map It could be $2 million, it could be $15 million to drill one of these wells. And your output varies [on the the same scale]. It could be two megawatts per well or 10 or 15 megawatts per well."

Typical Geothermal Project Develoment Process



Source: Geothermal Development in Emerging Markets by Rahm Orenstein, Ormat Technologies, Inc. Geothermal Innovation & Investment Conference, March 24th, 2009.

Given the risks of hitting dryholes and creating wells that produce less power than anticipated, the typical upfront capital required for a geothermal project of 40-50 MW with a typical life cycle of 30-35 years could be from $30 million to $50 million, according to developers. With the high risk profile of their endeavor and the difficulty of financing such activities, developers and other speakers at the conference pleaded with one particular person in attendance: Ed Wall, manager of the **U.S. Department of Energy's Geothermal Technologies Program**. What they asked for repeatedly is for Wall to use some of the $400 million for geothermal contained in the American Recovery and Reinvestment Act (ARRA) stimulus package to help developers mitigate this daunting dry-hole risk (see list on page 17).

"It's great to spend money on EGS. That's the future," said Glaspey. "But if you want megawatts on the ground today, you have to capitalize exploration. The way you do that is put it into drilling programs. Cost share [from the DOE] would be very nice for folks like us."

"There's a tremendous amount of conventional geothermal projects out there that desperately need assistance in order to do the drilling," said Abel from Prudential. "I think from a stimulus bill perspective, getting projects built, producing electricity and creating those jobs is where there's more bang for your buck."

Another option for DOE funding, according to Glaspey, is the loan guarantee program for renewable energy technology funded to the tune of $6 billion by the ARRA. "It may be possible for DOE to offer us loans at 3.5-4% interest," he said. "That's very encouraging, although we can't wait two years to get that kind of financing package," he added, referring to DOE's past difficulties with the loan guarantee program.

Long-Term Drivers

Despite the current difficulties, geothermal developers are operating in a marketplace with some very strong long-term drivers. Regardless of what happens with federal renewable energy standards and climate change legislation, utilities in western states are already under state laws requiring sharp increases in renewable generation. Because of its reliable baseload properties—in contrast to the intermittency of wind and solar—utilities and grid operators can more easily incorporate geothermal generators.

Those "junior developers" who can hang on through this difficult period will likely enjoy a more robust market environment within one to two years. Prudential Capital Group's Ric Abel pointed out at the March conference and in a separate interview with CCBJ that institutional lenders like insurance companies still have a large appetite to finance long-term projects like geothermal power plants built with fixed-price EPC contracts and 20-year power purchase agreements. "There is money available, although it's a lot more expensive than it was a year ago," said Abel. "While drilling and proving up the resources is an equity risk, building the power plant and producing electricity for a PPA is more of a debt risk."

Abel said geothermal projects are financed in similar fashion to combined cycle gas turbine plants and other fossil fuel-fired power plants, with a waterfall structure designed to ensure that asset maintenance—including reservoir maintenance in the case of geothermal—is adequately funded and creditors are paid before plant equity owners. "This structure was developed and perfected primarily with gas-fired projects.... Most of the major law firms that focus on project finance are very familiar with this structure and the documents associated with it. At various times, including in the recent period of hyper-liquidity, people have deviated from that structure, but now the pendulum has swung back and lenders are approaching power projects in this more standard format."

For geothermal projects, a "disciplined operating budget" to maintain reservoir viability is critical to giving long-term lenders assurance. "You've got to have continued funding to maintain the geothermal resource, which is your fuel supply, on an ongoing basis," he said.

Emerging Energy Research's Stephure points to some recent investment highlights that show the underlying strength of the geothermal segment, but also point toward consolidation trends. He noted that Canadian energy company **Alta-Gas** recently purchased a 25% stake in Magma Energy and Raser Technologies has recently executed a funding agreement with **Copper Canyon Mining**. Australian EGS geothermal developers **Geodynamix** and **Petratherm** have formed alliances and joint ventures with very large companies: Geothermix with Indian conglomerate **Tata** and Petratherm with Australian utility **TruEnergy** and oil & gas producer **Beach Petroleum**. "Companies with bigger balance sheets will be better positioned moving forward," said Stephure. "There are definitely some opportunities for these players to take advantage of the economic situation. They can fund a lot of activity in house and pick up projects from developers who are struggling. M&A activities are likely to occur. We may also see utilities move into this space, either developing or owning their own projects or partnering to help develop projects." In chaos lies opportunity is how some observers are characterizing 2009 and the geothermal industry has both. ✪

Leading Geothermal Power Market Participants

Power Plant Owners & Developers

Major IPPs And Utilities:
ArcLight Capital Partners
Calpine (USA)
Chevron (USA)
EnBW (Germany)
ENEL (Italy)
Geysir Green Energy (Iceland)
LaGeo (El Salvador)
Mid-American/CalEnergy (USA)
Mighty River Power (New Zealand)
Ormat Technologies (USA)
PNOC EDC (The Philippines)
Terra-Gen Power (USA)

Pure-Play Geothermal Developers:
Magma Energy (Canada)
Nevada Geothermal Power (Canada)
Polaris Geothermal (Canada)
Ram Power (USA)
Raser Technologies (USA)
Sierra Geothermal (Canada)
U.S. Geothermal (USA)
Vulcan Power (USA)
Western GeoPower (Canada)

Power Plant Equipment Suppliers:
Alstom (France)
Ansaldo Energia (Italy)
Fuji (Japan)
GE/Nuovo Pignone (USA)
Mitsubishi (Japan)
OAO Kalugo Energo (Russia)
Ormat Technologies (USA)
Siemens (Germany)
Toshiba (Japan)
Turboden (Italy)
UTC/Pratt & Whitney (USA)

Energy Conversion Technology Developers
Borealis/Power Chips (Gibraltar)
ElectraTherm (USA)
Exorka (Germany)
O-Flex
Ormat Technologies (USA)
Turbine Air Systems (USA)
UTC/Pratt & Whitney (USA)

Technical and Engineering Consultancies & EPC Contractors
Amec (USA)
Enex (Iceland)
GeothermEx (USA)
Geothermal Development Associates (USA)
Geothermal Resource Group (USA)
Horizon Well Logging (USA)
Hot Dry Rocks (Australia)
Mannvit Engineering (Iceland)
Ormat Technologies (USA)
Power Engineers (USA)
SAIC (USA)
SKM Consulting (Australia)
West Japan Engineering Co.
Wood Group (United Kingdom)

Drilling And Drilling Services Firms
Baker Hughes (USA)
B.J. Services (USA)
Boart Longyear (USA)
Halliburton (USA)
Iceland Drilling (Wales)
Schlumerger (France, USA, Netherlands)
Thermasource (USA)
Weatherford (USA)

EGS Developers/Technology Firms
AltaRock (USA)
Geodynamics (Australia)
Green Rock Energy (Australia)
Panax Geothermal (Australia)
Petratherm (Australia)
Potter Drilling (USA)

Source: CCBJ, EER, NEF and Geothermal Resources Council

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Geothermal Power in Developing Countries

With the best geothermal resources located along the Pacific Ring of Fire, there are enormous opportunities for developing geothermal power in Asian and Latin American countries that currently have little or none. The eastern and southern Mediterranean and the East Africa Rift zone (Kenya, Ethiopia, etc.) also present large geothermal development opportunities.

But developing geothermal power plants in many emerging markets is an enterprise fraught with high risks—risks that are layered on top of the ordinary risks of hitting dryholes and drilling under-producing wells that confront geothermal project developers in the United States and other developed countries. To build geothermal wellfields and power plants, most developing countries (the exceptions being the Philippines, Mexico, El Salvador and Indonesia) need foreign experts, suppliers and development capital because they lack the internal capacity—yet foreign firms often find it difficult to work in many developing countries because of the lack of frameworks to manage risks, delays in administrative processing, frequent requests for local patronage, contracts being violated and projects being shut down for murky political reasons.

"In some of these markets you have to add political risk to the drilling risks and credit risks that exist in developed countries," said Rahm Orenstein, director of business development for internationally active **Ormat Technologies** in a talk at the March 2009 Geothermal Innovation and Investment Forum sponsored by **Green-Power Conferences** in San Francisco. "Then you have off-take risk. In some countries, there's a high risk that your electricity customer won't pay you."

Poor market conditions are also a barrier to geothermal development in many developing countries. These include: Electricity markets that have not been fully restructured to encourage competition by independent power producers (IPPs), low rates for electricity that price geothermal out of the market, and lack of incentives to subsidize the up-front investment costs of geothermal power projects. "In many countries, geothermal has to compete with fossil fuels that still get subsidies and incentives," explained Orenstein. Additionally, many developing countries that have restructured their state power monopolies to facilitate more competition still retain monopolistic elements. "Any place we go and compete as an IPP is a market that has been deregulated to allow merchant power suppliers like us to compete, which is good.... But in some cases we discover that market is still to some extent monopolistic. Utilities may have been broken into a generation company and a transmission and distribution company, so now they have two monopolies."

For developing countries desperate for more domestic power sources—and for the worldwide effort to mitigate carbon emissions—the consequences that these risks and barriers will forestall geothermal power development in emerging markets are immense. **West Japan Engineering Co.** (West JEC), which has extensive experience in Central America, estimates that 3,000 MW to 4,000 MW—about 10 times current installed geothermal capacity—of new geothermal could be developed in that region given proper market structures, incentives and policies.

Geothermal-rich Indonesia has set a goal of building more than 4 GW of geothermal power capacity by 2014 (It currently has less than 1 GW online), but many international companies are reluctant to work there because of its unfavorable power market, bureaucratic inertia and reputation for corruption. In Kenya, some 4 GW of geothermal capacity—triple the nation's current electrical generation capacity—could be developed in the Rift Valley given proper market conditions and incentives, according to a study by UN agencies and the national power generation utility.

Foreign firms have successfully developed geothermal power projects in all of these regions and other developing nations. But it hasn't been easy.

Case In Point: Kenya

Ormat began developing a geothermal project in Kenya in the late 1990s, soon after the former state-owned power monopoly was unbundled into generation and transmission-distribution units. "Kenya was still heavily reliant on several hydropower projects for its electricity generation, and in the late 1990s the country suffered a major drought that caused generation to drop by some 30 percent," said Orenstein. The reliable baseload characteristics of geothermal made it an ideal resource for the country's power needs, according to Orenstein.

A **World Bank** supervised international competitive bid was issued by the utility, which was won by Ormat. Nine months after signing of a 30-year 50 MW power purchase agreement (PPA), the first 8 MW plant came online, and was soon expanded to 12 MW. By May 2002, Ormat had completed and demonstrated a total of 48 MW of steam capacity from the wells, but then it had to wait an agonizing six years to wade through what Orenstein called "administrative and political issues" before it could complete its power plant to reach that capacity. Ormat invested $150 million of its own funds for the wells and the plant; only recently was it partially refinanced by a loan from the German DEG lead consortium.

Kenya has relatively high electricity tariffs—between $80 and $120 per MWh compared to $60 to $80 for the rest of sub-Saharan Africa, according to a report by Julie Rowlett of the **Columbia University School of International and Public Affairs**. So Ormat's wholly owned Kenyan subsidiary **OrPower** is likely doing well. But according to Ormat's 2008 annual report, the firm, along with the handful of other IPPs operating in Kenya, is under pressure to reduce tariffs to allow the government to make good on campaign promises of cheaper electricity. Furthermore, its customer **Kenya Power and Light Company** is being re-organized. And the country is in a state of ongoing political turmoil between President Mwai Kibaki and Prime Minister Raila Odinga.

