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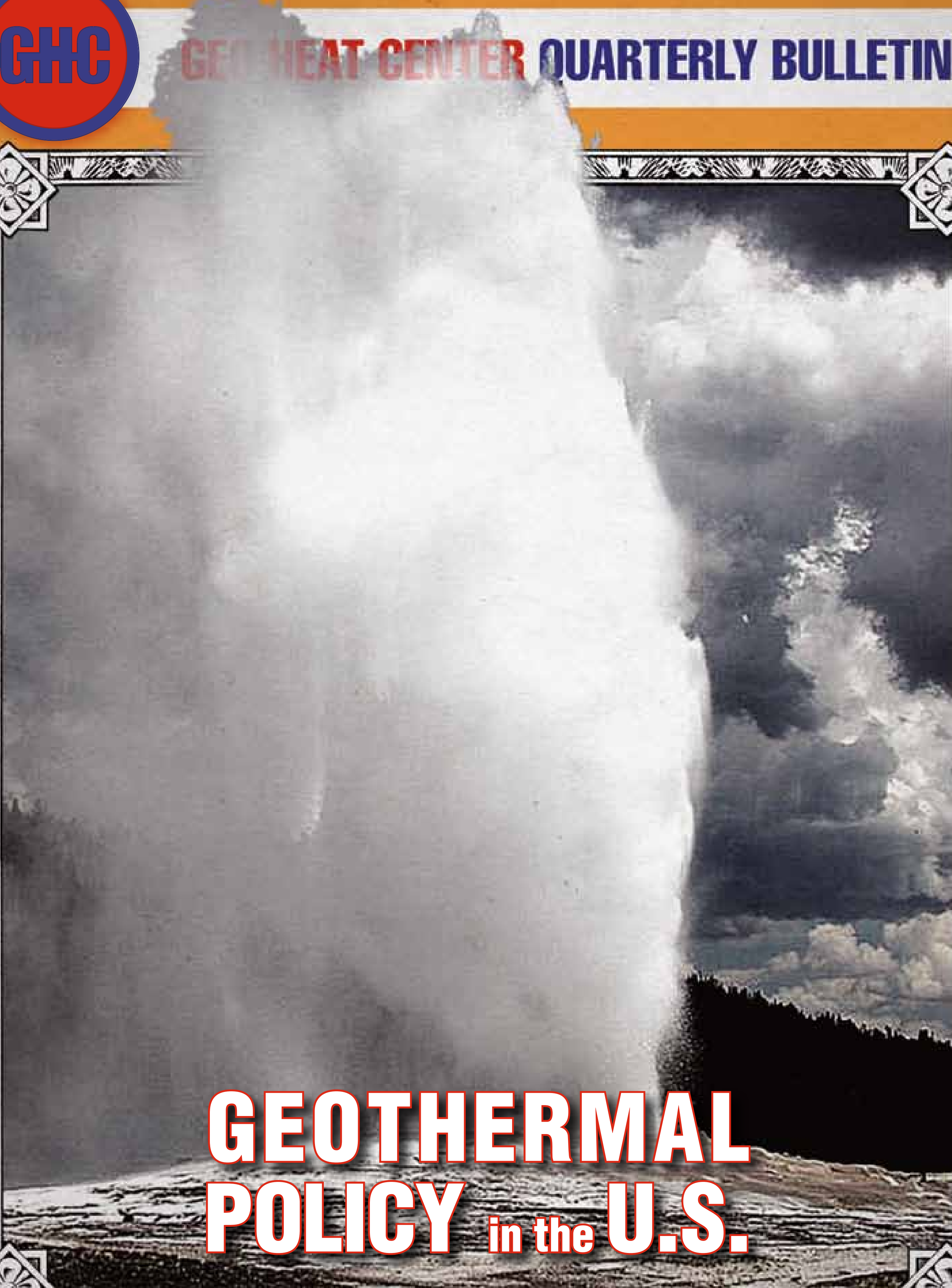

GEOTHERMAL POLICY in the U.S.

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A Quarterly Progress and Development Report on the Direct Utilization of Geothermal Resources

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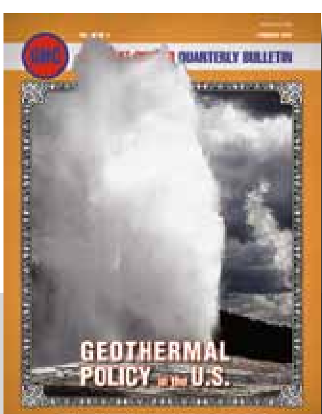

Cover: Old Faithful, courtesy of U.S. National Park Service. This quarter's cover is a loving homage to vintage "National Geographic Magazine" covers.

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DEVELOPMENTOF GEOTHERMAL POLICY IN THE UNITED STATES WHAT WORKS AND WHAT DOESN'T WORK

John W. Lund, Emeritus, Geo-Heat Center, Oregon Institute of Technology, Klamath Falls, Oregon; R. Gordon Bloomquist, Retired, Washington State University Energy Program, Olympia, Washington

ABSTRACT

Geothermal project characteristics and the conditions needed for success along with the various steps in developing a project are discussed. Geothermal policy in the United States started with the California Geothermal Resources Act of 1967 and the Federal Geothermal Steam Act of 1970. Various states followed defining a geothermal resource as either mineral, water, sui generis, heat or a combination of these. Federal incentives began with the Federal Energy Security Act of 1978 which included the Investment Tax Credits (ITC), followed by the Public Utility Regulatory Policy Act of 1979 (PURPA), and the Production Tax Credits (PTC). State incentives began with the Renewable Portfolio Standards in the 1990s, and various Renewable Energy Credits. Federal risk reduction policies to encourage geothermal development included the Geothermal Loan Guarantee Program in 1975, the Program Research and Development Announcement (PURDA), the User Coupled Drilling Program (UCDP), and the Program Opportunity Notice (PON) that provided funding for 23 direct-use projects in the late 1980s. More recently the American Recovery and Reinvestment Act of 2009 (ARRA) was funded at approximately $400 million for a variety of geothermal projects. To provide support to the various federal and state geothermal projects, the Geo-Heat Center at Oregon Institute of Technology was funded by USDOE Geothermal Technologies Office for over 30 years to provide technical assistance, preliminary feasibility studies and information dissemination of various successful projects throughout the United States.

GEOTHERMAL PROJECT CHARACTERISTICS AND WHAT IS NECESSARY FOR SUCCESS

Based on past experience the geothermal industry has learned that the following characteristics must be considered for a project to be successful (Lund, 2011):

- Every project is unique
- Simplicity is the key to operational success
- A strong promoter ("hero") is needed to develop each project (person and/or company)
- Resource characteristics determine the use and success or failure of a project
- Customers/market are needed to be successful
- Funding and cost are important
- Land, institutional, and environmental considerations play an important role
- Qualified persons/companies are needed
- The public/government/local concerns/acceptance must be considered
- Cascading can improve economics
- The resource temperature along with the flow rate and fluid chemistry will determine the best (economical) use of the resource. The following temperatures are general guidelines for the use of a resource along with the illustrations in Figure 1:
- >175˚C (350˚F) – flash steam electric power generation
- 100 to 175˚C (212 to 350˚F) – binary electric power generation
- 100 to 150˚C (212 to 300˚F) – industrial process energy/cooling
- 60 to 100˚C (140 to 212˚F) – space heating
- 30 to 60˚C (90 to 140˚F) – greenhouse and aquaculture pond heating
- 5 to 30˚C (40 to 90˚F) – geothermal heat pumps

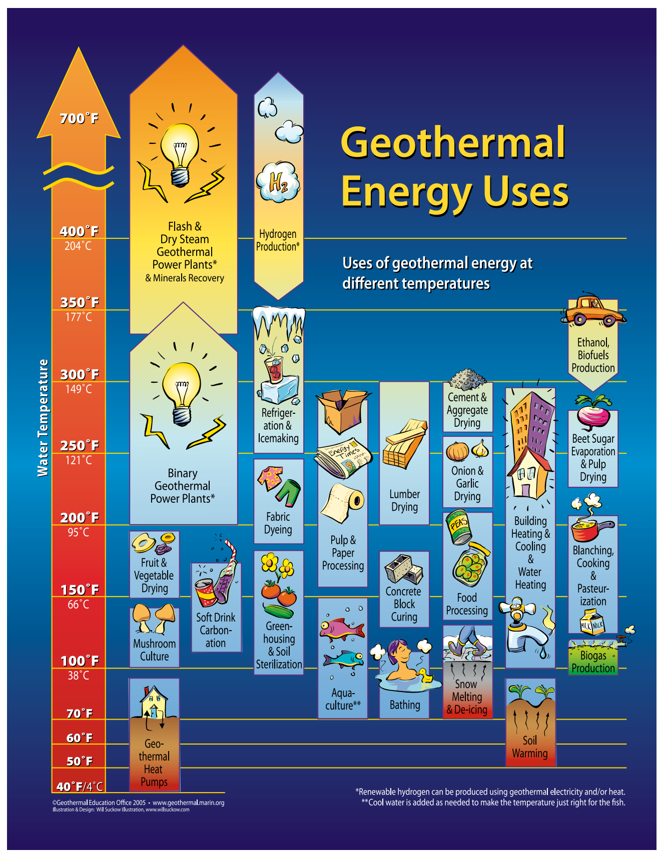

Figure 1. Geothermal Energy Uses (Geothermal Education Office).

A summary of the various factors needed to be considered (solved) for the success of a project are shown in Table 1.

Table 1. Conditions Needed to be Considered for a Successful Project (Lund, 2011).

	Flash	Binary	Direct-Use	GHP
Resource	XXX	XX	X	0
Ownership	XXX	XXX	XX	X
Permits	XXX	XXX	X	0
Environment	XXX	XX	X	0
Finance	XXX	XXX	XXX	X
Risks	XXX	XX	X	0
Expertise	XXX	XXX	XX	X
Market	XXX	XXX	XXX	XX
Hero/Leader	XX	XX	XXX	X
Transmission	XXX	XX	X	0
Public Acceptance	XXX	XX	X	0
Production Costs	XX	XXX	XX	X

XXX = Major X=Minor 0=None

NATIONAL ENVIRONMENTAL POLICY ACT

The National Environmental Policy Act (NEPA) of 1969 that became effective in 1970 was an environmental law that established a U.S. national policy promoting the enhancement of the environment and also established the President's Council on Environmental Quality (CEQ). NEPA's most significant effect was to set up procedural requirements for all federal government agencies to prepare Environmental Assessments (EAs) and Environmental Impact Statements (EISs). EAs and EISs contain statement of the environmental effects of proposed federal agency actions. The law applies to any project, federal, state or local, that involves federal funding, work performed by the federal government, or permits issued by a federal agency. Once a determination of whether or not a proposed action is covered under NEPA there are three levels of analysis that a federal agency may undertake to comply with the law. These three levels include: preparation of a Categorical Exclusion (CE), preparation of an Environmental Assessment (EA) and Finding of No Significant Impact (FONSI), or preparation of an Environmental impact Statement (EIS). If it is determined that a proposed federal action does not fall within a designated categorical exclusion or does not qualify for a FONSI, then the responsible agency or agencies must prepare an EIS. For geothermal projects, the EIS can require considerable time and funding to complete and is often contested, causing additional delays.

INITIAL EXPERIENCES IN PROMOTING AND DEVELOPING GEOTHERMAL PROJECTS

Two acts provided the initial framework for developing geothermal resources on public lands:

1. The California Geothermal Resources Act of 1967, and
2. The Federal Geothermal Steam Act of 1970.

Other western states followed suit over the years with the passage of their own geothermal acts – to establish a legal framework for leasing, exploration and development of geothermal resources – both for electrical power generation and direct-use.