To manage the risks of operating in countries like Kenya, Ormat buys political risk insurance from the **Multilateral Investment Guarantee Agency (MIGA)** of the **World Bank Group** or from **Zurich Re**, for most of its foreign projects, according to the company's annual report.

Ranking Developing Country Markets

Research outfit **New Energy Finance** has ranked the favorability of geothermal markets in both developed and developing countries. NEF's four criteria are:

Stability – political, economic and social, including a reliable electricity grid.

Availability of **local partners** to handle licensing, permitting and obtaining power purchase agreements.

A positive **policy framework** with high energy demand and limited supply

Incentives or subsidies such as feed-in tariffs, renewable energy certificate trading schemes and tax exemptions.

West JEC would probably add to that list a wholesale power market that is amenable to power purchase agreements (PPAs). Without PPAs, geothermal plants compete as merchant power producers, being dispatched only when their power is needed and their price is competitive. "Not all countries are like the United States where you can get PPAs," said Enrique Lima, general manager for overseas business. "In Central America, for example, it is difficult to get PPAs. You have to compete in the market where the price varies 24 hours a day. It can go from as low as 1 to 2 cents and as high as 10 to 13 cents at peak. But the duration of the peak is very short, so the average price you'll get is 3 or 4 cents. This makes it very difficult for geothermal to compete."

It's no suprise that Kenya is near the bottom of NEF's rankings with a 2.0 ranking out of 4.0 possible points. (See chart on left for all of NEF's rankings.) Many developing countries rank more highly, in NEF's view, including Chile, Hungary, Nicaragua, Guatemala, Indonesia, the Philippines and Turkey.

Global Geothermal Markets Rating

Country	Stability	Local Partners	Policy Framework	Subsidies	Ranking
Chile	+	+	+	+	4.0
Greece	+	+	+	+	4.0
Hungary	+	+	+	+	4.0
Iceland	+	+	+	+	4.0
Australia	+	+	+	+	4.0
Austria	+	+	+	+/-	3.5
Slovakia	+	+	+	+/-	3.5
Nicaragua	+	+	+	-	3.0
US	+	+	+	-	3.0
Guatemala	+	+	+	-	3.0
Indonesia	+	+	+	-	3.0
Japan	+	+	+	-	3.0
Philippines	+	+	+	-	3.0
Germany	+	+	+	-	3.0
Italy	+	+	+	-	3.0
New Zealand	+	+	+	-	3.0
Turkey	+	+	+	-	3.0
Costa Rica	+	+	+/-	-	2.5
El Salvador	+	+	+/-	-	2.5
Poland	+	+	+/-	-	2.5
Portugal	+	+	+/-	-	2.5
China	+	+	+/-	-	2.5
Thailand	+	+/-	+	-	2.5
France	+	+/-	+	-	2.5
Kenya	+/-	+	+/-	-	2.0
Mexico	+	+/-	-	-	1.5
Russia	+	+/-	-	-	1.5
Ecuador	+	-	-	-	1.0
Peru	+	-	-	-	1.0
Papua New Guinea	+/-	+/-	-	-	1.0
Djibouti	+/-	+/-	-	-	1.0
Ethiopia	+/-	+/-	-	-	1.0

Source: New Energy Finance. Countries were ranked on a scale of 0 to 4 points. Each of the criteria presented in the four columns is worth 1 point. A + symbol signifies that country fully meets the criteria and 1 point. A +/- symbol indicates that a country only partially meets the criteria and is awarded a 0.5 point.

Indonesian Puzzle

But according to New Energy Finance Associate Mark Taylor—and research by CCBJ's parent company **Environmental Business International (EBI)** on behalf of the Organization for Economic Cooperation and Development—the level of risks and difficulties presented by certain countries can be as much a matter of perception or opinion as fact. Indonesia, for example, is widely perceived as a very difficult market to develop geothermal projects due to broken contracts, turgid bureaucracies, an unfriendly power market and corruption. According to an executive with an international engineering firm active in geothermal worldwide, wholesale power prices in Indonesia are tied to the price of coal power, essentially pricing geothermal out of the market. This individual (who was interviewed confidentially for EBI's **OECD** study) doesn't believe that the government's plan to offer higher rates for geothermal and other renewables will succeed because of resistance within the electricity bureaucracy.

WJEC's Lima offered a more balanced perspective on Indonesia, telling CCBJ: "The Indonesian government is now thinking what kind of support is needed for geothermal and other renewables but they have not yet reached a conclusion." And Taylor says he has "talked to people who have developed projects there, and they say that if you know the people and the culture, it's not that bad." Indeed, **Chevron**, which calls itself the largest producer of geothermal energy in the world, has a 30-year history of geothermal work in Indonesia (through **Unocal** which Chevron acquired in 2004). According to Taylor, government officials in charge of boosting geothermal production to 4.4 GW by 2014 are aware of its reputation and working to ease some of the barriers and challenges.

A key insight that emerged from EBI's research is that some firms succeed handsomely in doing business in foreign markets where others fear to tread. One wind power developer told EBI that his firm avoided mature wind-power markets in OECD countries to focus on the opening markets in what he called "dodgy" countries with higher levels of political risk and corruption. While some firms reported avoiding China because of intellectual property risk and poor contract enforcement, several European wind power firms work quite successfully in China. It appears that a market which scares off some firms can offer opportunities to other firms that adapt to the country's business norms and market conditions.

For geothermal power developers, however, the higher levels of risk and difficulty imposed by operating in a "dodgy" country are much more formidable than for wind power because of the cost of quantifying and developing resources. While assessing the expected annual yield of a wind farm site is not a trivial matter, doing the drilling needed to prove and develop the geothermal resource for a 50-MW power project can run as high as $50 million or more.

Governments, Funding Institutions Step Up

Because of these high costs and the attendant risks of finding dryholes or hitting reservoirs with lower than expected power capacity, geothermal power development in emerging markets is often too risky for the private sector to do on its own. To offset these costs and risks, developed country governments, multilateral lending agencies like the World Bank and in some cases host country governments subsidize the exploration and resource development phase of creating a new geothermal power plant.

The impact of such subsidies can be seen in the contrast between the geothermal power development trajectories of the Philippines and Indonesia. The two countries are both rich in geothermal resources and both began developing them in the 1970s, yet the Philippines today has about 1900 MW of capacity online, meeting about 17% of total demand, while Indonesia has less than 1 GW meeting 5% of demand. According to multiple informants for EBI's OECD research, the Philippines' success story was based on a policy in which publicly owned **PNOC Energy Development Corporation (EDC)** took the exploration and drilling risk, selling steam to power plant developers.

By contrast Indonesia required foreign developers to fund exploration and drilling. "In the 1990s, you could do a geothermal power project in the Philippines for 4.5 cents to 5 cents U.S. per kilowatt-hour, but contracts in Indonesia were at 7.5 to 8 cents because developers were putting a big margin on for the risks being assigned to the projects," said EBI's source with the international engineering firm. (PNOC EDC has since been privatized and EBI's sources say the industry is watching closely to see how its development policies evolve.)

Looking forward, Taylor says that funding to underwrite the costs of resource exploration and wellfield development will be vitally important to building geothermal projects in most developing countries. "Right now, developing geothermal in these countries is so high-risk that there needs to be some sort of multilateral bank or government intervention to help out," he said.

He spoke recently with the head of the World Bank's $25 million GeoFund which subsidizes drilling and exploration and technology development. The official reported that the fund had lent $5 mil-

Developing Markets with Most Promise in Geothermal

- Brazil
- Canada (2 responses): political stability, history of resource development
- Chile (2 responses): resource and government support, great resource, new developers in area
- China (2): Universal carbon tax
- Iceland: size of resource
- India: universal carbon tax
- Indonesia (4) : lots of resources
- Japan
- Kenya
- Mexico
- Nevis Island (Antilles): great start, high electricity pricing
- Nicaragua: good resource
- Philippines (5): replace dependance on diesel powered generation; size of resource
- Turkey

Source: CCBJ 2009 Geothermal Survey conducted in April 2009. Question was: Many regions of the developing world such as Central America and parts of Africa have tremendous potential to develop more geothermal power, yet little internal capacity to develop their resources. In many cases, such countries present high risks for foreign geothermal developers and service providers. Please note the three developing countries that you think will grow their geothermal power capacity the most over the next 10 years and what factors will make those markets favorable for geothermal development.

lion and still had another $20 million to lend, which would likely go to subsidize three resource exploration efforts and five technology development programs. "The European Investment Bank and the European Bank for Reconstruction and Development have also offered funding, but the existing financing resources are absolutely not enough. To significantly ramp up geothermal power capacity in developing countries, it will be necessary for multilateral banks to step up their financing."

Enrique Lima of West JEC told CCBJ about a series of geothermal projects in countries such as the Philippines, Indonesia, Guatemala, Jordan, Panama, Colombia and other countries for which the initial stage of development were or are being financed by country-to-country development assistance programs. "This kind of financing through donations or soft loans may provide means to offset risk," said Lima.

Chile, Turkey, Hungary Entice Developers

According to Taylor, a country that has been particulary successful in turning around a negative reputation for geothermal development is Chile. Developers were plagued by long delays in receiving permits until the government streamlined the permitting by setting deadlines for administrative departments.

"Chile is one of the best markets now for two reasons," said Taylor. "It doesn't have a feed-in-tariff but it has an average wholesale electricity price of $115 per megwatt-hour, which is very high. The other reason is that it has an immense geothermal resource and developers who have looked at it are fairly confident that they can make projects work economically." The Chilean government is also offering a $5 million subsidy per geothermal project and is doing organized leasing and tendering of known geothermal resource areas.

"Many mining companies up in Northern Chile need a lot of electricity, and they're paying high rates for it," said Taylor. "There is a lot of geothermal [in the mining areas], with geysers and other surface expressions." Combining small distributed projects for mines and other remote industries with utility-scale projects, Chile can develop 2350 MW of geothermal power capacity according to an estimate provided by NEF from **Bob Lawrence & Associates**, a consulting firm.

Other developing-country markets have implemented feed-in-tariffs for geothermal, according to Taylor. These include Hungary with a $90 per MWh rate; Turkey with $70 per MWh; and **the Central American Electrical Interconnection System (SIEPAC)** linking Panama, Costa Rica, Honduras, Nicaragua, El Salvador, and Guatemala has set an $80 per MWh FIT (SIEPAC is still under construction as of April 2009).

Trouble In Central America: One Company's Experience

CCBJ's parent company Environmental Business International (EBI) recently conducted a series of confidential interviews with geothermal market participants on behalf of the Organization for Economic Cooperation and Development to assess the market barriers in different countries. EBI's informants (interviewed confidentially) told stories of extra costs, obstacles and delays due to government procedures and local business culture. One of the most daunting experiences was related by an international developer doing its first project in Central America. As a result of these experiences, the company will raise its revenue requirements for future projects in the country by 10% to 20%. (The country is not identified to protect the company's confidentiality.) Among the challenges:

* A government anti-corruption law made customs clearance cumbersome and expensive. A mistake like classifying a pipe fitting as a pipe could result in fines and special treatment of all the company's imports for a year.

* Conflicts between labor unions in Mexico and Central America resulted in a *de facto* ban on Mexican trucks crossing the border. In spite of a regional free trade agreement, shipments are re-loaded at the border—a requirement that could not be safely met for a 50-ton heat exchanger the company was importing. A logistics contractor had to negotiate a special arrangement with the unions.

* The company had difficulty importing the isopentane needed for the binary steam cycle because customs officials didn't know how to classify it.

* Banking regulations prevented the company from opening an account unless it established a domestic company. This meant that the company could not establish credit at local vendors and had to get quotes, write purchase orders and process invoices through its home office for all purchases.

* The project tender document gave the client—a quasi-public utility—the right to travel at the developer's expense to inspect the production of components. While traveling to inspect heat exchanger or turbines was justifiable, client staff insisted on traveling to visit the makers of commodity items like transformers and pumps.

* For some site preparation work, the company was forced to employ laborers instead of heavy equipment.

* After a site engineer was murdered, the company hired an armed security service to accompany all foreign staff 24 hours a day.

ARRA Update: Federal Procurement Picks Up at GSA, DOD and DOI

Federal government agencies are flush with cash to spend quickly thanks to the American Recovery and Reinvestment Act (ARRA), also known as the Stimulus Package. And a great deal of that cash will go to services and products related to energy efficiency and renewable energy projects. While the **U.S. Department of Energy (DOE)** is the largest recipient and disburser of ARRA funds for energy efficiency and renewable energy, other federal, state and local agencies also have a great deal of new money to spend on these segments by September 30, 2010.

As noted in our first edition of 2009 (January/February/March 2009), given the size and the phased implementation of the ARRA, CCBJ will cover aspects relevant to our readers over several editions in 2009. In this edition, we focus on federal procurement for services and products associated with energy efficiency and renewable energy by three federal agencies: **General Services Administration** (GSA), **Department of Defense** (DOD) and **Department of Interior** (DOI).

According to CCBJ's estimates, these three agencies will directly spend about $5.5 billion on contracts for renewable energy and energy efficiency projects by September 30, 2010. (Note: this does not include funds being channel to states, local governments, housing authorities, tribes and school districts by the **Department of Education, Environmental Protection Agency, Housing and Urban Development** and DOE.)

Five and a half billion dollars is a rough estimate based on an educated guess about the amount of capital project funds that GSA, DOD and DOI agencies will spend on energy-related projects. Congress gave the agencies wide latitude, telling the Army, for example, to spend $1.47 billion to "improve, repair and modernize... facilities, restore and modernize real property to include barracks, and invest in the energy efficiency of ... facilities." All other DOD departments, including reserves, received similar marching orders. Similarly, the **Bureau of Land Management, Fish and Wildlife Service** and other DOI agencies have been given money for "repair of roads, bridges, property, and facilities and for energy efficient retrofits of existing facilities."

With that kind of discretion, the full scope of GSA, DOD and DOI spending on energy efficiency projects like upgraded lighting and replacement of inefficient HVAC equipment and renewable energy projects such as solar water heating systems and wind turbines won't be known for some time. But early indications are that spending from DOD at least will be very robust.

In a March 2009 report to Congress, DOD highlighted hundreds of energy efficiency and renewable energy projects that will be funded with ARRA money. Just a few examples: $4.7 million for wind turbines at the **Air Force**'s Cape Newenham Long Range Radar site in Arkansas; $10.7 million for a PV system at Camp Pendleton Marine Corps Base in California; and $3 million to upgrade the HVAC system at Fort Leavenworth in Kansas.

Obviously, there's a lot of work on tap for equipment installers and integrators and engineering and construction firms. But DOD is also looking for consultants to do conceptual planning and analysis work. A whole section of ARRA DOD funding is devoted to research, development test and evaluation (RDT&E) projects, and DOD aims to spend much of that funding on energy related projects.

There are initiatives around designing more fuel-efficient military vehicles and developing renewable energy generation and energy devices for combat usage; contracts for those types of projects will prob-

Recommendations for DOE for Utilization of the $400 million in ARRA or Stimulus Funds for Geothermal Energy

Reduce drilling risk
Fund Exploration and Drilling
Incentives for exploration
Invest in exploration research
Create new test wells for deeper operations
Help finance geothermal development first cost
Construction loan capital for shovel-ready developments
Continue and Increase Loan Guarantees
Staff Up to Process Loan Guarantee Applications
Reduce development red-tape
Facilitate and ease permitting process
Concentrate on Hot Dry Rock Geothermal Energy
Invest in proving EGS technology
Fund EGS developments
Fund traditional deployment instead of EGS
Don't squander it on EGS
Invest in geothermal R&D
Advance hard-rock drill-bit development
Invest in cycle engineering and simulation
Advance hybrid solar/binary power plants
Fund new research for power conversion technology

Source: CCBJ 2009 Geothermal Survey conducted in April 2009. Question was: What three top recommendations would you give to US DOE for the $400 million it received in the American Recovery and Reinvestment Act (ARRA) specifically for geothermal.

ably go to firms' with prior experience in combat and weapons systems. But there are also RDT&E projects suitable for consulting engineering firms with expertise and capabilities in designing building energy systems. For example, the Army is looking to spend $3 million for planning of an ultra-low energy campus that can be a model for other facilities. The Navy and Marine Corps expect to spend $2.5 million on developing methods to integrate cogeneration into tactical systems. And the Air Force is in the market for ideas to maximize renewable energy development on its vast test ranges.

According to Chris Lippert, corporate initiative leader for energy efficiency at $2-billion consulting engineering firm **Tetra Tech**, federal agencies have pent-up demands for energy efficiency and renewable energy projects—demands that are finally being satisfied with ARRA funding. "DOD and all federal agencies have been under some form of federal mandate to reduce energy use for some time," said Lippert, citing the Energy Policy Act of 2005 and the Executive Order 13423 signed by former President George Bush in 2007. "But these mandates have not traditionally come with funding. Now that the stimulus package has made funds available, federal agencies are well positioned to implement a large wish list of projects to cut energy use and save on energy costs. There's a great opportunity for the private sector to provide those services."

While many businesses can become federal contractors, given the rigid timelines for spending in the ARRA, Lippert and others think that the vast majority of spending will go to existing contractors. "Existing contract vehicles are incredibly important," he said. "The contracting staff on the federal side is already overtaxed and now they're being asked to take on this significant chunk of work."

That doesn't mean that only those already in the federal doorway need apply because there is great scope for subcontracting work. In demand will be installers and integrators of renewable energy and energy efficiency equipment and projects, but also consulting firms with relevant expertise.

According to Lippert and other executives familiar with federal contracting, becoming a subcontract supplier to a federal contractor is not all that difficult. "As long as you can prove you have your relevant licensing, such as a plumber's license for installing solar water heating, you can start on day one," said Scott Sklar of the **Stella Group**, a firm that integrates solar, wind, geothermal and other renewable energy sources for public and private sector clients. "You may have to get some additional bonding and insurance."

Where to Find Opportunities

Sklar, Lippert and others agree that the best places to start looking for federal subcontracting opportunities are the federal websites, particularly GSA.gov and FedBizOpps.gov. "You have to take the time to troll through and look at all the opportunities," said Sklar. "The U.S. government is the biggest user of energy in the world and the biggest owner of buildings. I suggest focusing on the niches where you are most capable.... You may have done a lot of medium-sized business renovations and now you want to install solar systems for medium-sized buildings. Well, that's different from doing a giant base dormitory that is six square blocks. Focus on what your experience level is and look at the government through that lens."

Sklar takes note that energy efficiency and renewable energy contractors may be able to find significant opportunities with some of the 16 energy service companies (ESCOs) designated as primary energy service performance contractors by DOE in December (see list above). CCBJ's conversations with a couple of these entities indicate that they anticipate being in the market subcontracting vendors, but

DOE's Primary Energy Service Performance Contractors

Ameresco
Chevron Energy Solutions
Clark Realty Builders
Consolidated Edison Solutions
Constellation Energy Projects & Services
FPL Energy Service
Honeywell International
Johnson Controls Government Systems
Lockheed Martin Services
McKinstry Essention
Pepco Energy Services
Siemens Government Services
TAC Energy Solutions
The Benham Companies
Trane U.S.

their needs are probably more skewed to implementation rather than planning and analysis. (Funding for many of these projects is not tied to ARRA but rather to cost savings achieved by energy conservation measures; CCBJ will cover ESCOs and energy service performance contracting in our upcoming edition on energy efficiency and demand response.)

The GSA handles purchasing and procurement for multiple federal agencies, and many federal contractors hold what are known as multiple award schedule contracts that GSA administers. "A multiple award contract schedule allows any federal government agency and some state agencies and some contractors to the federal government to access the products and services through the GSA," said Al Tattersall, a senior vice president of federal contractor **GP Physics**. "The advantage to agencies in doing it this way is that it reduces the amount of time for contracting." GSA schedules have already been analyzed and vetted for fair pricing of products and services, and individual agencies can essentially shop among GSA schedule holders for vendors, then work through GSA to execute the contract quickly.

According to Lippert, federal agencies have different preferences regarding whether to procure services through a GSA schedule or handle their own procurement. "It really gets down to a specific branch of DOD, a region or even a specific base within that region," he said. "The preference may come down to a certain individual procurement officer's experiences."

The eLibrary on GSA.gov can be used to locate firms that hold multiple award schedule contracts. With stimulus money flowing, many of these firms will be already looking at how to ramp up their capabilities through subcontractors. "We have been approached by government agencies with which we have contracts, and we've been told that they are expecting stimulus funding that would expand the scope of work that we would provide through our existing contracts," said Tattersall.

There's also the option to look for specific contract opportunities being offered directly by federal agencies. GSA's FedBizOpps.gov website lists any contract greater than $25,000, according to Tattersall. "In this case, you're not looking for the contract vehicle but the types of procurement that are being opened for solicitation," he said. He suggests prioritizing solicitations based on NAICS codes and geography for regional firms, then contacting the relevant agencies directly.

For businesses that meet federal small business criteria (see SBA.gov/faqs), most federal agencies have liaison staff who can assist in locating prime contractors who may be bidding on specific projects. "You tell them the type of work you do and they will assist you, including telling you companies who are bidding on contracts where you could be a good subcontractor," said Tattersall. "Almost every military facility, including NASA, has someone responsible for getting small businesses involved in acquisition primarily because Congress sets targets for small business contracting."

Tetra Tech's Lippert says that such requirements will lead his firm to subcontract even when it possesses all the needed capabilities for a contract in-house. "We're a large firm and proud of our broad expertise, but since a number of federal clients have small business requirements in their contracting, we'll plan to exceed those," said Lippert. "There could also be niche technologies where we need to bring in a technical specialist."

(Tattersall and Lippert also noted that for small firms willing and able to become qualified as federal contractors, contracting requirements can put their firm in the prime contractor spot with larger firms acting as subcontractors. "Some of the small-business set-asides can be for quite sizeable contracts, so there's often a real need for the expertise and experience that a large business can provide. We are in mentor-protégé and joint-venture relationships with some small businesses that qualify for set-asides," said Lippert.)

As far as making contact with and cultivating a subcontractor relationship with a federal contractor, Tattersall recommends the additional step of registering as an interested party for solicitations of interest on FedBizOpps.gov. "They'll post your name as a company looking to subcontract."

Lippert underscores Tattersall's advice about using the small business liaisons at DOD facilities, but he says old-fashioned networking and marketing can be valuable as well. "Getting involved with groups, where they want to do business, that will give them insight and referrals is a good start," he said. "The Society of American Military Engineers, for example, has monthly meetings and is a great place to do business networking."