The California Act of 1967 made the first attempt at defining geothermal resources:

> *"Geothermal resource" shall mean the natural heat of the earth, the energy, in whatever form below the surface of the earth present in, resulting from, or created by or which may be extracted from such natural, heat, and all minerals in solution or other products obtained from naturally heated fluids, bines, associated gases and stream, in whatever form found below the surface or the earth, but excluding oil, hydrocarbon gas, or other hydrocarbon substances.*

The Federal Geothermal Steam Act of 1970 and amended in 1988, defines geothermal as:

Geothermal steam and associated resources means:

1. *All products of geothermal processes, embracing indigenous steam, hot water and hot brines:*
2. *Steam and other gases, hot water and hot brines resulting from water, gas or other fluids artificially introduced into geothermal formations;*
3. *Heat or other associated energy found in geothermal formations; and*
4. *Any by-products derived from them.*

The resulting U.S. geothermal policies addressed the following issues in either legal (permitting, environmental, ownership, etc.) and/or financial (rent, royalties, taxes, grants, loans, etc.) terms:

1. Resource ownership and access
2. Regulations for the development and production of geothermal energy
3. Taxation (i.e., deduction of intangible drilling costs, and reservoir depletion allowance).
4. Financial incentives and risk reduction.

Requirements of the Federal Geothermal Steam Act of 1970 resulted in the following issues:

1. The question of ownership at the federal level was not determined until 1977 and in California until 1981 in court cases;
2. These court cases determined that the geothermal resources are mineral in nature and belong to the mineral estate;
3. Thus, the federal government and the State of California claims geothermal ownership wherever it holds the mineral estate;
4. The creation of the Known Geothermal Resource Area (KGRA) – where competitive leasing was required, or designated by the US Geological Survey;
5. Required an environmental assessment on all projects – either an EA (Environmental Assessment – minor) or an EIA (Environmental Impact Assessment – major).

The states followed with their own specific definition of geothermal resources. The definition varied from state to state:

- **Mineral resource** (Federal, California, Hawaii, New Mexico, Texas, and Nevada (if only used for heat content – classified as water otherwise),;
- Water resource (Alaska, Colorado, South Dakota, Utah and Wyoming);
- Sui generis – i.e. unique in itself: Idaho, Montana (governed by groundwater law), Washington (direct-use as ground water);
- Water or mineral (Oregon);
- Heat (North Dakota);
- Steam, hot water, heat or mineral (Arizona).

OREGON EXAMPLE

As an indication of how complicated geothermal rules and regulations can be, the Oregon classification system is as follows.

- If the water/steam is less than 250˚F (120˚C), then the use comes under the jurisdiction of the Oregon Department of Water Resources and is classified as "water".
- If the water/steam is over 250˚F (120˚C), then the use comes under the jurisdiction of the Oregon Department of Geology and Mineral Industries and is classified as "mineral".
- In addition, if the production well is over 2,000 feet (610 m) in depth, then the permitting comes under the Oregon Department of Geology and Mineral Industries – later changed to come under the jurisdiction of the Oregon Department of Water Resources.
- Now only injection wells over 2,000 feet (610 m) in depth, require permitting under the Oregon Department of Geology and Mineral Industries
- Ownership of the resources belongs to the owner of the surface estate.

ASSESSMENT OF GEOTHERMAL RESOURCES

To assist in the understanding and development of geothermal resources in the United States, the Geological Survey under the Department of Interior prepared several Circulars describing the geothermal resources by individual states. These data included reservoir thickness, volume, estimated temperatures and potential heat content. These Circulars were:

- Assessment of Geothermal Resources of the United States – 1975, Geological Survey Circular 726, edited by D. E. White and D. L. Williams. This publication included a listing of resources above 150˚C and also those from 90 to 150˚C.
- Assessment of Geothermal Resources of the United States – 1978, Geological Survey Circular 790, edited by L. J. P. Muffler. This publication include hydrothermal convection systems greater than 150˚C; systems from 90 to 150˚C; areas of favorable for discovery and development of local sources of low-temperature (<90˚C) geothermal water in the Western United States; and, thermal springs in the Central and Eastern United States.
- Assessment of Low-Temperature Geothermal Resources of the United States – 1982, Geological Survey Circular 892, edited by Marshall J. Reed. This publication included the estimated reservoir values and thermal energies of identified low-temperature geothermal resources in the Western United States, and low-temperature geothermal resources in the Central and Eastern United States.
- Assessment of Moderate- and High-Temperature Geothermal Resources in the United States, 2008, edited by Colin F. Williams, Marshall J. Reed. Robert H. Mariner, Jacob DeAngelo, and S. Peter Galanis, Jr., US Geological Survery Fact Sheet 3082.

ADDITIONAL FEDERAL LEGISLATIONS

The original Federal Steam Act of 1970 provided the following requirement for leases on Federal lands:

- Rent on non-KGRA federal land at $1.00/acre/year
- Rent on KGRA lands at $2.00/acre/year
- Rent increased to $3.00/acre/year after 6 years, only if designated a KGRA;
- Lease size; 640 to 2,560 acres (260 to 1,036 ha), with due diligence required (i.e. active exploration for a geothermal resource), with a maximum of 26,600 acres (10,350 ha), (later increased to 51,200 acres (20,700 ha)) leased in any state;
- Royalties for both electric and direct-use developments ranged from 10 to 15% on a net-back basis – either based on fossil fuel replacement or on actual sales.

The Federal Steam Act of 1970 was modified in 1974, 1980 and 1988 to address the need to provide incentives, reduce risk and thereby increase the competiveness of geothermal energy. This was intended to accelerate the leasing of federal lands. The royalty structure was also reduced as an added incentive as follows:

- For electricity production the royalties were:
  - › 1.75% of gross proceeds for the first 10 years
  - › 3.5% after 10 years
  - › A portion of the fees were sent to local governments
- For direct-use the royalties were:
  - › Annual fee per well between $100 and $1,000.

Other federal incentives included the Investment Tax Credits (ITC) enacted in 1978; The Public Utilities Regulatory Act of 1979 (PURPA); and the Federal Production Tax Credit (PTC) first applying to geothermal in 2004.

PURPA had the following requirements:

- Allowed for the first time the generation of electricity by non-utility companies, thus creating the private power industry;
- Required regulated utilities to purchase the output from these

facilities at their avoided cost; and

- Required utilities to provide transmission and backup service at a reasonable rate.

As a result several hundreds of megawatts of new geothermal generation came on line during the 1980s.

The ITC was the first significant federal tax provision under the Federal Energy Security Act of 1978. This act provided for deduction of intangible drilling costs and allowed for percentage reservoir depletion allowances. Intangible drilling cost deduction allowed a taxpayer investing in the drilling of a well for geothermal deposits to elect to expense the intangible drilling costs involved in the construction of the well in the same manner as an investment in oil and gas wells. Eligible intangible costs included such things as wages, fuel, repairs, hauling and incidental supplies that can represent a significant portion of field development expense. Unfortunately, slim hole temperature gradient and geochemical test wells as well as injection well costs were ineligible and must instead be capitalized with costs being recoverable only after production is established through depreciation (Bloomquist, 1986).

The percentage reservoir depletion allowance traditionally available to oil and gas was also extended to geothermal by the Energy Security Act of 1978. The Act provided for the percentage of gross income deductible for depletion, declining from 22% in 1978 to 15% for 1984 and years thereafter.

Two other tax credits were also provided by Congress in 1978, including the Residential Energy Credit and the Business Investment Credit. Both were later modified in 1980 under provisions of the 1980 Windfall Profit Tax Act (Bloomquist, 2003, and Bloomquist et al., 2008). The Residential Energy Credit allowed an individual taxpayer a credit for qualified renewable energy source expenditures made in conjunction with a principal residence. The amount allowed was 40% of the first $10,000 or a maximum of $4,000. This tax credit has unfortunately been eliminated. The Business Investment Credit provided a 15% tax credit for business investing in certain kinds of alternative energy property including geothermal. The percentage allowed was reduced to 10% and made permanent in 1992.

The Production Tax Credit (PTC) was first implement for wind and solar under the New Energy Policy Act of 1992, and later extended to closed-loop biomass and geothermal in 2004 (on a limited basis) and 2005 (on a full basis). For geothermal the initial tax credit was 1.8 cents per kW hour, available for five years and could be taken in addition to the business investment tax credit. More recently the tax credit was increased to 2.0 cents/kWh. It was one of the most important policy changed provided to the geothermal industry. However, a company could not take both the ITC and the PTC; they had to choose one or the other.

ADDITIONAL STATE LEGISLATIONS

A number of states also enacted tax incentives programs. These programs took the form of business tax credits, residential tax credits, property tax exemptions, sales tax exemptions and exemptions on public utility taxes. Some, but not all, of these programs also applied to eligible geothermal heat pumps installations.

The Renewable Portfolio Standards (RPS) were adopted in numerous states staring in the 1990s. These included provisions for:

- Ensuring a minimum amount of renewable energy is included in the portfolio of electricity resources for the state;
- Requiring retail electricity suppliers to include a minimum amount of their electricity supply from eligible renewable resources;
- Some states require that the amount of renewable energy come from specific resources such as solar PV, wind, geothermal, etc.,
- A typical requirement is: "20-20" – i.e. 20% renewable by 2020 (CO, HI, NM, DC), or "25-25" (IL, OR and MN), or "33-30" (CA).

Other state incentives include Renewable Energy Credits (REC), often referred to as "green tags" or "green certificates". These are provided by the state utility commission and have a market value of 1 to 2 cents/kWh. The RECs significantly improved the economic viability of a number of renewable generation technologies, including geothermal.

FEDERAL RISK REDUCTION PROGRAMS

A number of risk reduction programs to promote the development of geothermal projects in the U.S. were implemented by U.S.DOE-GTP (Department of Energy) (Geothermal Technologies Program) starting in 1975 through the early 1980s. These included the Geothermal Loan Guarantee Program (GLGP) initiated in 1975, the Program Research Development Announcement (PRDA) initiated in 1976, the Program Opportunity Notice (PON) initiated in 1979, and the User Coupled Confirmation Drilling Program (UCDP) initiated in 1980. The most ambitious program was the recent American Recovery and Reinvestment Act (ARRA) which started in 2009.

The GLGP provided the following:

- Loan guarantee for up to 75% of project costs with the federal government guaranteeing up to 100% of the amount borrowed;
- Encouraged new entrants into the geothermal market and enhanced competition;
- It was successful in furthering geothermal development in a number of locations including bringing direct-use and electrical generation projects on-line; and
- Amended in 1980 to allow for the granting of loans up to 90% of the total aggregate project cost providing that the applicant was an electric, housing or other cooperative or municipality; however, loans were limited to $100 million per project and no qualified borrower was to receive more than $200 million in loans.

The PRDA covered the following:

- Provided funds for detailed feasibility studies;
- Program directed at the completion of detailed engineering and economic feasibility studies of direct applications of geothermal resources; and
- USDOE targeted specific applications:
  - › Industrial process steam and moderate to low temperature heat for industrial plants (example: Honey Lake wood waste power plant in California);
  - › Agricultural, space, water and soil heating for greenhouses, grain drying, irrigation pumping and extraction of chemicals from agricultural produces;
  - › District heating and cooling for commercial-sized buildings or business complexes and residential development; and
  - › Mineral extraction. Process steam and moderate to low temperature heat for ore concentrating, leaching and flotation processes.

Solicitations for proposals were typically issued once or twice per years and grants were limited to between $100,000 and $125,000. Though generally considered to be successful, the program could have been significantly more successful if more emphasis had been place upon geologic, geophysical and other resource data as an integral part of the proposal evaluation process or if grants had provided monies for resource assessment as an integrated part of the program. The PRDA program was, however, closely tied to the USDOE Program Opportunity Notice (PON) Program described below.

The PON provided incentives for a number of geothermal direct-use projects:

- Provided opportunity for interested parties to propose direct utilization or combined electrical/direct application projects;
- Funded projects that would demonstrated single or multiple uses of geothermal energy;
- Applications included: space/water heating and/or cooling for residential and commercial buildings; agriculture and aquaculture uses; and industrial processing; and
- Grants were competitive and required cost share.
- The various projects funded included (Figure 2):
  - › Heating of 5 schools
  - › Heating of a hospital
  - › Heating of a prison
  - › District heating for 8 projects
  - › 4 agribusiness projects
  - › 3 industrial projects
  - › 14 of 23 projects are still operating

The most well known and successful systems are the district heating systems in Klamath Falls, Oregon, Elko, Nevada, and Boise, Idaho, a total of almost 100 buildings.