"We certainly get cold calls and have people sending us information, but even in this modern world where we're all tied together through technology, my preference would be to meet someone face to face at a SAME meeting or have an introduction facilitated by a small business liaison from one of the DOD branches." If such introductions lead to a potential relationship, it is always preceded by thorough vetting, said Lippert. "Just because we have this glut of funding, we'll still continue to do thorough vetting of subcontractors. The taxpayers don't want to see projects funded that aren't high quality." ☼

Reasons for Regional Variations in U.S. Geothermal Power Prices

- 1) Transmission Access; 2) Utility Attitude towards renewables; 3) RPS requirements; 4) Supply and Demand; and 5) Competition from other sources
- Regulatory structure, energy efficiency mandates, market manipulation of pricing
- RPS states, proximity to fuel, natural resource availablity, transmission constraints, labor costs
- RPS and transmission infrastructure
- States pushing RPS have higher prices; regions with marginal pricing based on natural gas-fired generation currently have lower pricing
- Transmission access, level of Renewable Portfolio Standards, utility attitude towards geothermal
- Transmission capacity/ installed power conversion technology
- Free market pricing is subject to the law of supply and demand, and stimulus/incentive. We are seeing voluntary standards causing some important rises in price paid for renewables, with incentives coming from contribution to portfolio in a utilities footprint, and what that utilty thinks it can safely pass to their rate base. A Federal Renewable Porfolio Standard will change the game significantly (at a cost to all rate payers). Time will tell, but in the meantime, there is sufficient demand and pricing to make hydrothermal projects work financially, and that is what it's all about.

Source: CCBJ 2009 Geothermal Survey conducted in April 2009. Question was: Please comment on variations in power prices in U.S. states and regions and what causes these variations.

Ormat Leads Market With Technology and Vertical Integration

Ormat is the clear leader with $350 million in sales, but more competition is seen for low-temperature geothermal projects using binary technology

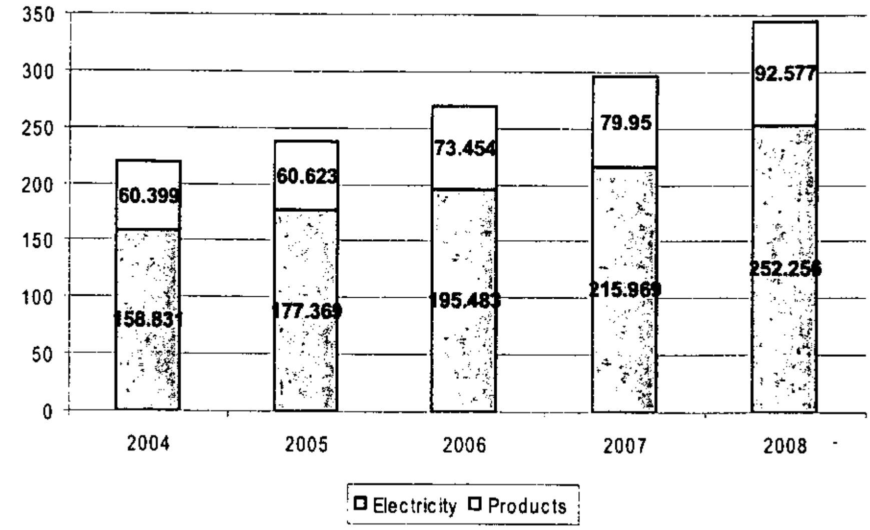
The geothermal power industry is made up of project developers and independent power producers (IPPs); scientific and technical consultants; drilling outfits and drilling technology firms; manufacturers of power plant equipment; and consulting engineers who explore for resources and design and build power plants. Many firms perform multiple roles in this value chain, but there is only one truly vertically integrated corporation whose activities and revenue streams stretch from resource exploration through equipment manufacturing to engineering, procurement and construction (EPC) contracting and power sales: **Ormat Technologies.**

According to its 2008 annual report, Ormat generated $344.8 million in revenues in 2008, 16.5% growth over 2007. Ormat's power sales revenues from its geothermal plants (both Ormat-built and acquired) and recovered energy generation (REG) plants (see below for more on REG) accounted for $252 million or 73.2% of revenues with product sales accounting for $92.6 million or 26.8% of 2008 revenues. Ormat built 109 MW of company-owned geothermal and REG capacity in 2008 and increased its portfolio to 505 MW. Ormat is on track to build between 82 MW to 94 MW by the end of 2010 for its own portfolio, according to a company spokesperson.

This cash flow from electricity sales puts Ormat in an enviable position relative to smaller developers that are struggling for needed upfront development capital in the current economic climate. "The cash flow generated by our portfolio of operating geothermal and REG power plants provides us with a robust and predictable base for our exploration, development and construction activities, to a certain level without the need to tap into external liquidity sources," notes the annual report. "We believe that this gives us a competitive advantage over certain competitors whose activities are dependent on external credit and financing sources, particularly in light of the current global credit and financial crisis."

The company's reported highlights for the last year alone show just how broad and diverse its geothermal operations and revenues are. Among its accomplishments: Signing a $65 million contract to supply and oversee construction and startup of a geothermal power plant in Costa Rica; Starting commercial operation of 35 MW of new plant capacity in Kenya; Securing rights to some 150,000 acres of land in Alaska, California, Hawaii, Nevada, Oregon and Utah; Acquiring 51% ownership of a New Zealand geothermal plant; Signing a joint venture to develop a new geothermal project in Nevada; joining a power development consortium in Indonesia; Signing EPC contracts with developers in New Zealand and Nevada worth $42 million and $76 million; Signing a $16 million supply contract for a geothermal project in Turkey; And closing a $63 million tax credit financing deal for an existing plant.

Ormat Revenues 2004-2008 ($mil)



Source: Ormat 10-K for fiscal year 2008 ended December 31, 2008. Products includes revenues from four groups: Power Units for Geothermal Power Plants; Power Units for Recovered Energy-Based Power Generation; Remote Power Units and other Generators; and Engineering, Procurement and Construction (EPC) of Power Plants. Electricity includes three groups: Energy and capacity; Lease portion of energy and capacity; and Lease income.

Israeli Roots, But U.S. Was 72% of Ormat's Revenues in 2008

A U.S. company with Israeli roots, Ormat was founded to develop and market heat exchangers and turbines using the organic rankine cycle (ORC) which Ormat founder Lucien Bronicki and his collaborator Harry Zvi Tabor, both Israeli, developed in the early 1960s. ORC uses working fluids with boiling points lower than water to recover energy and generate steam and power from heat sources that would otherwise be insufficient to power steam generators. The original technology was developed at **the National Physical Laboratory** in Jerusalem in the frame-

Ormat 2008 Revenues ($mil)

	Electricity	Products	Total
Foreign	$45	$51	**$96**
USA	$207	$42	**$249**
Total	**$252**	**$93**	**$345**

Source: Ormat 10-K for 2008.

work of solar energy research. Lucien Bronicki formed Ormat in 1965 in Israel.

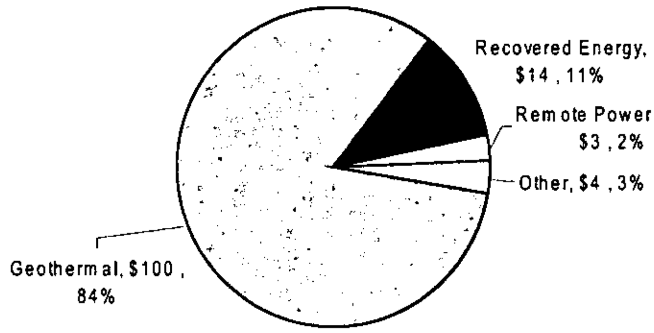
Bronicki originally targeted solar thermal applications in remote off-grid villages, but with that technology facing poor commercial prospects, what emerged from his work was the small Ormat Energy Converter (OEC), a power unit for remote telecom stations, offshore oil and gas rigs and other off-grid facilities that need small amounts of electrical power.

In 1972, Ormat was established in the United States where it supplied OEC units to the Trans Alaska Pipeline. According to material published on Ormat's website, for remote power applications the OEC uses natural gas, kerosene, diesel and other combustion fuels to heat the working fluids, which the hermetically sealed unit condenses and re-uses, allowing continuing operations for many years with periodic refueling and maintenance. More than 3,500 OECs of up to 7 kW capacity have been have been installed in 63 countries, according to Ormat's website.

Ormat turned its attention to geothermal, solar and biomass in the 1970s, with geothermal eventually becoming its major focus. Its business model has steadily evolved from that of a supplier of power systems and components to a vertically integrated firm that builds, owns and operates its own geothermal power plants as an IPP, as well as an EPC contractor that builds power plants for other geothermal project developers.

The company continues to market small OECs and REG systems. For its REG segment, Ormat foresees major growth by selling to North American natural gas pipeline operators who produce waste heat at compression stations driven by gas turbines. Ormat reports that the **Federal Energy Regulatory Commission** (FERC) is asking proponents of new or expanded pipelines to improve their energy efficiency.

Ormat Product Revenues: Expected Sales in 2009 ($mil)



Source: Ormat 10-K for 2008. Products include revenues from four groups: Power Units for Geothermal Power Plants; Power Units for Recovered Energy-Based Power Generation; Remote Power Units and other Generators; and Engineering, Procurement and Construction (EPC) of Power Plants.

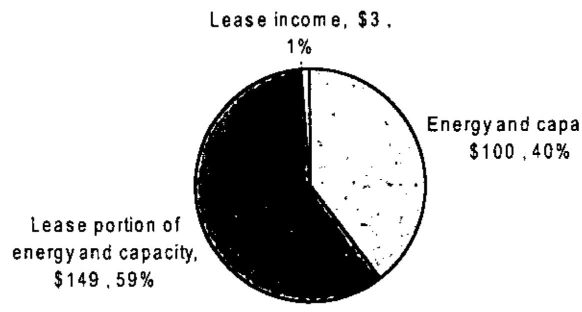
Ormat has begun building 5 to 6 MW REG systems along interstate natural gas pipelines and midstream gas processing facilities. The company also see opportunities for REG in the power sector in Colorado, Massachusetts, Ohio, Pennsylvania, Washington and other states where utilities can install REG systems on power plants and count the capacity toward their renewable energy standards. Additionally, North and South Dakota and the U.S. **Department of Agriculture** have qualified REG systems for low-interest loans. In North America, Ormat estimates the market potential for REG at 1,000 MW. After building out this domestic market, the company plans to target Europe which has "similar potential," according to the report.

By contrast, the potential for adding geothermal power in the United States is much larger. Ormat's Director for Policy and Business Development Paul Thomsen says the company sees the potential for geothermal power capacity to grow to 30,000 MW to 40,000 MW by 2050, or an order of magnitude larger than the less than 3,000 MW in 2009. As has been widely reported, a 2007 **Massachusetts Institute of Technology** study projected a potential of 100,000 MW of geothermal generating capacity if enhanced geothermal systems (EGS) can be deployed successfully. (For more on EGS, see page 29.)

More Competition for the Binary Technology Segment

Ormat built its geothermal power business by leveraging its ORC expertise to create what became known as binary geothermal power plant technology. When Ormat first entered the geothermal market in the early 1980s, its technology was an upstart contender.

Ormat Electricity Revenues: 2008 ($mil)



Source: Ormat 10-K for 2008

Most of the action was focused on using conventional flash steam generation with high-temperature geothermal resources of 350 degrees fahrenheit and above. But when Ormat's technology came on the scene, those high-temperature resources were starting to become more scarce because they were the most favorable for geothermal power and therefore developed first. By the mid-1980s, geothermal project developers increasingly needed energy conversion technology that could make use of lower-temperature resources. "Until then people had only been looking for resources that had high temperature steam," said Thomsen.

While Ormat grew its business over the next two decades, it also facilitated the growth of the geothermal industry. Its niche technology position grew into a commanding lead in the fast-growing binary power plant segment, leaving the steam segment to other players, mostly large turbine manufacturers. "Ormat has never tried to compete with Mitsubishi or GE or other manufacturers on huge steam turbines," said Thomsen.