Figure 2. The locations of the 23 PON projects.

The UCDP provided the following:

- It provided mainly for direct-use projects but did include some electrical generation projects;
- Cost sharing with industry for the confirmation of hydrothermal resources, such as siting drill holes, drilling and flow testing, reservoir engineering, and drilling of injection wells;
- Absorbed a portion of the risk associated with the confirmation of hydrothermal reservoirs in the initial stages;
- Developed an experienced infrastructure of exploration, reservoir confirmation and utilization engineering consultants, contractors and equipment manufacturers who would reduce reservoir confirmation risks in the future;
- Cost sharing – 20% if successful; 90% if not successful;
- The Raft River 5 MWe experimental project funded in part; and
- Loans up to $3,000,000.

Unlike the PON program that was directed primarily at direct application of geothermal energy, the Industry Coupled Program was designed to be a cooperative effort between the USDOE and industrial organizations engaged in geothermal exploration for electrical power generation. The program was initiated to foster development by providing for:

- Cost sharing with industry for exploration, reservoir assessment and reservoir confirmation; and
- The release to the public of geoscientific data that would increase the understanding of geothermal resources.

The program was never well publicized and when employed not particularly successful in meeting its intended objectives because release of geoscientific data had little impact on broader industry participation in geothermal development since most land positions were already well established (Bloomquist, 2003, and Bloomquist et al., 2008).

Several additional loan programs were authorized through provision of the Energy Security Act that passed Congress in 1980. These included Feasibility Study Loans, Reservoir

Confirmation Loans, and System Construction Loans. The Reservoir Confirmation Loans Program was designed to replace the User Coupled Drilling Confirmation Loan Program to change the emphasis from direct-use projects to electrical generation projects. Despite passage and authorization by Congress, none of the loan provisions of the Energy Security Act were actually implemented because successive administrations failed to request the need appropriations (Bloomquist, 2003, and Bloomquist et al., 2008).

The ARRA program of almost $400 million of 2009 was implemented to "jump-start" a variety of geothermal projects including (Figure 3):

- A total of $368.2 million was allocated for 148 geothermal projects such as;
- Rehabilitating wells, proving resources, installing power plants, direct-use projects, and geothermal heat pump projects;
- Specific projects include:
  - › Innovative exploration and drilling projects ($97.2 million)
  - › Coproduced, geopressured and low temperature projects, mainly electric ($18.7 million)
  - › Enhanced geothermal systems demonstration projects ($44.2 million)
  - › Geothermal data development, collection and maintenance ($33.7 million)
  - › Ground source heat pumps ($62.4 million)
  - › Cross cutting R&D ($111.9 million)
- The funding is ongoing.

GEOPOWERING THE WEST PROGRAM (GPW)

This program (GPW) was implemented by the UDOE-Geothermal Technologies Program in 2001. The organization consisted of representatives from various federal organizations such as DOE, Idaho National Engineering and Environmental Laboratory, Scandia National Laboratories; National Renewable Energy Laboratory, and U.S. Bureau of Land Management, all the western state energy offices, along with a number of research centers, trade and education associations such as the Geothermal Resources Council, Geothermal Energy Association, Geothermal Education Office, and the Geo-Heat Center. The main goals of the GPW program were:

- Contribute to the overall increased use of domestic renewable energy, as recommended in the National Energy Policy, by:
  - › Doubling the number of states with geothermal electric power facilities from four to eight by 2010, and
- Supplying the heat or power needs of 5 million western homes and businesses by 2015.
- The program would pursue these goals by:
  - › Bringing together national, state and local stakeholders for state-sponsored geothermal development workshops;
  - › Working with public power companies and rural electric cooperatives to promote use of geothermal power;
  - › Promoting increased federal use of geothermal energy;
  - › Helping American Indians identify and develop geothermal resources on tribal lands; and
  - › Sponsoring non-technical educational workshops.

The GeoPowering the West working groups had a number of meetings and implemented some of program objectives over approximately a five-year period and did accomplish some of the goals (i.e. there are now 8 states with geothermal electric power facilities); however, the goal of heating 5 million western homes by 2015 may only be met with the help of geothermal heat pumps. All the western states were funded by the program to implement local programs, and a few, such as Montana, Idaho, Utah, Colorado and California are still active in pursuing some of the goals proposed by the GPW program.

Figure 3. ARRA projects and funding (Milliken, 2011).

TECHNICAL ASSISTANCE PROGRAMS

One of the first, most successful and long-lived programs providing financial assistance to developers was the USDOE's Technical Assistance Grant Program.

The program intent was to provide assistance to potential developers of geothermal energy who had little or no expertise in the geothermal field in order to promote the rapid development of direct application resources. Assistance was provided to all public and private entities on a non-competitive, first-come, first-served basis. Assistance was available in resource assessment and/or preparation of technical and economic feasibility studies and was limited to 100 hours. Assistance was provided either by one of USDOE's technical center or by a consultant selected by the center. A secondary aim of the program was to establish expertise in the private sector consulting industry (Bloomquist, 2003, and Bloomquist et al., 2008).

Due to an increasing desire to involve more private sector consulting companies in the provision of technical assistance, the program was later scaled back with the technical centers being restricted to eight hours of direct assistance on any one project unless an exception was provided. Technical assistance continues to be available through the Oregon Institute of Technology Geo-Heat

Center (GHC) with funds being made available through the USDOE. The program has been highly successful with numerous projects having been benefited by its ongoing availability. The initial work of the GHC included detailed state geothermal data basis and development status publications in 1979 for Alaska, Idaho, Montana, Oregon, Washington and Wyoming.

The Geo-Heat Center, established on the Oregon Institute of Technology campus in 1975, has been providing technical assistance to geothermal developers for over 30 years. This work has mainly been funded by USDOE Geothermal Technologies Program. The Center staff has responded to assistance requests from all 50 states and over 60 countries. In addition to technical assistance for direct-use, small scale electric power and geothermal heat pumps, the Center staff have performed feasibility studies, implemented Task Ordering Agreements (TOA) for specific projects, provided information dissemination in the form of a Quarterly Bulletin and writing technical papers, maintains a website with over 1900 files that includes data on 12,000 wells and springs in 16 western states, and performs outreach by offering training, presenting papers at technical meetings and with site visits. As an example of activity on the GHC website from 2008, the average hits per day were 11,000, the average users per day were 2,000 and the average downloaded pdf files per day were 4,000. Approximately 2/3 of the users were from the U.S., 10 to 15% were international requests, and the remaining from unknown sources.

CONCLUSIONS – WHAT WORKED AND WHAT DIDN'T WORK

Although all of the USDOE financial assistance programs, with the exception of ARRA and the technical assistance programs were terminated due to lack of congressional support, USDOE sometimes directly, but more commonly through one of the National Laboratories has continued to provide limited financial support. This support is generally directed to specific technologies, critical component development, resource exploration or demonstrations. Recent solicitations have been directed at for example small power plant demonstrations, critical power plant and well field components e.g. downhole pumps and enhanced evaporative cooling, direct-use applications and enhanced geothermal systems. All of these programs have required an industry cost share. Many of the initiatives, however, remain under-funded, and many projects have suffered from burdensome regulatory and administrative requirements (Bloomquist, 2003, and Bloomquist et al., 2008).

Some states have also provided significant financial assistance; of these, California is by far the best example. Funding has come from geothermal royalties on state lands and the states' share of Federal royalties. Projects supported included for example, resource assessment, drilling, technical assistance, regulatory compliance, technology development and demonstration and enhanced injection. In a number of states, such as Oregon, New Hampshire and Nebraska, investor-owned and/or public utilities had established incentive programs directed at promoting geothermal heat pumps. Some states provide tax reductions for installing geothermal heat pump systems, mainly of the closed loop design. Starting in 2008 the USDOE provided tax incentives for geothermal heat pumps by providing a 30% tax credit for residential installations and a 10% tax credit for commercial installations.

An indication of the influence of USDOE geothermal programs on the development of direct-use projects is shown in Figure 4. Note the increase in energy on-line after the start of the PON and other direct-use program staring in 1975. A similar increase in electrical generation starting in 1975 influenced by USDOE-GTP programs is shown in Figure 5.

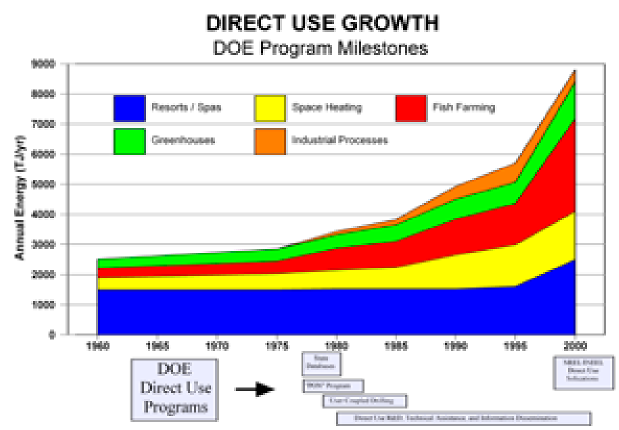

Figure 4. Direct-Use Growth with USDOE-GTP Programs 1960 to 2000.

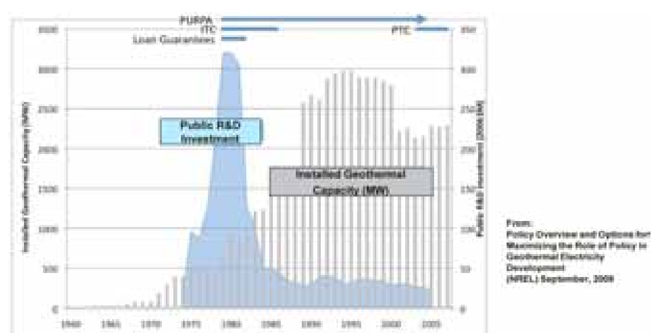

Figure 5. Installed electrical generation with USDOE-GTP program 1960 – 2008 (Milliken, 2011).

One of the main problems with USDOE-GTP support of geothermal projects has been the variable funding over the years from a high of around $150 million (1980) to a low of $5 million (2007) as shown in Figure 6. Since around 1984 funding for the GTP has remained fairly constant at around $30 to $40 million annually. The only recent increase was for the ARRA program in 2009. In addition the emphasis of the USDOE-GTP R&D program, as in part directed by

Congress, has changed annually. Some of the most resent emphasis are on Enhanced (Engineered) Geothermal Systems (EGS), Co-produced fluids from oil and gas wells, and Geothermal in Sedimentary Basins.

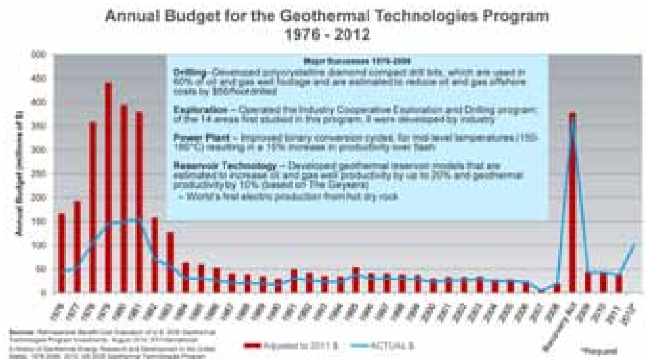

Figure 6. USDOE-GTP funding by year (Milliken, 2011).

Some of the other impediments to geothermal development are:

- Lack of reservoir insurance, however, a program of this type would tie up funds for up to 20 years, and the results are difficult to evaluate;
- Lack of public involvement and knowledge of geothermal energy (the “hidden” renewable resource);
- Leasing difficulties and time frame for leasing on federal lands, especially when the Forest Service is involved;
- Lack of recent emphasis on direct-use for small-scale developers;
- Transfer of the geothermal heat pump program to USDOE Building Technologies where it receives less emphasis;
- EAs and EISs are expensive and time consuming and often contested; and
- Information from USDOE funded projects is often limited or difficult to access for the information.

A summary of the major success for the GTP from 1976-2012 are:

Drilling – Developed polycrystalline diamond compact drill bit, which are used in 60% of oil and gas well footage and are estimated to reduce oil and gas offshore costs by \$56/foot drilled.

- Exploration – Operated the Industry Cooperative Exploration and drilling program; of the 14 areas first studied in this program, 8 were developed by industry
- Power Plant – Improved binary conversion cycles; for mid-level temperatures (150-190˚C) resulting in a 15% increase in productivity over flash
- Reservoir Technology – developed geothermal reservoir models that are estimated to increase oil and gas well productivity by up to 20% and geothermal productivity by 10% (based on The Geysers) – world’s first electric production from hot dry rock.

Other U.S. geothermal accomplishments include:

- Geothermal heat pumps is the fastest growing geothermal application with over 100,000 units installed annually and a total of over one million united installed – we are the worldwide leader;
- A number of universities have contributed to the education and development of geothermal resources along with have R&D programs including: Utah (EGI), Southern Methodist, Stanford, Oregon Institute of Technology, MIT/Cornell, University of Nevada – Reno, etc.
- Private industry has developed geothermal electric power as a worldwide leader, with over 3,000 MWe presently installed; and
- Geothermal energy is now mentioned along with other renewables (most of the time.)

U.S. renewable energy policy has continued to change over time in an attempt to best meet the needs of these emerging technologies. Geothermal has been the focus of numerous policy initiative directed at expanding the industry and bringing both electrical and direct applications on-line. Much of the early emphasis was placed on direct financial support in the form of loans, guaranteed loans, grants, government cost sharing or insurance. However, as Federal funding became less and less available the emphasis turned more towards creating markets for geothermal power and/or rewarding companies for success through production tax credits or direct monetary support. No matter what form policy takes, it is critically important that it provide a level playing field for all renewable (Bloomquist, 2003, and Bloomquist et al., 2008).

EDITOR’S NOTE

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BUILDING A COMMUNITY-BASED DATA NETWORK FOR GEOTHERMAL ENERGY

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ABSTRACT

There are many issues associated with the development and sustainability of a network of data sites and databases hosted by academic-based groups. Some of these are technical, most are nontechnical issues. These academic institutions have always had the dual missions of conducting research on geothermal systems while educating the next generation of geothermal professionals and researchers. Now, a third role is emerging, that of data stewardship as it applies not only to research and education, but also: 1) as a tool for industry as they push forward with delineating and producing geothermal resources, 2) for state and federal agencies to help them meet their missions and mandates, and 3) as a tool to inform the public on the importance of geothermal energy.

The basic notion of a data network is that several data sites come together to collaborate on acquiring particular suites of data and making them available to the larger user community. Over the last ten years, there has been a growing awareness of the importance of better data management; indeed both Congress and the White House continue to strengthen the bipartisan goal of free and open access to all data created by the federal dollar. For academic-based data sites, there are many challenges to building and sustaining an effective data network. The first challenge for a network is to agree on the system standards for sharing and providing access to the data among the data sites, the nodes, on the network. Several international and national groups have developed global standards that can be utilized, but the key issue is on the specific implementation of these as system standards for the network. The bigger challenges are operational and reflect social-cultural and political realities. The conclusion is that first and foremost the focus must be on the geothermal user community. Then a successful network must operate under the principles of openness, collaboration, flexibility and a willingness to change. The latter is critical as the developers and the community being served become more knowledgeable and involved, as technologies evolve, and as opportunities for sustainability come and go. As long as the academic groups and the interested federal and state agencies are willing to collaborate there should be few barriers to creating the envisioned dynamic system.

INTRODUCTION

Significant growth in contribution of geothermal to the international energy portfolio requires reducing the risks and cost of defining resources, characterizing new classes of larger energy resources, optimizing management and expansion of exploited geothermal fields, expanding direct use of geothermal, and ensuring a path for technology growth into the future, in particular providing the science and engineering basis for conventional and enhanced geothermal systems (EGS). All of this is predicated on an enhanced knowledge, and knowledge requires accessible data. This summary statement comes from an unpublished proposal (W.S. Snyder and J. Moore, co-PIs) and is summarized on the National Geothermal Data System website (NGDS, in which all co-authors participate; www.geothermaldata.org). In this paper, we do not address the NGDS specifically, although most of what we say is applicable. Rather, we are addressing the fundamental challenges for academically based groups involved in creating, maintaining, sustaining, and expanding such a network, utilizing the data needs of geothermal energy as an example. We certainly hope that the insights we present here will be incorporated into the NGDS as it moves forward. We are also fully aware of the importance of working with federal and state agencies on these endeavors and of international collaborations - we are doing both. But here, we focus on the issues associated with bringing together this group of core academic institutions. A network can be envisioned as an Internet-connected series of nodes (data sites), that allow for a common approach to finding data among the linked sites. Each of the co-authors' groups have for years collected and provided data to researchers, industry, state and federal agencies, and the public and this collaborative approach extends the reach and effectiveness individually and collectively. The issues discussed here reflect our collective experiences.

DATA STEWARDSHIP - WHY YOU CARE

Over the last ten years there has been a dramatic increase in awareness of the need to fully manage data generated by research and development activities, industry and federal and state agencies. This long education process perhaps has not yet peaked, but the realization that data are the underpinnings of science and engineering, the basis for investment decisions, and that they are crucial for land and natural resource management has been noted and documented by the National Science Board (NSB, 2005), the National Academy of Sciences (NRC, 2002, 2009), and emphasized by Congress and the White House (e.g., Interagency Working Group on Digital Data, 2009; OSTP, 2009; and http://www.ostp.gov/cs/issues). This awareness is continuing to grow with the advent of federal agency data management plans and requirements, the awareness from major publications of the importance of data, continued discussion by the Federal Interagency Working Group on Digital Data and in a number of National Research Council reports, as well as in the general literature (e.g., NRC, 2002; Atkins et al., 2003; Atkins et al., 2011; Hey et al., 2009; Nature Editorial, 2009; NRC, 2009; and many more). We seem to be moving at a faster pace. This is a good thing. Both Congress and the White House continue to strengthen the bipartisan goal of free and open access to all data created by the federal dollar. However, we as an industry, science, and nation have not done an adequate job of capturing and providing these scientific data to users (researchers, industry, state and federal agencies, and the public) and not just data produced by federal funding.

Many of the data critical for this expansion of geothermal energy are inaccessible - they are beyond the reach of those who could use them. A Department of Energy DOE report by Deloitte (2008, pg. 27) concluded that: "A study conducted in 2000 for NREL (Entingh, D., 2002) revealed that over a 25-year period, numerous geothermal research efforts were conducted with state and federal funding and that the analysis and information contained in those research documents are difficult to access. That same study cited that much geothermal resource attribute data also exists but is distributed among numerous locations and often stored in boxes, without any data index or organization. Even these identified data represent a small part of the overall data that exist, but is inaccessible and that would significantly help the efforts to expand geothermal's portion of the nation's energy portfolio if we could find and access them."

But the issue of data stewardship goes beyond geothermal and DOE - it is a general problem that cross-cuts many disciplines and institutions. Each person, be they a researcher, employee of a company or a federal or state agency, needs to become more aware of the long-term value of the data they generate through their activities - to become better data stewards. For researchers, no longer is it sufficient for them to document their work by only publishing a paper, even if a supplemental data table is included. For companies, data management is an issue of retaining knowledge, the corporate memory, making better business decisions, and being able to do a better job of attracting outside investments. For agencies the impetus for better data stewardship can be a mixture of what drives both researchers and industry, but also the fact that they are the public's stewards of data generated by their tax dollars. It is not sufficient to think of data management only in terms of datasets and their associated papers. We need systems where all data associated with all research can be accessed in their most granular, discrete form while maintaining the attribution of each bit of data to its original author. These data must be openly accessible, once they are public, but held privately during a publication moratorium period. We need to have seamless links from the databases to publications. This will allow future users to easily move from the published paper to the data and metadata behind the publication and just as easily utilize these data in their ongoing research as well as give researchers citation credits for their efforts at data stewardship.

THE VISION

For geothermal energy, a data network as a system needs to capture the full geologic, geophysical, and engineering context of geothermal systems on scales ranging from regional to the individual well bore to the thin section and microscopic scales. Thus the system must be able to handle physical, geophysical, geochemical and a host of other data for use by scientists, engineers, project managers, investors, researchers, and others. In addition to supporting the science and engineering aspects of geothermal resources and associated research, the system would provide the basis for financial investment risk analysis. It will also support state and federal agencies with land and resource management missions and serve as an interface to the public and decision-makers. Finally, it can and should be designed to contribute to enhancing the education pipeline and diversity for people entering the geothermal industry. In summary, it is far better to under-populate an expansive data system than it is to rebuild a narrowly designed one. Hence, the ultimate system must meet the breadth and depth of needs as we can see them now and that is designed to efficiently and effectively expand and migrate into the future as the needs, visions, and technologies change. It cannot be built all at once, but having a clear roadmap of where we want to be is critical to the network's long-term success and viability.

SOME BASICS

Data Types

There are many ways to describe the types of data that must be accommodated, but the baseline distinction is as follows:

- **Data resource:** a generic term for all digital files that can be stored at a data site.
- **Data product:** includes preformatted text documents, photos, diagrams, datasets, videos and viewable maps. Metadata may or may not be included or may be incomplete.
- **Datasets:** a type of data product where discrete data are provided, typically in spreadsheets, sometimes word processing tables. They are "products" in the sense that they are usually pre-populated and preformatted with data selected by the author, not the user. Metadata may or may not be included or may be incomplete.
- **Discrete data** are the "base" or "raw" data that populate the tables and fields of a database; these include data and the metadata that describe the data.

In addition, all data products and most datasets are "static"; that is they reflect the content views and filters of the authors who created them and cannot (and should not) be modified. Conversely, some datasets and all discrete data are "dynamic" in that the content of any grouping of data may change with time as more data are captured into the data system. The concept of a "dynamic dataset" is important. A dynamic dataset (which can include or solely be comprised of geospatial data) is one whose structure is defined by an author or user, data are pulled from a structured database (or data warehouse), and are updated periodically from the database, hence "dynamic" (for example, time series data from a remote sensor).

Metadata

Metadata are "...'data about data', or more explicitly structured information that describes, explains, locates, or otherwise makes it easier to retrieve, use, or manage a … resource" (NISO 2004), be that a digital document such as a report in Word format, a spreadsheet of chemical analyses on a rock sample, a photo, a map, etc. The definition or at least the application of metadata can become blurry because what metadata is to one person may be data to another. The easiest way to think about this is to not overly worry about the distinction between data and metadata, and ask and answer the question: "Do I have sufficient data to totally describe the feature I'm dealing with?" - for example, a chemical analysis of a rock. In addition, metadata are a means of allowing others to find data - as long as enough metadata information is provided. What are the results reported as (elemental, oxide, etc.)? What are the measurement units? What are the errors and what type of instrument was utilized? What standards were used? Etc. These metadata are critical to document the quality of the data - without them, allows the assumption that the data are of lower quality. Each metadata element has to have a definition that is more formal than those just listed so others (or machines) can understand what is meant. Therefore, metadata are important. Also each piece of discrete data has to have a definition associated with it - something that describes that data point, be that in a cell in a spreadsheet or a field in a structured database. Finally, the data are not random, but have relationships among them; for example the SiO2 as a type of chemical analysis (analyte) has to be associated with a sample (think sample number) as well as with its value (e.g., 53.2) and that value with a unit (e.g., %).