One industry veteran estimated that binary technology accounts for about 10% of the existing stock of geothermal capacity worldwide, and that Ormat has built 95% of those plants. Despite its lower penetration in commissioned power plants, binary technology represents the greatest growth potential because of the prevalence of undeveloped geothermal resources under 350° F, according to many industry experts. (Other factors go into the choice between flash steam technology and binary technology; see Nevada Geothermal profile on page 27 for more information.)

"In the United States, the low-temperature resources are huge," said Enrique Lima, general manager for overseas business of **West Japan Engineering Co.** (West JEC), a prominent and globally active geothermal consulting engineering firm. "The amount of hot water available is very large and the temperatures are well suited to the application of binary power generation. This is why many companies are trying to tap these resources."

Ormat Projects

Domestic	**Location**	**MW***	**Power Purchaser**	**Contracts Expiration**
Ormesa Complex	East Mesa, CA	57	Southern California Edison Co. (SCE)	2018
Heber Complex	Heber, California	92	SCE / SoCal Power Public Authoriy	2015-2031
Steamboat Complex	Steamboat, Nevada	84	NV Energy, Inc.	2018-2028
Mammoth Complex**	Mammoth Lakes, CA	14.5	SCE	2014/2020
Puna	Puna, Hawaii	30	Hawaii Electric Light	2027
Brady Complex	Churchill County, NV	22	NV Energy, Inc.	2022/2027
North Brawely	Imperial County, CA	50	SCE	2029
OREG 1	North and South Dakota	22	Basin Electric Power Cooperative	2031
OREG 2	North Dakota	5.5	Basin EP Coop	2033
Total Domestic Operating Projects		**377**		
Foreign				
Momotombo	Nicaragua	28	DISNORTE/DISSUR	2014
Zunil	Guatemala	24	Instituto Nacional de Electricidad (INE)	2019
Olkaria III Complex(8)	Kenya	48	Kenya Power and Lighting Co. Ltd.	2029
Amatitlan	Guatemala	20	INE	2026
GDL	New Zealand	8	Norske Skog Tasman	2015
Total Foreign Operating Projects		**128**		
Total Operating Projects		**505**		Expiration+
Under Construction				
OREG II	ND, MN, MT	16.5	Basin EP Coop	25 years
Peetz	Denver, Colorado	4	Highline Electric Asn	20 years
Puna	Puna, Hawaii	8	Hawaii Electric Light Company (3)	n/a
GRE(4)	Minnesota	5.3	Great River Energy	20 years
East Brawley	Imperial County, California	30	Southern Calif. Power Public Authority (5)	n/a
Jersey Valley	Nevada	18-30	NV Energy, Inc.	20 years
Total Under Construction		**82-94**		

*Source: Ormat 10-K for 2008. Projects under ownership only; *Ormat Share in Generating Capacity MW; **50% ownership; +Expiration in years following commercial operation date*

Lima points to other countries where binary geothermal development could be the pivotal enabling technology for geothermal because of the abundance of underground reservoirs of 350° F or lower. "Exploration and development of low-temperature resources is happening in countries as diverse as Australia and Greece, and in countries like Hungary, Romania, and Jordan, where oil and gas exploration has led to discoveries of hot water and interest in geothermal energy."

According to Tim Stephure, clean and renewable power generation analyst at **Emerging Energy Research**, binary technology is slightly more expensive than conventional flash steam generation technology, but Stephure says this disadvantage is mitigated by the fact that the exploration and drilling risks are reduced because developers have a better chance of tapping resources of sufficient enthalpy (heat energy) for the binary process. "In cost comparisons to wind or varying solar technologies, binary geothermal technology is very economically favorable," said Stephure. "The low-temperature market will probably have the highest growth rate going forward as there are so many more areas that can be explored.... Nevada has tremendous opportunities in this regard as well as some other states like Utah."

Ormat's Thomsen underscored Stephure's viewpoint about the lower risk levels and costs of drilling for low-temperature geothermal reservoirs. "Probably 90 percent of the geothermal projects in existence today were built on top of reservoirs that had some kind of surface expression such as hot springs or rapidly melting snow," he said. "Now that most of these have been developed, the industry is looking for what we call blind resources."

"Geothermal is where the oil & gas industry was in the 20s and 30s when they thought they were running out of oil because most of the reservoirs with surface manifestations had been utilized," said Thomsen. "We're now looking at deeper more moderate temperature resources that aren't inherently obvious or haven't been developed previously. In this phase, the advantage of Ormat's technology being able to user lower temperature heat is critical."

Stephure noted that European countries are banking on using binary technology as well as emerging EGS technology to tap the lower temperature geothermal resources under their soil as well as hot dry rock (HDR) resources. "A lot of European countries don't have those high-temperature resources you see along the Pacific Ring of Fire," said Stephure. "Germany has implemented a feed-in tariff for geothermal of up to €0.27. The base is €0.20 with enhancements of €0.04 if you do combined heat and power and €0.03 if you do EGS. This is the first direct incentive of this kind."

Technology Providers and Developers Vie to Compete With Ormat in Emerging Geothermal Niches

United Technologies, Raser, Turbine Air Systems, Exorka and others develop in manufacturing, the lab and in the field.

Although Ormat dominates the low-temperature binary segment of the geothermal power market today, competitors have emerged in the last several years. **United Technologies Corp.** is its most high-profile competitor on the power systems technology front. Since 2006, UTC has marketed its PureCycle binary technology systems for geothermal power. PureCycle is a 280-kW modular unit that can be deployed in arrays to create commercial-scale plants. According to Michael Ronzello, North American sales and business development manager for **PureCycle** (marketed by UTC's **Pratt & Whitney Power Systems** division), PureCycle promises faster construction cycles. "Our modular approach to power plant deployment drastically reduces construction time," said Ronzello, indicating that plants can be constructed in 6-12 months (after hot water supply is established). "We have the capability to leverage Pratt & Whitney Power Systems 20 plus years of expertise and experience in the power business to provide full turnkey geothermal power plants using PureCycle".

While UTC doesn't publicly disclose prices for its equipment, Ronzello said the company expects to compete with Ormat's cost per MW of capacity by sourcing components from a UTC-owned affiliate. "We use off-the-shelf components and technology from our sister division, Carrier, the leader in commercial HVAC equipment," he said. According to Ronzello, Carrier produces components for PureCycle "in a pre-engineered, pre-manufactured fashion that drives down costs, increases quality and allows customers to take advantage of the lead time that is common in Carrier."

Raser Gains Efficiency With Networking

UTC's largest customer and best advocate is **Raser Technologies** (Provo, Utah). Raser has leveraged its expertise in electric motor technology to develop methods of networking the modular UTC units for optimal performance and efficiency. "Just like there are people who make computers and people who network computers together to function better, we've figured out how to network [the UTC PureCycle units] together so they can work in harmony and produce electricity more efficiently," said Richard Putnam, Raser's director of investor relations.

It's not clear yet how UTC's PureCycle systems will compare with Ormat's in terms of performance, costs and reliability. The geothermal developer community, while not unhappy with Ormat's equipment and EPC work, would certainly welcome additional competition in binary technology. But with over 20 years of experience and a proven ability to execute the guaranteed EPC contracts that lenders need to see before financing projects, Ormat will not be an easy competitor to take market share from. "We have been able to simplify our processes over time," said Thomsen. "We have fewer moving parts. We have a low speed turbine that doesn't require a gear box. Our power plants have become much more efficient over time [and EPC] projects much more streamlined and more efficient [resulting in] longer run times, greater longevity, less wear and tear on turbines, less opportunity for pump failure, less piping."

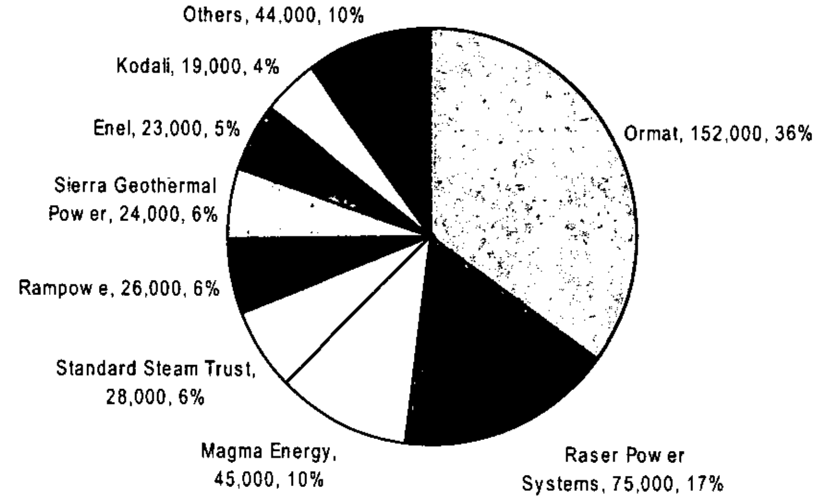
The industry is watching closely to see how the first Raser-UTC plants perform and what their construction costs are. Raser brought its first project online in 2008, the 11-MW Thermo No. 1 plant in Beaver County, Utah. According to Putnam, production wells drilled for the plant revealed a larger-than-expected geothermal reservoir capable of supplying steam for more than 200 MW of power plant capacity. "We had thought there were maybe 20 to 30 megawatts, but after doing some nice drill-out, GeothermEx, an independent geothermal consulting company, was able to verify and independently report that this is now a 230 megawatt resource," he said.

Raser's annual report for 2008 reported a capital cost for Thermo No. 1 of $88.1 million, with at least another $9.5 million needed to get the plant up to full operating capacity. That would seem to indicate a capital cost of about $7,000 per kilowatt of gross capacity. (After supplying its own pump loads Thermo No. 1 will produce 10 to 11 MW net from gross power capacity of 14 MW). That amount is far higher than the typical $4,000 per kW of gross capacity cited by developers at the recent Geothermal Innovation and Investment Conference or the $3,500 to $4,500 per kW range cited for Ormat plants by Ormat's Thomsen. (Those cost ranges include the highly variable cost of resource exploration and wellfield development. "We know the price of plants we build down to the penny. What we don't know is the cost of developing the resource," said Thomsen.)

But according to Putnam and Raser CEO Brent Cook, the nearly $100 million price tag for Thermo No. 1 included the production wells that revealed the reservoir's very large potential plus the cost of a larger transmission line to ship more electrons than anticipated to the company's electricity customers (currently the City of Anaheim, Calif.). "We are comfortable that the $57 to $59 million range is accurate for non–recurring development costs," wrote Cook in an email. "We expect our costs to be $3,800 to $4,200 per MW installed cost."

Raser's Beaver County development is just the opening salvo in a four-state development program that the company

BLM Geothermal Competitive Leases by Acres, 2007–present



Source: Compiled by Emerging Energy Research; By state the 2007-2008 leases are 52% in Nevada, 34% in Utah and 9% in Oregon, 4% in Idaho. Others include Agua Caliente, Oski Energy, Geothermal Technical Partners, Silver State Geothermal, Vulcan Power, Geothermal Rail Ind. Dev., Miller Dusty, S4 Consultants, Montera Energy Ventures, US Geothermal, Calpine, First Covenant Construction, US Renewables Group, Kelsey South, High Valley. Figures in acres rounded to the nearest thousand acres. BLM is Bureau of Land Management.

expects to yield hundreds of megawatts. Indeed, Raser aims to become a major developer and IPP operator of geothermal projects in the United States, Indonesia and elsewhere.