Extensible Markup Language (XML)

XML (eXtensible Markup Language) has been an indispensable part of moving data around on the web including the catalog and thematic web services mentioned below. It is a set of rules and guidelines for describing structured (or semi-structured) data in plain text, standardized by the World Wide Web Consortium (W3C). It is used to create a text-based file with "tags" that describe and provide structure to the data, which together with the schema (the ordered relationships among the data) make the document machine readable, understandable and parsable so data can be extracted by the user's computer in an application, such as a browser. It requires that each data element have a specific name and definition. The power is that if an XML schema is adopted as a standard, say for well logs or bottom hole temperatures, then it allows these relevant data and metadata to be mutually shared across nodes on a network and with any other global site provided they accept that particular schema. Also, such standardized content promotes easy data mash-ups by the user who may find data at various sites and desire to compile them into a single data set. Finally, it should be noted that newer mechanisms for data exchange on the Internet continue to evolve, e.g., JASON, REST, etc., but the toolsets and standards for these have not yet matured to the same level as XML and XML schemas.

User Focus

The major lesson learned to date is that technology alone cannot drive the creation of a network - rather, more attention must be paid to the users, those that generate and use the data and have little or no interest in the technologies behind the data systems. IT mechanisms should influence, but not dictate how data are acquired, what data are acquired, or how those data are tagged for archiving. For example, web services, linked data mash-ups, and Resource Description Framework (RDF) documents are wonderful tools that have sprung from the notion of the semantic web and efforts of the World Wide Web Consortium (W3C) and Open Geospatial Consortium (OGC) to make data machine readable and easier to find over the internet. These are very useful tools for data discovery and access, but when they are used to dictate to users and/or data sites what data and metadata they need to capture and how they should work with and present those data, without regard to the goals, needs, resources or time frames of those users or data sites, then the process has been reversed and IT is dictating technical expectations rather than responding to scientific and engineering community needs. However, the thesis here is that all technologies, including those of the semantic web, must be considered, developed and implemented within the context of their impact on real world social-cultural-political-economic frameworks. In effect, a mega-use case scenario. These use cases should not be constructed from the view or vision of a perfect world, but with respect to their impact and acceptance by real people, organizations and institutions. One advantage of an academically based network is that it is rooted in the user community and thus inherently does a better job of understanding the views, workflows, and needs of the people who comprise the geothermal community.

THE NETWORK

For academically based data sites, the challenges for building and operating a collaborative network are many, but not insurmountable. For example, seamless linkages of data to analysis and visualization tools need to be provided, in particular high-level modeling programs and required computational resources. When dealing with research results and data involving industry partnerships, moratorium and proprietary data must be handled carefully and securely. At the same time, it must be made easy for users to discover, aggregate and synthesize data in ways that allow them to focus on the analysis of these data rather than on finding and compiling them. Additionally, research-level data must be better utilized within the education enterprise to train and attract our next generation of geoscientists and geoengineers.

Network Operation

Inherent in the definition of a data network is that it provides more than just links pointing to other websites, the type of URL link you find on most websites that direct the user to other sites of possible interest. The underlying goal of any network is to interoperate at some level that makes the finding and sharing of data easier by the nodes on the network and/or outside users. This can be thought of as two levels of data service in networks: 1) "data sharing"; sharing data among the nodes on the networks, and 2) "data access"; providing the outsider user with single point access to data from all nodes at once. The Environmental Information Exchange Network (www.exchangenetwork.net), which has been operating for over seven years, is an example of the latter, and focuses on the needs of each node on the network, and then each node serves its own customer base. The developing NGDS is an example of the second type where each node remains the steward of the data it hosts, and a common catalog of data that each site hosts is made available for users to search and discover the data of interest. The data access type of network provides access to data through two basic methods: the catalog and digital library, and the thematic web services.

Digital Library:

A digital library includes a central catalog which includes the metadata index of its data resources and mechanisms for user retrieval of those data resources. These metadata include a specific "Uniform Resource Identifier" (URI) that provides the unique internet address of the specific data resource so that users can find and download the resource. Thus, the catalog facilitates user discovery and access to the specific products of interest. One need expressed by the geothermal user community is to provide the ability to be able to access a broad spectrum of data resources, preferably through one search location. The catalog can do just this by providing the user with the ability to search the central catalog for resources held in data repositories at various nodes throughout the system. The user should be able to search by text string and for those data resources with geospatial metadata, through a map browser. Users should be able to download all discovered items by standard methods.

Thematic Web Services:

Web services provide mechanisms to move data over the Web through a proscribed set of technologies that are an outgrowth of a World Wide Web Consortium (W3C) initiative; they are now, for the most part, commodity items. The nomenclature "thematic web services" is used to distinguish the process of using web services as user accessible, pre-defined search and data retrieval mechanisms from those IT operations where web services per se are used for a number of background operations. The two should not be confused. Thematic web services provide users with pre-defined data products and datasets and contrast with ad hoc search and data resource retrieval. We have developed several web services as part of our ongoing work on the NGDS.

The key to successful implementation of such web services is to work with the user community to identify those services that various segments of the community would find useful. A "web services listing" should be part of the system catalog to provide a central point for users to survey the available web services and select which ones they might want to utilize. Some thematic web services will be specific to a particular node, and the URL will reflect that. If the web service pulls data resources from multiple nodes, this should be transparent to the user.

STANDARDS, PROTOCOLS AND BEST PRACTICES - A MOVING TARGET

It is incumbent on any network, indeed any data site, to compare and assess the relevant standards, protocols and specifications being worked on and/or implemented by a variety of national and international groups. For the geosciences, these groups include the Marine Metadata Interoperability Project (MMI; www.marinemetadata.org), EarthChem (www.earthchem.org), the U.S. Geoscience Information Network (USGIN; usgin.org), CUAHSI Hydrologic Information System (HIS; http://his.cuahsi.org), Canadian Well Logging Society (www.cwls.org), Energistics (www.energistics.org), CGI (Commission for the Management and Application of Geoscience Information of the International Union of Geosciences), Dublin Core (an implementation of ISO standards (see below) for data product metadata, www.dublincore.org), the NGDS (www.geothermaldata.org), and others. These groups in turn are assessing and adopting various standards, protocols and specifications sanctioned by organizations such as the Open Geospatial Consortium (OGC), World Wide Web Consortium's (W3C) web service standards and specifications, International Organization for Standardization (ISO; in particular ISO 19115, ISO 19139), Federal Geographic Data Committee (FGDC), the North American Geological Map Data Model (NADM), and others.

Operational Issues

In an ideal world, the adoption of these standard specifications and protocols by a data network would be easy. However, in the real world it is not for several reasons. First, and perhaps most confusing are conflicting standards and/or differing implementations of the standards from two or more standards groups. This quote from Wikipedia on standards for library documents exemplifies the problem:

> "Standardization for library operation has been a key topic in international standardization (ISO) for decades.

Standards for metadata in digital libraries include Dublin Core, METS, MODS, DDI, ISO standard Digital Object Identifier (DOI), ISO standard Uniform Resource Name (URN), PREMIS schema, Ecological Metadata Language, and OAI-PMH." (http://en.wikipedia.org/wiki/Metadata).

Second, most of these standards and/or their implementations reflect IT development, not necessarily what the scientific user community needs or the way it works and thinks. What group is in the best position to assess this latter question - one outside of the community or one from within the community? And third, some of these standards, while helpful technically, may compromise the content and therefore the utility of data. Again, what group is in the best position to assess this particular question? Specific issues relevant to the discussion on the development and sustainability of a geothermal data network are content models and their resulting XML schemas.

Content models

Content models capture the data and metadata content needed to describe a specific geological, geophysical, engineering, or other feature or entity, for example a well log. Think of these as the column headers in a spreadsheet where the follow-on rows denote particular instances of a feature or entity. Content models are important in part, because they can be used directly to develop thematic web services and/or the data from them can be extracted and aggregated into a database that serves as the basin for web services and other search and download operations. The problem is that the content models can vary widely depending on the community they are meant to serve. Are petroleum well log standards now being promoted by Energistics (www.energistics.org) the ones needed or used by the geothermal community? How do you handle legacy well logs that do not fit those evolving "standards"? Choosing content models can be problematic because they raise several questions. Whose definition, whose model do you adopt? Does it reflect the community of users it is meant to serve or does it have some other purpose? Is it so complex that it will not be used? Is it too simple that it does not provide sufficient description? Who makes these decisions?

Content models to XML, Catalogs and Web Services

The user may well see content models in the form of spreadsheets with pre-defined fields they fill out ("loaders/ templates") and give to a database, but they won't see the XML code that is extracted from them and that is used in data storage, discovery and sharing; the XML that is the heart of the data network's catalog and web services (see above). The power is that if a particular XML schema is adopted as a standard, it allows data to be read and translated by any system and therefore the data are more easily shared, compiled and understood. The challenge lies in deciding whose XML schema is adopted for a particular subject.

XML schemas of particular interest for geoscience and geothermal include: GeoSciML (a mark-up language developed initially for geologic maps, but being extended for mineral deposits and mining and other geologic entities; www.geosciml.org), International Geo Sample Number (IGSN; formerly SESAR; global sample number standardization; www.igsn.org), CUASHI's Hydrologic Information System (HIS) WaterML (focuses on surface water hydrology, but will be extended for subsurface hydrology in the future; http://river.sdsc.edu/Wiki/ WaterML.ashx), EarthChem XML (targets geochemical data, http://www.earthchem.org/developers), and USGIN (content models only), and others.

The fundamental problem with the content model-XML couplet is that every content model-schema requires singular definitions for each data element and a set schema and associated ontology of how the data are interrelated (that is the "knowledge" of the data structure). A much longer discussion on knowledge and ontologies is needed to fully explore this problem, but in short, the problem revolves around the fact that data and knowledge are not the same thing. Linking of data and making it easier to find data and the pre-wired relationships among data elements may contribute to knowledge, but 'knowledge' is much more than that. Data, while comprising the foundation of knowledge, are an insufficient measure of it. Furthermore, and perhaps most important for the practical pursuit of bringing more geothermal energy online, if everyone is forced to use one definition for each word and to link those words in a single type of sentence structure, the construction of new knowledge is actually curtailed. While making it easier to find data online, a rigid content model-XML couplet can make it more difficult to innovate with those data in the real world of geothermal energy which is complex and incompletely understood.

The issue of content models and their XML schemas is complex and important for data systems, in particular geothermal data, because so little of the needed data have yet been captured by any data system and we will have to rely on the community to help populate the databases; indeed the users may be required to do so via new federal funding policies. For the foreseeable future, the answer to the question of whose XML schema to use lies in the operational "data sharing" approach, championed by the Environmental Information Exchange Network mentioned earlier. This approach utilizes translation and data interchange templates that allow nodes to share data. It also provides for the construction of a common catalog for finding data from the network as a whole. This approach allows data from an entire network to be shared with that from another network without forcing each node or network to operate in exactly the same way. Over time, and with international collaboration, there will likely be convergence toward more shared implementations of specifications and protocols, but that cannot be a forced operation. Uhlir, P.F., et al. (2009) and other studies have captured this natural flow and emphasized that convergence will happen naturally, over time, if it is allowed to happen. The point here is that this convergence must be allowed to happen naturally for all data systems and in particular for geothermal data. If barriers are created to this convergence process, then a true community of best practices and data sharing will not develop and cannot be sustained.

Summary

Experience to date provides three lessons. First, a practical operational question is whether or not the user will fill out all the fields of a complex content model. If they won't, then what? Structuring the content models into minimal/required, recommended, and optimal data helps. The optimal (and therefore most complex) level is the most desirable, but the minimal level will at least allow key legacy data - and also newly generated data - to be captured by a data system and therefore not be lost. Second, translation templates need to be used for sharing data with differing XML definitions and schemas both within the network and among networks. Finally, a true, open and global dialog needs to be developed on the issues of standards, protocols and best practices among groups interested in the problem for the geosciences, in particular for geothermal. This process must recognize that different groups have different missions and mandates that must be accommodated.

In summary, it is imperative for the network to assess, adopt and implement standard specifications and protocols in a deliberate and considered manner. That takes time, and thus a philosophy of being flexible, and an architecture that allows change. This flexibility includes the way the specifications and protocols are implemented. This is particularly true when tying together existing data sites into what become nodes on the network. Metadata and data content models and their resulting XML schemas and vocabularies are key examples of where the implementation of "standards" can be problematic, but this does not present insurmountable problems if short-term solutions are not forced upon a situation that is inherently a long-term process.

NONTECHNICAL ISSUES

Building a viable, collaborative data network revolves around nontechnical issues more than it does technical ones. As noted, for an operational data network, the system members technically interact through a common set of standards, protocols and specifications for information discovery and interchange. The system also provides a framework to manage, coordinate and maintain system activities and products. The system may provide a publically recognized, central place to begin the search for geothermal data (e.g., for the NGDS, the www.geothermaldata.org site), however, the intent of a distributed system is to allow users to begin their search at any point in the system. This latter point is important because it maintains the equal standing of all nodes on the network.

There are many fundamental issues that must be addressed before we can achieve the vision of a seamless, integrated data network, including:

1. Developing a process to reach agreement on the standards, protocols, technical specifications, etc. required to share data between systems.
2. Minimizing the changes that the established system data sites need to make to participate
3. Recognizing and accommodating the fact that a single solution may not be achievable (financially, technologically, culturally, politically, etc.) so this cannot be a basis of system functionality.
4. Understanding that systems need to be responsive to their users, so agreements about technical issues need to be adaptable to the needs of the users.
5. Providing flexible, clear and concise operational procedures as well as specifications that make it possible for other data sites to join the network in the future.

Finally, an underlying design criteria for a distributed system is that all associated data sites are and will remain independent entities with their own missions and mandates, and will receive full credit for the data they serve regardless of the point of access for these data.

SUSTAINING THE NETWORK

Sustainability will always remain an issue for an academically based data network and there is no simple answer to the question of how to sustain such a network for the long-term. Self-funding from the home institution is not feasible. Other schemes are possible, such as user fees, etc., but these will only account for part of the costs. However, evolving relationships between the customers, that is the user communities, and the federal funding agencies may provide a partial answer. As we write this paper, things are moving rapidly both within our user communities and with the federal funding agencies (Department of Energy and National Science Foundation in particular). These agencies are themselves going through an evolution of thought on the importance of data stewardship and their roles within the overall data life cycle (e.g., NSF's EarthCube initiative). For some agencies, it makes sense that the agency itself should host some of the data generated by their operations. However, for other data, it imperative that they be hosted outside of the agency or the underlying issues of transparency and trust will remain cloudy and debatable. One of the themes of this paper is that there needs to be long-term partnerships between agencies and academically based data sites, in particular data networks. Another underlying theme is that this improved data stewardship has costs associated with it, i.e., irreducible baseline costs. Thus, as agencies continue to increase their efforts to manage and provide access to data generated by projects and activities they fund, a long-term agency-academic partnership will evolve that includes both funding academically based data networks and relying on these networks to provide some of that public access to federally-funded data. Finally, it is important to note that these academically based data networks have to be self-governing for them to work at all, much less be sustainable; whereas federal agencies may provide financial support, it is the user community that must decide what and how things are done.

SUMMARY

Our interaction with the geothermal community and our experience building multiple data systems has provided many insights into both improving our individual data sites and into sustaining a distributed data network. We are fully aware of the importance of working with federal and state agencies on these endeavors and of international collaborations - we are doing all of this.

The future lies in partnering with the federal funding agencies to continue to build systems that: 1) accommodate the needs of individuals, research teams and projects, and commercial enterprises, 2) provide public outreach and education, and 3) help meet the internal needs of the agency. The network must be technically and operationally flexible to mold to the needs of users and each of the nodes on the network; it must not unnecessarily force users or data sites to conform to the data system. All of these aspects present significant problems to building and maintaining a data system, but none of them are new to us and all of it grows from our roots in the user community.

In summary, the future of an academically based network for geothermal data and the geothermal community is bright, provided we continue to operate under the principles of openness and collaboration; and provided, too, that we remain flexible and responsive to the community we serve as it becomes more knowledgeable and involved, as technologies evolve, and as opportunities for sustainability emerge. So long as the academic groups and the interested federal and state agencies are willing to collaborate there are no insurmountable barriers to creating the dynamic system we envision.

EDITOR'S NOTE

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STARTING FIELD TEST OF KALINA SYSTEM USING HOT SPRING FLUID IN JAPAN

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ABSTRACT

To apply smaller-scale geothermal generation such as high temperature hot spring field about 90˚C, we carried out a development project of a 50 kW class Kalina cycle geothermal power generation system. From 2010, on site generation project is progressing at Matsunoyama hot spring field in Niigata Prefecture at middle of Japan. This is first test using a 50 kW class Kalina system that potential is estimated as 723 MW using hot spring fluid in Japan without drilling. Before starting generation, we analyzed geochemistry of Takanoyu #3 test well, and surrounding wells to estimate the stability of production of hot spring fluid. And we estimated low scaling risk to heat exchanger from equilibrium calculation.

At the end of 2011, we started power generation test to estimate stability generation system and to solve several technical and law problems for promotion of this business model.

INTRODUCTION

As one of geothermal direct use, bathing in hot springs is used for many people and countries, especially in Japan.

In Japan, about 28,000 hot springs (Onsen) and 15,000 hotels related hot springs exist in 2010. And total guests staying at hotels of hot springs are about 130 million as same as population in Japan.

And the range of temperatures of hot springs is very wide from 25 to over 100˚C. In non-volcanic area, for example Shikoku Island, in Kanto plane etc., the temperature of over 95% of the hot springs are lower than 42˚C. In this case, the owners of springs, mainly official public baths, have to heat water using boilers to bathing temperature and people living in the non-volcanic areas are able to enter the springs in their living area.

And in volcanic area, for example Hokkaido, Tohoku area, Kyushu Island, etc., the temperature of over 60% of the hot springs are higher than 42˚C. Kimbara (2005) collected temperature data of 4,536 hot springs. According to this data, the temperature of about 15% of the hot springs are higher than 60˚C and 4% are higher than 90˚C.

Especially on Kyushu Island, several hot spring sources have high temperature heat sources enough for power generation by single flash system, for example, Suginoi-hotel power plant (1,900 kW), Kuju-hotel power plant (990 kW) and Kirishima-International hotel power plant (100 kW). The depth of the production wells of these plants are less than 400 meters and much shallower than depth of production well (about 2,000 meters) of usual commercial flash type geothermal power plants.

In several areas, the temperature of hot springs shows about 90 to 100˚C especially near volcanic areas. This is not enough for flash power generation. And in this case, the initial temperature of the hot springs are too high for bathing (about 42˚C), hot spring owners are making various efforts such as cooling by a long channel or stirring by human power. It means the energy of the hot springs are wasted.

To usefully utilization the high temperature hot spring water (about 100˚C), a development project of a 50 KW class Kalina cycle power generation system was conducted (Muraoka et al., 2008c).

The concept of this system is as shown in Figure 1. If we incorporate a small-scale Kalina cycle power generation system into the upper stream of the high-temperature hot springs, we could obtain electricity and adjust the bath temperature without any dilution of balneological constituents. The minimum power generation temperature by the Kalina cycle is 53˚C which is adequate to bridge over for bath use after power generation. And we can use heated cooling water for space heating, etc.

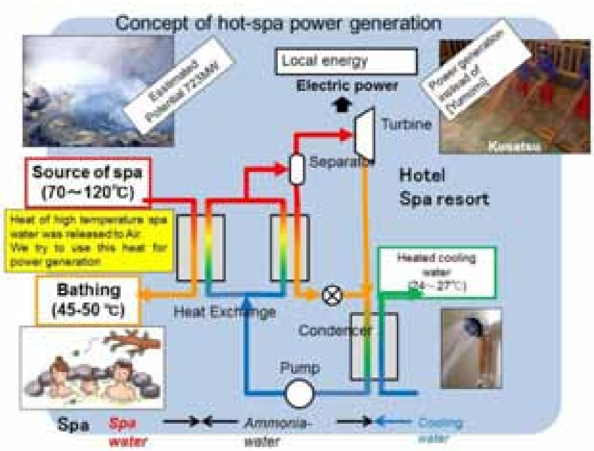

Figure 1. The concept of power generation system using hot spring fluid

This paper describes an outline of our ongoing projects for the development of a small and low-temperature geothermal (high temperature hot spring) power generation using Kalina system at Matsunoyama field.

REVIEW OF THE KALINA CYCLE POWER GENERATION SYSTEM

The Kalina cycle, one of the binary cycle power generation methods using an ammonia-water two component mixture as a low-temperature boiling medium, was invented by Dr. Aleksandr (Alex) I. Kalina in 1980. This system can generate electricity with thermal water less than 100˚C, because the boiling point of ammonia is -33.48˚C under an atmospheric pressure.

The first Kalina cycle power plant of 3,100 kW has been operated at the Kashima Steel Work, Sumitomo Metal Industries, Ltd., Ibaraki Prefecture, Japan since 1999, where the thermal water 98˚C from a steel revolving furnace is used. The first geothermal Kalina cycle power plant of 1,700 kW has been operated at Húsavík, northern Iceland since 2000. The second geothermal Kalina cycle power plant of 3,300 kW has been operated at Unterhaching, the southern suburb of München, Germany since 2007, where deep thermal water at a temperature 120˚C is produced from the molasse sediments at a depth of 3.4 km in the non-volcanic region.

The minimum power generation temperature of the Kalina cycle is estimated to be 53˚C for the water cooling system by Muraoka (2007) based on the data from Osato (2003) as shown in Figure 2. This, however, means the minimum temperature when a thermal conversion range ΔT is consumed for power generation. To realistically generate electricity using an effective thermal conversion range, the initial water temperature is expected to be 80˚C or more. If a flow rate is very high, the initial water temperature 70˚C may be considered. A utilization temperature limit is determined by the discharge temperature and discharge rate of thermal water.

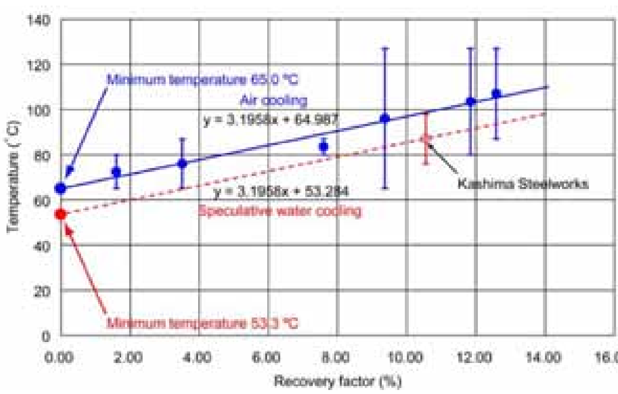

Figure 2. Relation between the inlet water temperature and recovery factor in the net electricity output ratio to the thermal energy input in the Kalina cycle (Muraoka, 2007; Osato, 2003).

Kalina cycle power generation systems of a 2 MW class and larger scales are practically utilized as described above. To apply the Kalina cycle to hot springs, we need down-sizing of the system, because discharge rates of most hot springs are small. Then, we aim to assemble a Kalina cycle system as small as 50 kW in the net electricity and 64.5 kW in the gross electricity. The energy conversion efficiency of the Kalina cycle was originally known to be higher than the organic Rankine cycle (ORC), particularly in the lower temperature range (Figure 3) (Osato, 2005). This efficiency should be kept as far as possible even in the down-sizing process. The cost of the system will be important as a market force in the near future, but the efficiency is more important in the prototype assembly.

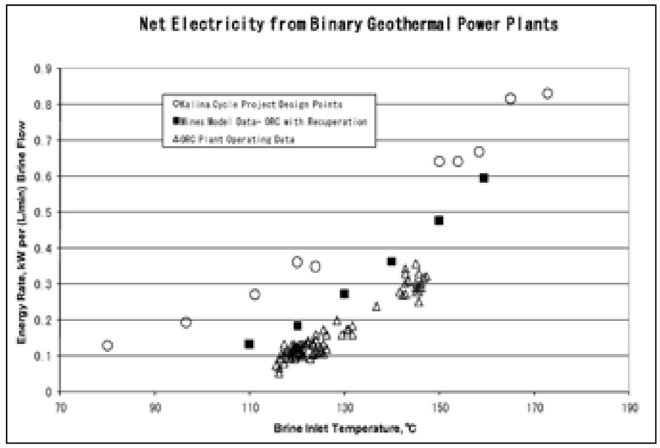

Figure 3. Comparison between the inlet temperature and net electricity of Kalina and organic Rankine cycles (Osato, 2005).