After Ormat, Raser is the second largest acquirer of geothermal leases on federal land since 2007. According to figures compiled by **Emerging Energy Research**, Ormat purchased leases to about 150,000 acres (the company owns leases on a total of 220,000 acres according to its annual report), followed by Raser with approximately 75,000 acres and **Magma Energy** with about 45,000 acres (see chart above). "We have accumulated domestic geothermal interests in Nevada, New Mexico, Oregon and Utah," notes Raser's report. "With the help of internal and external geologists, we intend to continue to identify, evaluate and acquire additional interests in properties." And last year, Raser and **Indonesia Power** were the successful bidders on a geothermal concession in Indonesia that covers approximately 100,000 acres with potential resources. At CCBJ's deadline, Raser and Indonesia Power will still finalizing their joint venture agreement.

Turbine Air Systems Exploits Rankine Cycle

Another emerging potential Ormat competitor that some in the geothermal industry are excited about is **Turbine Air Systems** (TAS; Houston), an industrial cooling and heating systems manufacturer that has begun developing technology for geothermal applications. TAS already has a foothold in the power industry with its modular inlet chilling units that can increase the efficiency of gas-fired power plants in hot climates. "TAS has translated this modular construction to geothermal power and advanced waste heat recovery organic Rankine cycle systems," states a company brochure. The company aims to leverage its experience in the power sector to offer design and engineering services for geothermal developers rather than just off-the-shelf sales.

Halley Dickey, director of geothermal business development for TAS, told CCBJ that the company has developed a renewable energy division aiming to provide power plants to solar thermal power projects as well as geothermal and industrial heat recovery. "We've been working on the development of our organic Rankine cycle program for seven years," he said.

"We own some unique patents related to geothermal binary technology." The first plant to deploy a TAS system may be on the horizon, as Dickey said the company is negotiating with an undisclosed potential U.S. client to supply a 15-MW plant in 2010.

Kalina Has Backers & Detractors, Needs Manufacturer

A third competitor in the binary geothermal power systems segment is **Exorka** (Munich, Germany), which markets binary technology based on the Kalina system using an ammonia-water mixture as a working fluid. One speaker at the March 2009 geothermal industry conference disparaged the Kalina system from the lectern, saying that after promising to revolutionize the industry and unseat Ormat, the technology had gotten nowhere. The speaker claimed that there are only two Kalina plants worldwide and neither are operating. One conference participant speculated to CCBJ that the difficulties facing the Kalina process stemmed from its use of a mixture of ammonia and water; because the two fluids boiled at different temperatures, Kalina systems had to cope with constantly changing compositions.

But Exorka's CTO Gestur Bardarson reported that four of five Kalina cycle plants built since the late 1990s "have mostly shown high reliability, although some equipment problems have been present [but] no more ... than can be expected for new technology employed in the first commercial plants." A 2-MW plant in Husavik, Iceland, achieved a capacity factor of between 89% and 96% from 2005 to 2007, according to Bardarson. A 3.3 MW waste heat plant at a **Sumitomo Metal Industries** steel plant in Japan has been running smoothly since 1999 with an annual capacity factor as high as 99%, he said.

Raser's Richard Putnam told CCBJ that company staff has evaluated Kalina technology and visited some of the pilot plants. "We believe the technology has a positive operating history that should be discussed. It is unclear who will take the manufacturing lead on the technology, but we believe the technology is sound and proven."

There is also a prospective nano-technology entrant, Power Chips being developed by Gibraltar-based **Borealis Exploration**. The technology was announced in 2003 with a promise of superior power conversion for geothermal applications, waste heat recovery and other applications. A news release described Power Chips as "solid state thermotunnelling devices which use a combination of thermionic emission and quantum mechanical electron tunnelling to increase the rate of electron emission in solid-state converters." But Power Chips appears to either be in deep stealth mode or inactive since the last news relase posted on its website is more than two years old. (An email inquiry to Borealis was not returned by CCBJ deadline.)

Ormat, of course, is not standing still technologically. Thomsen says that the company's more than 25 years of experience designing, managing and operating geothermal plants gives it a technical edge over prospective competitors. "Converting heat to electricity is very expensive and hard to do," said Thomsen. "Some of our competitors have tried to do cookie-cutter type plants that they can produce rapidly. We started with small units and gradually built larger and larger units, refining our knowledge and expertise continually."

Ormat also has an operational edge that enables it to get the most MWh out of its plants for the lowest operating costs, according to Thomsen and Ormat's annual report. "Our intimate knowledge of the equipment that we use in our operations allows us to operate and maintain our projects efficiently and to respond to operational issues in a timely and cost-efficient manner," states the report. "Moreover, given the efficient communications among our subsidiary that designs and manufactures the products we use in our operations and our subsidiaries that own and operate our projects, we are able to quickly and cost effectively identify and repair mechanical issues and to have technical assistance and replacement parts available to us as and when needed."

Ormat Takes a Crack at EGS

Ormat is pushing the frontiers of geothermal technology in two key initiatives with the **U.S. Department of Energy**, one to explore the potential to exploit hot water that is co-produced with oil and gas and another to advance enhanced geothermal systems (EGS).

At the **Rocky Mountain Oilfield Testing Center** (RMOTC) in Wyoming, a 250-kW Ormat binary power unit started generating electricity in September 2008 using heat from 190° F water that is co-produced with oil. The potential to generate on-site power from such a set-up is enormous. RMOTC estimates that U.S. oil and gas wells that produce hot water along with hydrocarbons could generate "upwards of 5,000 MW of power," according to an RMOTC news release.

Ormat's Thomsen told CCBJ that the project is "over-producing what we had expected it to do." But moving ahead with co-production at oil and gas drilling sites will be a challenging endeavor. For one thing, there's the fact that according to RMOTC, the water recovered with oil or gas is usually only heated to a maximum of 220° F, far lower than what geothermal developers prefer to produce power economically. Furthermore the costs of operating such a system will depend on how the hot water is disposed of, i.e., through reinjection or surface dumping.

Probably much more significant to the future of geothermal power is Ormat's DOE-funded work on EGS with collaborators **GeothermEx**, **University of Utah**, **U.S. Geological Survey** and others on two

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EGS demonstration projects.

As discussed in in the following feature on enhanced geothermal systems, EGS has the potential to vastly expand geothermal if it allows power to be produced successfully from hot dry rocks—as opposed to the conventional hydrothermal resources relied on for all geothermal power today, both flash and binary. The demonstration projects aim to hydraulically stimulate fractures that can enhance the production of hot water of sufficient enthalpy to generate additional power. "It's still very early stage R&D, but we're excited about not only developing technology to create standalone resources for EGS but also to create new life or viability for existing resources."

"We still need to prove the technical viability, and then get to the point of proving commercial viability," said Thomsen. "Ormat's experience has shown us that you can have complete technical success and zero commercial viability and vice versa." He also averred that it will be important to focus not just on the potential of EGS to greatly expand the pool of resources available for geothermal power but to look for ways to use the emerging technology to enhance existing geothermal power sites.

"If you can go back to wells that are less productive and, for lack of a more scientific term, tinker with them and produce more heat, we might determine that our potential hydrothermal resources may be much larger than we thought. For example, if you drill a well in a standard hydrothermal resource and don't get adequate permeability or heat, you might be able to use EGS technology to fragment back into the reservoir and stimulate adequate permeability and heat."

Growing Organically

With its healthy balance sheet and dominant vertically integrated position, Ormat might be expected to be on the hunt for project developers long on leases but short on capital. But according to Thomsen, the firm is reticent to diminish its third-party customer base through acquisition even though that might provide competitive advantages. "The only time we compete directly against another developer is when we're bidding on a resource at the federal land auctions," said Thomsen. "Once another developer is successful in achieving its resource position, we look to provide them with third-party power plant equipment."

Thomsen says that last year Ormat executives were asked by some in the geothermal industry whether they were considering making a bid for **Nevada Geothermal Power** when the developer was trying desperately to finance its Blue Mountain Project during the 2008 economic collapse. "People asked us 'Are you looking at this as potential acquisition?' We said no. We don't want potential third-party clients living in fear that we would acquire them when they run into financial difficulties."

Some financial analysts or deal-makers might argue Ormat is undervaluing the benefits of consolidation. But it's hard to argue with a business model in which Ormat's development arm pushes ahead with its own projects while earning revenues from equipment sales and EPC contracts—including $76 million from Nevada Geothermal for designing and building the Blue Mountain project.

Ormat's future is clearly tied to supplying and servicing a vigorous and growing geothermal industry, and to that end the company is a cheerleader for its counterparts as well as a competitor. Thomsen echoes a theme heard commonly in geothermal circles: The industry deserves more respect and recognition, and when elected officials, utility commissioners and activists talk about the importance of renewable energy, geothermal should be mentioned in the same breath as wind and solar.

"On one hand it can be frustrating that people don't recognize geothermal and its reliable baseload attributes as compared to wind and solar," said Thomsen. "But on the other hand, the investor-owned utilities we sell power to all know who we are and what we do. Geothermal might not be on the front page of the Wall Street Journal or the New York Times, but there are not many utilities who aren't familiar with geothermal. Serendipitously, after CCBJ interviewed Thomsen in April, Morgan Stanley put geothermal power on the cover of the *Wall Street Journal* on May 20, 2009, with a full-color ad touting geothermal as a sound investment, while promoting its expertise on the industry. "Unlike wind or solar energy, geothermal utilizes a constantly present energy source —the Earth. Just below our feet lies an industry that could reach $122 billion by 2030." While Morgan Stanley's 20-year valuation of the industry may be little more than an educated guess, the firm's promotion of its expertise harkens to what Thomsen says utilities have known for years: "To quote Michael Yackira, CEO of **NV Energy**, 'Geothermal projects don't look any different to an IOU than any other fossil fuel project,' While that's not sexy, it's a badge of honor for the industry. We're seen in their integrated resource plans as being just as reliable as coal or natural gas plants." ☼

Typical Geothermal Plant Development Costs ($/kw)

Development Stage	Cost ($/kW)
Exploration and resource assessment	400
Well field drilling and development	1,000
Poewr plant, surface facilities, transmission	2,000
Other dev't costs (fees, working cap, contingency)	600
Total development cost	4,000

Source: Geothermal Tomorrow, U.S.Department of Energy's Office of Energy Efficiency and Renewable Energy; Costs for a typical 20 MW plant or a total of $80 million; Does not include financing charges of interest rates 5-6% for some utilities or as high as 15% for IPPs."

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Nevada Geothermal Power, Last in Before the Credit Freeze, Looks to Heat Up the Geothermal Market

Cost of Developing a Geothermal Project

High front end costs

- High upfront confirmation costs, compared to other renewables
- Drilling, money, leasing, time

Phasing exploration mitigates risk

- Geochemistry, geology, geophysics and permitting: $2.5 million
- Temperature gradient drilling, slim-holes: $2.5 million
- Production test wells: $3.0 -$6.0 Million X 2
- $15 million plus to feasibility! Requires high risk upfront equity!

Source: Nevada Geothermal Power, presentation by CEO Brian Fairbank at Greenpower Conferences' March 2009 Geothermal Innovation and Investment conference

Like several other pure-play geothermal developers, **Nevada Geothermal Power** (NGP) is a Canadian company with a U.S. subsidiary targeting development prospects in the lower 48. NGP became something of a celebrity in the small U.S. geothermal world last year because it secured project financing for its 49.5 MW Blue Mountain power plant near Winnemucca, Nevada, just before credit markets locked up in the third quarter of 2008. But the company's experience also illustrated just how difficult it is to finance a geothermal power project in this economic environment.