For our project, the Kalina cycle system was developed at Energent Corporation with the Geothermal Energy Research & Development Co., Ltd. (GERD). A 90 kW unit using the Eular turbine technology was developed with a high speed generator and magnetic bearings. The length is about 80 cm. The rotor is about 13 cm in diameter and 500 g weigh. The operating speed is 56,000 rpm. The Euler turbine technology can also be applied to ORC's, replacing the radial inflow turbine. (Welch et al., 2010, 2011).

POTENTIAL OF HOT SPRING POWER GENERATION IN JAPAN

The potential of hot spring generation using 50 kW class of Kalina system was estimated at about 723 MW by Muraoka et al. (2008c). This value was estimated as follows;

1. We apply 50 kW Kalina cycle power generation system to currently wasting energy from high temperature hot springs such as Beppu, Tamagawa without new drilling
2. We ignore less than 30 kW output.

When we allow new drillings, the width of potential areas of hydrothermal resources at a temperature from 53˚C to 120˚C above the pre-Paleogene basement units are estimated to be 22.2 % of the entire on-shore territories (Figure 4), where hydrothermal resources higher than 120˚C are ignored. Compared with the potential areas of the hydrothermal resource higher than 150˚C (Muraoka et al., 2008a), it is obvious that the lowering of the power generation temperature dramatically enlarges the resource fields toward the non-volcanic fields. The total electricity potential is estimated to be 8,330 MW in entire Japan (Muraoka et al., 2008b).

MARKET AND PROBLEMS FOR HOT SPRING POWER GENERATION SYSTEM

Firstly, this system is useful for hot spring hotels and towns including many hotels. And the market for Kalina and ORC binary cycle systems is not only for hot springs but also the high temperature wells of oil, gas, coal and metal mining field. This system is useful for the waste high temperature fluid of factories such as the Kashima Steel Work, Sumitomo Metal Industries, Ltd. The potential of generation from waste heat of factory is estimated about 2,000 MW.

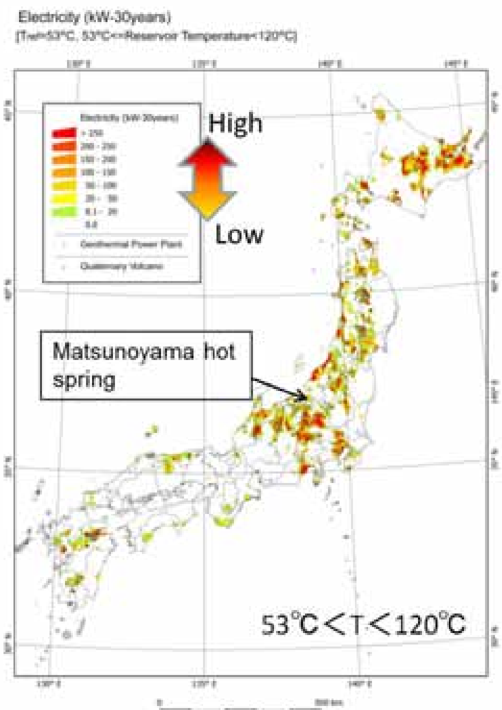

Figure 4. Distribution of hydrothermal resources at a temperature from 53 to 120°C above the pre-Paleogene basement units and the site of Matsunoyama hot spring.

This market area of Kalina and ORC systems is important for decreasing CO_2 release and self power generation in hot springs and factories. Especially, after the big earthquake of eastern Japan at March 11, 2011, the nuclear power plant accident was very serious with many radioactive materials release to the air and sea. Due to decreasing electric power from nuclear power plants, geothermal and hot spring power generation becomes important and we have to use hot spring fluid usefully.

Power generation from hot springs has the possibility to be the symbol of the hot spring resorts. Many guests will visit the hot spring resorts with power generation system.

To progress small hot spring power generation systems, we have to solve several problems. Firstly, the small Kalina system is under development and still high cost. The machine cost has to be deceased by spread market and development technology. And to decrease cost, we have to check the long-term stability of the generator and pipeline system including scale problem.

We have to check and change the laws related to small power generation. For example, even in small power generation systems, an official boiler technician is needed to run the generator and many procedures and high cost machines are needed to connect with commercial electric lines in Japan. These add to the high cost of maintaining the generation system.

Also if a lot of hot spring fluid is need to generate more power, the owners of hot springs tend to worry about sustainability of production. We then need to estimate the sustainable maximum power for the hot spring field based on the production temperature and rate and the mechanism of origin of the hot spring.

The Ministry of the Environment (MOE) of Japan started to support this hot spring generation three year project, titled “Development and Demonstration of Small-Grid Power Generation System using Hot Spring Heat Source” from fiscal year 2010 (FY2010). This project is managed by the Geothermal Energy Research & Development Co., Ltd. (GERD), the Institute for Geo-Resources and Environment of AIST, and Hirosaki University. In this stage, power generation test by 50 kW class Kalina cycle system using about 100°C hot spring water will be carried out at Matsunoyama hot spring field in Nigata prefecture in middle part of Japan. This project mainly consists of several subjects: (1) production of hardware and estimation of long term stability including scale problem, (2) connection to electric line and estimation of maximum power with spring water flow, (3) estimation and monitoring of surrounding hot spring system.

MATSUNOYAMA TEST FIELD

The Matsnunoyama hot spring field exists in Tokamachi city of middle part of Niigata prefecture about 200 km NNW from Tokyo shown in Figure 4. In Matsunoyama hot spring resorts, about 20 hotels and several hot spring wells exist. The oldest well, Takanoyu #1, was drilled in 1938 to 170 meters depth and about 90°C, 60 l/min flow. After that, several wells such as Takanoyu #2, Kagaminoyu, Yusaka were drilled and these temperatures are about 90°C

In 2007, a new hot spring well, Takanoyu #3, was drilled to about 1,200 meters depth. At the first production test, the fluid temperature was about 97°C and flow rate was about 630 l/min. This production rate is the largest in Matsunoyama hot spring resort.

After this test, the production rate from Takanoyu #3 is about 230 l/min and several parts of the fluid is not used for bathing and released to river directly due to over production to hotels.

Then, Takanoyu #3 is selected for the test well of the hot spring generation project, “Development and Demonstration of Small-Grid Power Generation System using Hot Spring Heat Source” from fiscal year 2010 (FY2010) by MOE due to high temperature and flow rate.

GEOCHEMISTRY OF MATSUNOYAMA

After October 2010, we started the flow rate, temperature and geochemical monitoring of Takanoyu #3 for generation test well and Kagaminoyu, Yusaka, Koshinnoyu and the mixture of Takanoyu wells as surrounding well from Takanoyu #3 less than 1 km due to estimate influence of power generation test as shown in Figure 5.

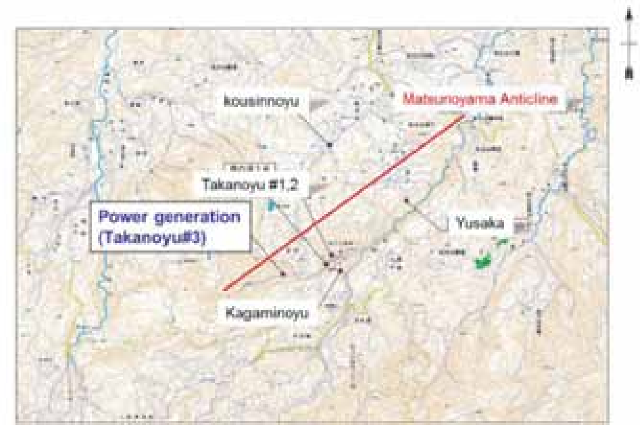

Figure 5. Site of Takanoyu#3 and surrounding monitoring hot spring well.

From October 2010 the flow rate, temperature and geochemistry of the monitoring wells are almost constant and these values will be the background for the power generation test at the end of 2011.

Table 1 shows the fluid composition of Matsunoyama wells with high Cl concentration about 9,000 mg/l in all wells measured in November 2010. Takanoyu #3 has about 3,700 mg/l Na, 140mg/l K, 2,070 mg/l Ca and 27.3 mg/l HCO_3 and did not change from production start in September 2007.

Table 1: Geochemistry of hot spring of Takanoyu #3 and surrounding wells (mg/l)

	Na	Cl	K	Ca
Takanoyu #3	3700	9400	140.3	2070
Yusaka	3708	9252	103.3	1980
Kagaminoyu	3392	8764	83.4	1882
Kousinnnoyu	5680	8661	30.7	205
	HCO_3	SO_4	Mg	Si
Takanoyu #3	27.3	85.5	0.6	66.7
Yusaka	23.0	80.0	7.7	36.7
Kagaminoyu	19.3	81.1	15.7	20.1
Kousinnoyu	316.6	2.6	44.1	11.5

Figure 6 shows the isotope diagram of the hot spring fluid and river water. This shows that the hot spring fluid did not match on meteoric line.

ESTIMATION OF SCALING

From this composition, we estimated the possibility of scaling in this system by calculating equilibrium of silica and carbonate minerals using Solveq-Chiller by Reed (1982). The diagram of mineral equilibrium is shown in Figure 7.

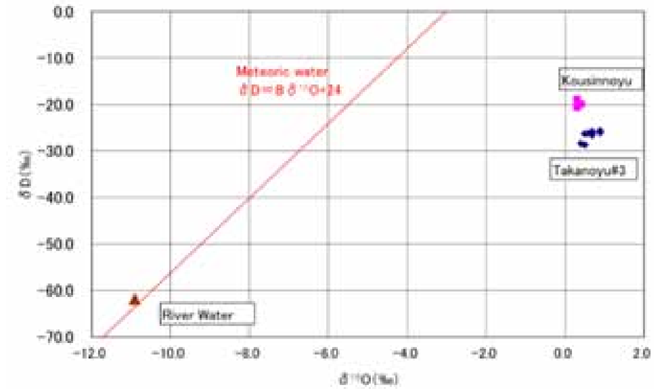

Figure 6. Isotope diagram of hot spring fluid of Matsunoyama field and river water.

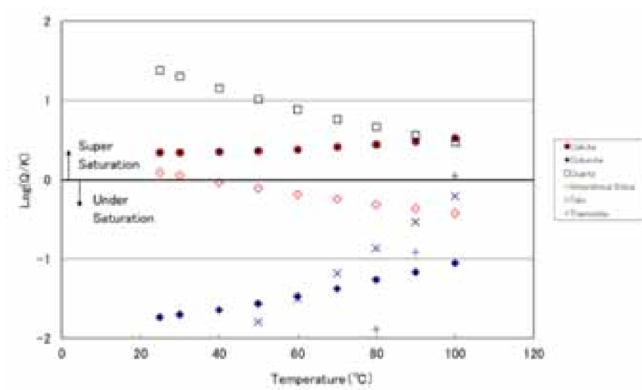

Figure 7. Estimation of equilibrium of scale minerals of Takanoyu#3.

During the cooling process of the hot spring fluid from 100 to 40˚C, on heat exchanger, quartz (SiO_2) and calcite ($CaCO_3$) are supersaturated, but other minerals such as dolomite ($MgCaCO_3$), talc ($Mg_3Si_4O_{10}(OH)_2$) tremolite ($Ca_2Mg_5Si8O_{22}(OH)^2$) and amorphous silica (SiO_2) are under saturation. And we estimated the scale problem will not be so serious because silica scaling usually as amorphous silica under saturation over 40°C at Matsunoya #3 and the degree of super saturation of calcite is decreased with temperature deceasing. Then to prevent scaling, we have to take care to prevent vaporize fluid in heat exchanger.

The reason for low risk of scaling is due to low HCO_3 and Mg concentration at Takanoyu#3. Then, the scaling risk will increase in high HCO_3 regions near volcanic area.