The credit facility NGP received from **Trust Company of the West** on August 29, 2008 enabled it to give **Ormat Technologies** a full notice to proceed on a previously negotiated $76 million engineering, procurement and construction (EPC) contract and to conclude a $4.5 million deal with **Wilson Utility Construction** for a transmission line to the regional grid. As of spring 2009, the project was on schedule and NGP expected Blue Mountain to be in commercial operation by the end of the year. The power buyer is investor-owned utility **NV Energy**.

"Our timing was perfect," said CEO Brian Fairbank in recounting his firm's dash for cash last summer. "We had been working with **Morgan Stanley** on a 30-month construction loan that would have then been replaced with production tax credits for permanent financing." With a proven resource of 50 MW (40 MWe) and the guaranteed turnkey EPC bid from Ormat, the project looked solid, until the credit markets started to unravel in mid-2008. "All summer we'd been sitting down with Morgan Stanley and the syndicating banks trying to close the deal, but it was apparent even then that the credit markets were not working. Around the end of July we were basically running out of time and needed to move forward." That's when NGP got its financing deal done with TCW—at 14 percent.

"In today's economic environment, this financing looks good," said Fairbank. "It's a facility up to $180 million that we draw as we need it." Fairbank says NGP is currently packaging a production tax credit (PTC) based financing, a task that is by no means easy since the tax credit capacity of U.S. financial institutions has shrunk dramatically with their declining profits. The American Recovery and Investment Act (ARRA) stimulus bill extended the "placed in service" date for tax credit qualification for geothermal projects to December 31, 2013, so Fairbank is confident that buyers will be found. The plant's commercial operation date (COD) looming—it could arrive by October 2009—and the impetus to take out the 14% debt is rather compelling.

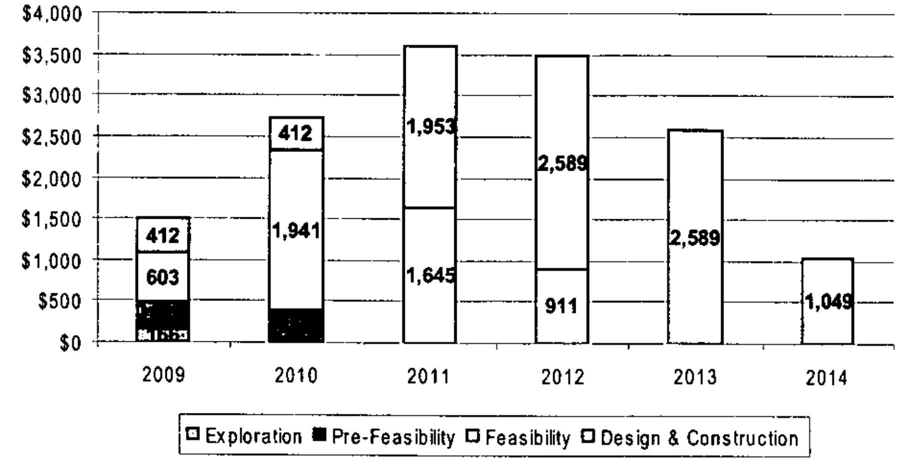
Selling the PTCs is NGP's most preferable option; as noted in CCBJ's Q1 2009 edition, the House-Senate Joint Committee on Taxation estimates that PTCs taken over the 10-year qualification period are worth roughly 50 percent more than the investment tax credit that Blue Mountain and other renewable generators can also qualify thanks to ARRA. "The PTCs are worth $21 a megawatt-hour to start with, indexed to inflation. So if we're selling power at $75 to $80 per megawatt-hour, that's pretty significant," said Fairbank. Accelerated depreciation is also on offer, and combined with PTC value, Fairbank figures that NGP can offer a buyer about $100 million worth of tax benefits.

However, in today's climate, Fairbank acknowledges that he may have to go with the new tax credit option provided by the ARRA: a grant in lieu of a 30% investment tax credit (ITC). But like other geothermal developers eyeing the grant-in-lieu-of ITC, Fairbank is concerned about how much of the upfront exploration and drilling costs will be considered tangible costs by the U.S. Treasury for the purpose of calculating the ITC. At CCBJ's deadline, guidance on that issue had not come forth.

As is the case for many geothermal projects, in the process of drilling wells to tap the underground hot water resources at Blue Mountain, NGP ended up hitting one dry-hole—not literally dry but of sub-commercial enthalpy (heat energy)—and some "false starts" in Fairbank's words on injection wells (used to stimulate continuing flow of hot water). "We drilled a well to the north that didn't turn out."

At $3 million to $6 million per well, the ability to include unproductive wells in the investment cost basis that qualifies

U.S. Investment Needs for Current Geothermal Projects ($mil)



Source: Prudential Capital Group, presentation at March 2009 Geothermal Innovation and Investment Conference; Inducates a total of $15 billion in new investment required to maintain momentum of projects underway

for the ITC is not trivial. According to Fairbank and other geothermal developers, typically 20% to 30% of the wells drilled on such a project end up not functioning as expected—but such dry-holes are an inevitable part of development, and they help the developer and its technical consultants understand more about their reservoir and target future drilling more accurately.

In fact, with the production drilling already completed, this gives Fairbank and his team reason to think that there is another 50 MW of geothermal power capacity to be tapped from the geothermal reservoir under their ground. "In oil and gas terms, there's an inferred or possible resource toward the mountain to the east," said Fairbank. Geoscientific and geochemical indications give strong hints of this. "The water we're producing now is 375 degrees Fahrenheit, but the chemistry of the water indicates that ultimate source temperatures greater than 400 Fahrenheit. In the long run we may not have found the hottest part of the resource." But more drilling is needed to prove it.

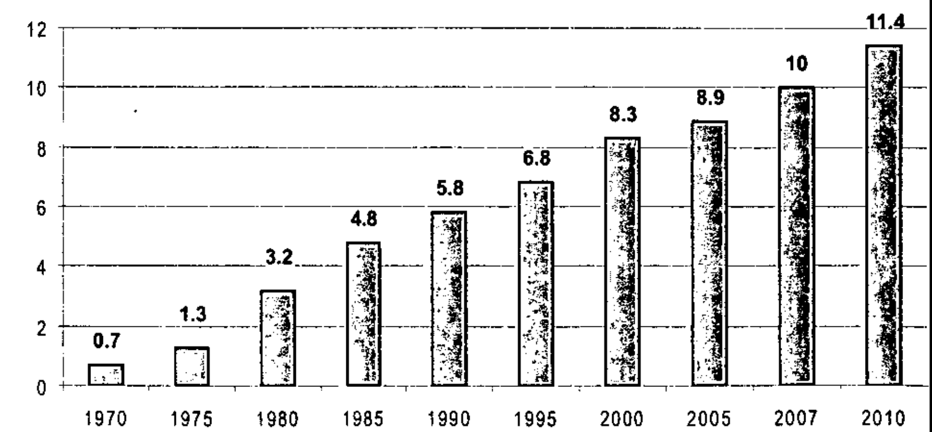
And speaking of temperatures, NGP's 375 degree Fahrenheit geothermal resource was hot enough to allow use of conventional flash steam technology—which would have resulted in a somewhat less costly power plant. But early on NGP chose the binary technology offered by Ormat, which uses working fluids and heat exchangers to capture the heat energy in lower temperature geothermal resources. According to Fairbank, the decision was based in part on the fact that while initial drilling turned up 375 degree Fahrenheit hot water, NGP couldn't be sure subsequent wells wouldn't be too cool for flash technology.

Plus, the closed-loop binary systems offered benefits for reservoir longevity and air quality permitting. "With binary you reinject 100% of the water and that helps maintain the overall resource's longevity because you're pressuring the reservoir," said Fairbank. "With flash, you're losing the vapor, about 30 percent of the water."

"Flash plants also have some slight air emissions in the vapor," said Fairbank. The most common is hydrogen disulfide—the rotten egg smell. "[To meet air quality regulations] you have to scrub that out. You can deal with it, but binary is absolutely emission free."

NGP is pursuing development of three other projects: Pumpernickel Valley and Black Warrior in Nevada and Crump Geyser in Oregon. With TCW funding for Blue Mountain only, NGP expects to be in the market for more financing soon. Because the expensive drilling programs must be funded by scarce equity—in the "hyperliquidity" era that ended last year, some debt funding might have been available—NGP is hoping that **the U.S. Department of Energy (DOE)** decides to use some of its $400 million in ARRA funding for geothermal to subsidize drilling programs. Either that or a piece of the $6 billion in new loan guarantee funds in the ARRA, hopefully made available in a process more streamlined that past DOE loan guarantees. "The existing established loan guarantee program is for technology [but for applicants] it has been more trouble than it was worth," said Fairbank. "My understanding is that the new program may be for other things, including geothermal drilling. The geothermal industry needs that." ✪

Global Geothermal Capacity, 1970-2010 (GW)



Source: Rocks To Riches: Global Geothermal Development by Mark A. Taylor, New Energy Finance. June 2008.

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EGS Could Vastly Expand Geothermal Power But Funding of RD&D Projects Needed

Conventional geothermal industry competes with EGS for scarce funding.

In our page one overview for this edition, CCBJ characterized the geothermal power industry as the veteran journeyman shortstop on the baseball team of the Low-Carbon and Renewable Power Segment. Well, if one thinks of the geothermal power industry as a professional baseball team, **enhanced geothermal systems** (EGS) would be the 15-year-old phenom impressing the pro scouts. Only that metaphor is not grand enough. Imagine that the scouts have discovered a whole high school full of future all-stars who are destined to break every baseball record without using steroids and triple the size of Major League Baseball's fan base and revenues. That's just the kind of game-changing status that EGS is gaining in geothermal research and investment circles.

While the U.S. resources for conventional geothermal power—also known as "hydrothermal" because underground hot water provides the steam supply for power plants—are limited to the West and capable of growing to between 30,000 and 40,000 MW, geothermal plants using EGS could be built almost anywhere. A **Massachusetts Institute of Technology** (MIT) study projects that EGS technology could enable geothermal power to supply 100,000 MW of capacity in the United States, nearly 10% of current installed electrical generating capacity.

But as of 2009, EGS (which also stands for engineered geothermal systems and is alternately known as HDR, for hot dry rock) is more like a kid trying out for little league. After three decades of research and field testing, there are no EGS power plants pumping electrons to a utility grid. "So far there have only been test power plants run on true EGS experiments where they've actually fractured the rock and circulated the water," said EGS expert David Blackwell, co-author of the MIT report and a professor of geophysics at **Southern Methodist University** at the March 2009 Geothermal Innovation and Investment conference in San Francisco.

Blackwell acknowledged that European EGS projects in France and Germany are generating grid power, albeit in amounts of 3 MW or smaller. But he told the audience that those projects are not what he considers true EGS because their developers drilled into subterranean rock with existing fractures. "They didn't actually make the fractures," said Blackwell. In Blackwell's and many others view, the first company to accomplish a true EGS project will likely be **Geodynamics** of Australia, which looks ready to culminate six years of R&D with a 1-MW geothermal plant in South Australia's Cooper Basin. The pilot project will power the remote town of Innamincka as early as the summer of 2009, displacing a diesel generator that costs $15,000 a month to fuel. "That will be the first real long-term, large-scale test of EGS," said Blackwell.

EGS Basics

So what is EGS? In a nutshell, it is using hydraulic fracturing techniques—commonly deployed in the oil & gas industry—to open up sealed fractures in hot rocks far underground, then using injection wells to push cold water through the newly opened fractures where it is heated and returned to the surface to supply heat for power generation. EGS "emulates naturally occurring hydrothermal circulation systems—those now producing electricity and heat," wrote Jefferson Tester and co-authors of MIT's 2006 report, *The Future of Geothermal Energy*.

MIT's report has generated buzz in the media and in investment circles. Before the recession, EGS drew some venture capital, which had been rare to non-existing in the mature geothermal industry. **AltaRock Energy**, which aims to develop a pilot EGS project by drilling into granite below the hydrothermal reservoir that fuels The Geysers power plant in California, received $26.25 million from **KPCB**, **Khosla Ventures**, **Google.org** and **Vulcan Capital**; **Potter Drilling** has received $4 million from Google.org.

Not exactly big numbers in the clean energy field where solar took in 40%, biofuels 11% and wind 6% of $8.3 billion in global cleantech investing in 2008. Indeed, most money going into EGS has come from governments, including the United States, Germany and Australia. MIT's report authors warn that governments will have to keep putting up money for some time to come. "It is likely that government will have to fully support EGS fieldwork and supporting R&D. Later, as field sites are established and proven, the private sector will assume a greater role in cofunding projects—especially with government incentives accelerating the transition to independently financed EGS projects in the private sector."

Australia, which has little in the way of conventional hydrothermal resources, is one of the most aggressive EGS funders. The government has pledged about $45 million for pilot projects, and several hundred million dollars in shareholder investments have flowed into about 10 public companies. Along with Geodynamics, the leading firms include **Panax Geothermal** and **Petratherm**. Yet, in the United States, many in the geothermal industry would prefer that government keep the fledgling EGS phenom on a diet and feed them instead, or as the case may be, keep them alive through this current period of capital scarcity. "It's great to spend money on EGS. That's the future," said Doug Glaspey, CEO of **U.S. Geothermal**. "But if you want megawatts on the ground today, you have to capitalize exploration. The way you do that is put it into drilling programs."

Hot Dry Rock vs. Hot Wet Rock

To one pioneering EGS/HDR researcher, starving RD&D to support the existing geothermal industry would be a case of history repeating itself. Donald Brown was one of the three scientists from the U.S. DOE's **Los Alamos National Laboratory** who pioneered HDR and created a test project—one of the few "true EGS experiments" in Blackwell's rankings—at Fenton Hill, New Mexico. "HDR was actually Bob Potter's invention," Brown told CCBJ. "Mort Smith and I modified it, and I wrote the patent."

The Fenton Hill team developed two confined HDR reservoirs, the first from 1975 to 1977 and the second from 1983 to 1985. The first phase was centered at a depth of about 9,200 feet with a mean temperature of 385° F and the second phase was 11,500 feet underground with a mean temperature of 455° F. Contractors **Dowell Oil Well Services** and **Halliburton** fractured the rock with hydraulic pressure until fissures and cracks that had been long sealed by precipitation were forced open—a common technique in the oil & gas industry. This part of the process included a feat that still impresses Brown today: a massive hydraulic fracturing in which Dowell injected 5.7 millions over two and half days at a surface pressure of 7,000 PSI. "No EGS stimulation has ever approached those numbers."

Hoop stress created by the pressurization made the reservoirs tight at their margins. Injection wells pumped cool water down and through the fractures, where it was heated, then up to the surface—so the system operated in a closed loop, comparable to an automobile cooling system. "The stimulated joints were held open by reservoir pressure, a pressure greater than the joint closure stress so that the HDR reservoir was highly dilated," said Brown. "We were not at all worried about the joints plugging up again with dissolved minerals, since all the dissolved mineral species reached equilibrium in the pressurized close-loop circulating fluid within about two weeks. No precipitation occurred thereafter anywhere in the earth loop."

Years of testing concluded in 1995 showed the potential to generate about 1-MW of electric power, so the team began soliciting a partner from the geothermal industry. "It would have involved bringing in a company like Ormat to build a binary power plant," said Brown. "We got bids, the bids were evaluated and a winning contractor had been selected." The project would have provided invaluable information on "how to best produce heat in an engineered HDR reservoir," according to Brown.

"Our modeling suggested that the one-third cubic kilometer reservoir would last 10 to 20 years. It could be extended laterally or in depth, and I've got other tricks up my sleeve to increase the productivity and lifetime, but we would need to run a reservoir to demonstrate those." But Brown says DOE declined to fund the project at the last minute, instead directing money to building a 29-mile pipeline to carry recharge water to The Geysers, then owned by **Unocal, Calpine** and **Northern California Power Authority**. According to a report by some consulting engineers for the project, the $48 million project was 40% funded by DOE and other public agencies.

"It was frustrating," recalls Brown. With a change in leadership at DOE's geothermal program, he says the agency "didn't understand HDR. They didn't understand what we had done. They just wanted to get us as a thorn out from under their saddle. We kept saying how good HDR was and they kept saying 'but the industry doesn't like it so we're not going to fund it.'"

Echoing Blackwell's viewpoint, Brown contends that most existing EGS test programs are not true HDR, but rather HWR, or hot wet rock. Other industry sources and the MIT report confirm this, but note that the aim of these projects is to engineer those currently unproductive hot rocks to increase their permeability and make them productive for geothermal power. Brown contends HWR technology misses the true home run potential for geothermal, however. "Less than 1% of the geothermal resource is naturally occurring fluids in place, either along faults or in a steam dome like at The Geysers," he said. "The other 99% is HDR. When you can utilize HDR, you go from a few little fly specks on the world map to the rest of the map."

Regardless of disagreements over HDR vs. HWR, Brown agrees with the rest of the EGS crowd in saying that better drilling technology is needed to enable EGS to go forward on a large scale. While conventional hydrothermal drilling doesn't go much below 10,000 feet, candidate resources for EGS power plants start at 10,000 feet deep and can be as much as 30,000 feet below the surface.

The MIT report says both "evolutionary" and "revolutionary" techniques will be needed; in the former category, the report authors look for "more robust drill bits, innovative casing methods, better cementing techniques for high temperatures, improved sensors, and electronics capable of operating at higher temperature in downhole tools"; and in the second category, "new methods of rock penetration [with] lower production costs."

Brown, who has come back from retirement to work on HDR as a guest scientist at Los Alamos, likes the hard-rock polycrystalline diamond compact (PDC) drag bit now being developed by a company called **Novatek International**. "It can improve the drilling rate by a factor of three and will cut our front end costs down considerably so the economics of HDR become more attractive." Brown is also working with some undisclosed venture capital investors who are considering a demonstration project at Fenton Hill.

"The reservoir is still there, and one of the wells is still in decent shape," he said. "If we started today we would probably have power coming off the lines in three years." He says the investors would look to patent some of the technology coming out of the project and build on their first-in-class reputation and expertise to roll out more and larger EGS/HDR projects... They're willing to lose money on the first power generation demonstration. They know that we have to produce power to go to the bankers in order to get funding to step out into other areas and do this HDR."

This theme was echoed by speakers at the March geothermal conference in San Francisco. "We need to cross that first hurdle of getting some demonstration projects going," said Susan Petty, CEO of **AltaRock Energy**. Government funding will be key, according to Petty and others.

"Hydrothermal projects have high upfront capital costs, but EGS has an even higher upfront capital cost with the added difficulty that it's an emerging technology," she said. "We've going to have to rely on funds from the government to help us continue our R&D and to guarantee loans or to provide low-cost capital so we can get our wells through, set up demo sites and run these systems for a while so we can show they work."

Yet, North American conventional geothermal developers—with more 3,000 MW of capacity in the pipeline largely stalled by the recession—say they need DOE money to go forward. "It's very important that these hydrothermal development programs not get stalled," said Brian Fairbank, CEO of **Nevada Geothermal Power**.

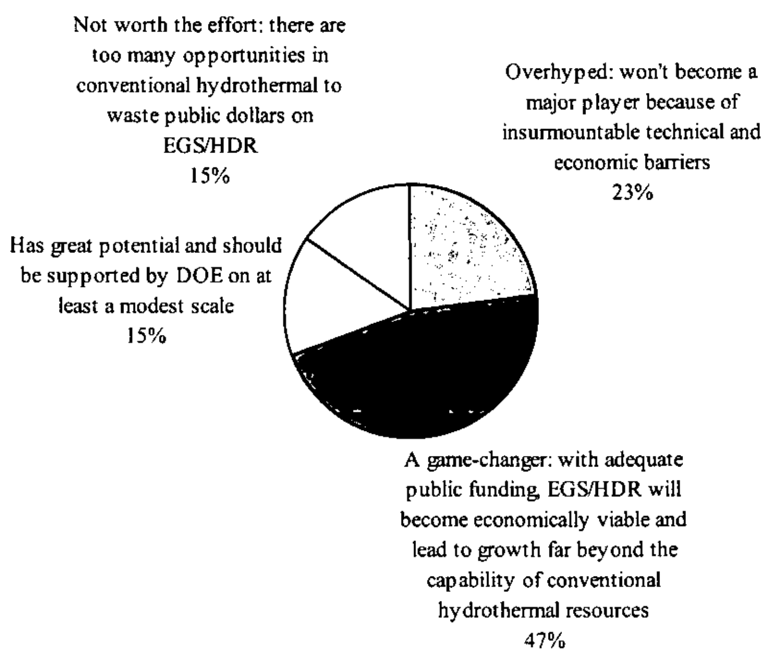
In other words, DOE's $400 million for geothermal is already overcommitted before the agency has had time to come up with disbursement guidelines.

Geothermal industry veterans, lenders and investors expressed a range of opinions to CCBJ about EGS's ultimate viability. "Do I think it can work, sure. But is it economic? I don't know enough to really comment one way or anther," said Ric Abel, managing director for electric finance at **Prudential Capital Group**. "When you start drilling holes 20,000 or 25,000 feet down, and you have to get a fluid down there and back up, you're talking about an enormous parasitic load. I just don't have a good feeling for how the economics will come together."

A veteran geothermal engineer who now consults for investors told CCBJ: "EGS is the holy grail, and like the holy grail it may be just a myth." But many who follow geothermal and other renewable energy technologies contend that with adequate public support, EGS/HDR will fundamentally change the geothermal game. "Work that we are doing in Canada suggests that with adequate investment we can utilize EGS successfully even when temperatures are between 125 and 150 celsius (257 and 302 Fahrenheit)," said Michal Moore, who is a senior fellow at the Institute for Sustainable Energy, Environment and Economy at the **University of Calgary** in Alberta, and a former member of the California Energy Commission. "With the impending changes to coal emission requirements and the retirement of a significant amount of nuclear baseload electric power, the potential of EGS geothermal is critically important."

Brown, who helped invent the concept of HDR geothermal energy, is now finishing a book covering the HDR Project at Fenton Hill and working with his project backers in Washington to get needed support from natural-resource agencies for restarting Fenton Hill (it's located in a national recreation area). At 77, his enthusiasm for EGS is as strong as that of a rookie slugger at the plate. "I want to see HDR out there commercialized and I'm working very hard to do that. Our plant can be online within three years, and from there, the future of HDR is almost unlimited." ✪

Opinions on Enhanced Geothermal Systems (EGS)



Source: CCBJ 2009 Geothermal Survey conducted in April 2009. Question was: Enhanced geothermal systems (EGS), also known as hot dry rock (HDR) technology, can vastly expand the use of geothermal power in the United States and elsewhere. Yet after more than 30 years of research, EGS has only been the subject of small-scale demonstration plants (and many observers say those projects are not using true HDR resources). Please check the category that best describes your general view of the future of EGS/HDR:

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Section 1: The CS SB 243 enacts royalty rates that mirror the federal royalty rates for a geothermal resource.

1. 1.75% of gross revenues for the first 10 years
2. 3.5% of gross revenues for the following years