STARTING POWER GENERATION TEST

The power plant system was installed at Takanayu #3 in December of 2011. The power generation system contains about one meter length power generator, heat exchanger for hot spring fluid with ammonia/water mixture, separator ammonia gas from water, ammonia tank and pumping system. The system size is about 5 m^3 as shown in Figure 8 with control system in the building to cover from 3 m depth snow.

Figure 8. The Kalina power generation system using hot spring fluid at Matsunoyama.

Outside of the building, as shown in Figure 9, there is the wellhead of Takanoyu #3, cooling tower and transformer to connect electric line.

Figure 9. Wellhead of Takanoyu#3.

On 16 December 2011, the opening ceremony for this project was carried out with the senior vice minister of the Ministry of the Environment (MOE) and the Governor of Niigata prefecture attending. After this ceremony, power generation test was carried out and we survey the sustainability of generation system and hot spring fluid.

Recently, several companies are developing small binary power generation system for hot springs and several hot spring resorts are planning to start small power generation project.

To promote the small hot spring power generation system, the result of Matsunoyama project is important.

SUMMARY

We started a 50 kW class Kalina cycle power generation test at Matsunoyama hot spring field in December 2011. In this test, we will survey the stability of generation system and environment of hot springs mainly geochemistry.

In Japan, there are about 723 MW generation potential to develop small Kalina system for hot spring field. To promote this system, we have to survey and solve several technical and social problems.

EDITOR'S NOTE

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CASCADED USE OF GEOTHERMAL ENERGY: EBURRU CASE STUDY

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Samuel Kinyanjui, Jomo Kenyatta University of Agriculture and Technology

ABSTRACT

Geothermal energy can be used both for electricity generation and direct applications depending on the enthalpy and chemistry of the resource. High to medium enthalpy resources are used for electricity generation while medium to low resources are mainly used for the direct applications.

Geothermal energy in Kenya has been primarily used for electricity generation mainly because of lack of focused attention on direct applications. On commercial level, direct applications are only at Oserian Development Company, a privately owned flower growing firm where geothermal fluid is used to provide heat for greenhouse heating. Minor uses are at the Lake Bogoria Spa Resort where geothermally heated water from a hot spring is channeled to warm a swimming pool and at Eburru where shallow steam wells provide heat energy for drying agricultural products and the condensed steam is used as drinking water.

Cascaded utilization of geothermal energy ensures efficient and cost effective utilization of the available energy. It is hereby proposed that energy from the two shallow wells at Eburru be used in a cascaded manner for drying of agricultural products, greenhouse heating, honey purification, poultry hatching, recreational facility in a steam sauna and for provision of the much needed potable water. This will be used as a demonstration center for utilization of geothermal energy as well as a source of income to the local community.

An assessment of the energy potential and chemistry of the fluid from the two shallow steam wells needs to be carried out to assess the technical viability of the intended uses as well as establish whether there is a need to drill a new well for this project. The cost of undertaking this project has been estimated to be about USD 40,000.

INTRODUCTION

A geothermal resource has heat, pressure and water that can be harnessed for the benefit of mankind. Utilization of geothermal energy and the other by-products depends heavily on the thermodynamic and chemical characteristics of the fluid. These factors require detailed assessment to help determine the energy potential and the technical viability of any utilization project. Geothermal resources have been classified using temperatures and/or enthalpy hence classified to suit either electricity generation or direct applications (Table 1). The high temperature resources are ideally used for electricity generation using conventional power plants while medium to low temperature resources are utilized for direct uses or electricity generation using binary technology.

Table 1. Basic technology commonly used for geothermal energy.

Reservoir Temp.	Reservoir Fluid	Common Use	Technology commonly chosen
High Temp. (>220°C)	Water or Steam	Power Generation Direct Use	Flash Steam; Combined (Flash and Binary) Cycle, Direct Fluid Use Heat Exchangers Heat Pumps
Medium Temp. (100-220°C)	Water	Power Generation and Direct Use	Binary Cycle, Direct Fluid Use; Heat Exchangers; Heat Pumps
Low Temp. (30-150°C)	Water	Direct Use	Direct Fluid Use; Heat Exchangers; Heat Pumps

In 2010, approximately 78 countries were reported to utilize a total of 438 PJ/yr of geothermal energy directly, an increase of about 78.9% in the last 5 years, (Lund et al., 2010). More than half of this energy is being used for space heating and another third for heated pools. The remainder supported industrial and agricultural applications.

Compared to other renewable energy technologies, geothermal is unique as it provides a base-load alternative to fossil fuel based electricity generation, but can also replace those used for heating purposes especially in utilization of low heat energy applications (Mburu, 2010).

In Kenya, commercial direct application of geothemal energy is only at the Oserian Development Company, a flower farm utilizing a leased geothermal steam well with 16 MWt potential, for heating rose flower greenhouses. The heating reduces humidity in the greenhouses and hence eliminates fungal infection resulting in reduced production cost. Flowers grown in a heated greenhouse are of better quality and increased production. The hot geothermal fluid is also used in soil fumigation and for sterilization of the fertilized water for recirculation. Carbon dioxide from the well is also used to enhance photosynthesis hence improved yield.

THE EBURRU GEOTHERMAL FIELD

Eburru geothermal complex, located 40 km north of the Olkaria geothermal power plant, is composed of two major volcanic centers at an elevation of more than 2,600 meters above sea level.

Geothermal Occurrence and Utilization at the Eburru Field

Detailed surface exploration studies at the Eburru geothermal field were carried out from 1985 to 1990, after which six deep exploration wells were drilled between 1989 and 1991. Two of the six wells are productive. Currently a 2.5 MWe project to utilize the steam from one of the wells drilled in Eburru is underway.

Active fumaroles and hot grounds are abundant in Eburru. Previous studies by Velador et al. (2003) documented that 80% of the fumaroles are associated with north-south faults in eastern Eburru, and 50% are associated with one main north-south fault. Steam from naturally occurring fumaroles and from two shallow steam wells have, drilled in the 1950s, has been condensed to provide potable water and to dry agricultural produce.

Direct Utilization of Geothermal Energy at the Eburru Field

Geothermal energy is evident around the Eburru shopping center. Surface manifestations can be seen in the form of fumaroles, steaming and altered ground. The local community has been harnessing this energy, though mostly in uncoordinated and on an individual level (Figure 1).

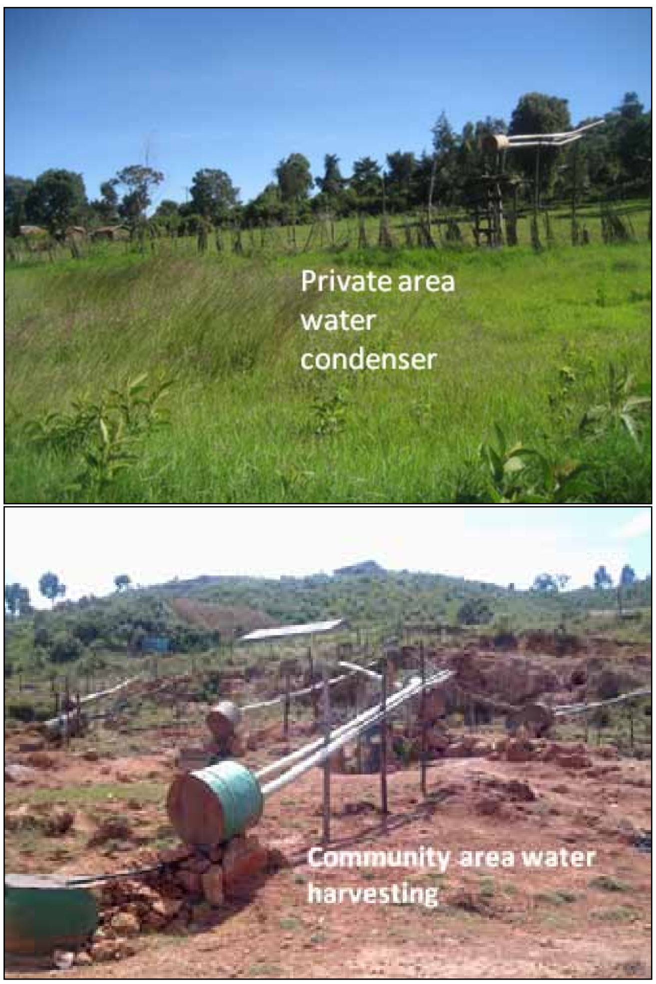

Figure 1. Uncoordinated local steam condensation at Eburru.

The community has however made some efforts and are currently using and managing two shallow steam boreholes drilling in the 1950s to provide potable water for the community and heat for drying pyrethrum and maize (Figures 2 and 3).

Figure 2. Geothermally heated pyrethrum drier.

Figure 3. Shallow steam boreholes used for portable water and crop drying.

PROPOSED DIRECT APPLICATIONS AT EBURRU PROJECT

The Eburru water harvesting from the two steam shallow wells and the pyrethrum drying projects (The Ex-Peter's dryer) have been running from the colonial times. Though the project is owned and managed by the community, an evaluation done on 19th January 2010 showed that the project is not efficiently operated. There are substantial leakages of steam and the condensed water (Figure 3). More-so, heat energy from one of the boreholes is not utilized at all. Heat from the 2nd borehole can be used for greenhouse heating, refining honey or to warm an artificial brooder. The steam exhausting from the condensing pipes can be used in a recreational sauna. If upgraded and maintained, the proposed projects can avail more water and energy as well as act as a training and demonstration center.

Figure 4. Inefficient utilization of the geothermal energy.

Upgrading the Tree Nursery Project

Next to the condensed water storage tanks is a community tree nursery (Figure 5). At the tree nursery, tree seedlings are grown for local uses and for sale. The seedlings are irrigated using water obtained by condensing steam. By increasing the amount of condensed steam, more seedlings can be raised hence more returns.

Growing the tree seedlings in a geothermally heated greenhouse will enhance productivity and quality as well as reduce the amount of water loss through evaporation. Horticultural crops such as tomatoes and cucumber can also be grown in the geothermally heated greenhouse (Figure 6). Such a project would have economic benefits to the community.

Figure 5. Tree nursery project in Eburru.

Figure 6. Geothermal heated tomato greenhouse, Tunisia.

Upgrading the Bee Keeping Project

When the bee keeper removes the honey from the honey combs he has to process the raw honey immediately to prevent it from crystallizing. Once the raw honey comes into contact with the oxygen in the air it reacts and begins to crystallize immediately. One of the cheap and common methods of purifying honey is through heating under low and controlled temperature. Heat-treatment after extraction reduces the moisture level and destroys yeast cells. Though honey can be extracted faster and more completely at higher temperatures, the combs will become softer and might break. Therefore, extraction temperatures should be kept low.

During heat treatment, honey is subjected to a double heat treatment, both aimed at purifying the honey. First the honey is heated to 50ºC. The crystals formed in the honey will melt. The honey is held at this temperature for 24 hours. Undesired substances like parts of bees and pollen will float and they are removed. Then the honey is heated quickly to 75ºC, filtrated and cooled immediately to 50ºC. This second process takes only a few minutes. The wax cappings are melted down and collected for sale to cosmetic companies.

A bee keeping project next to the tree nursery (Figure 7) would benefit from the availability of a geothermal heat. Honey can be purified using heat from the geothermal fluid.

Figure 7. Eburru community bee keeping project

Honey Purification Process

Careful heating the honey in a water bath to wax melting temperatures (about 65˚C) and subsequent cooling in a water bath with running water (Figure 8) may prolong storage life. For small quantities, this is an acceptable compromise between spoilage by fermentation and some loss of quality by heating.

Figure 8. Small-scale heating of honey in a water bath.

Figure 9. Commercial Purifier (India).

Another method is based on pasteurization and the destruction of the yeasts. The osmophilic yeasts found in honey die after only a few minutes of exposure to temperatures between 60 to 65˚C. If the honey is heated and cooled quickly enough, with special heat exchangers feasible only on an industrial scale, very little damage occurs to the honey. Often these pasteurization treatments have two functions, the prevention of fermentation and the postponement of crystallization (Figure 9).

A Geothermal Steam Bath

Geothermal fluid has many dissolved minerals some of which are essential for skin therapy. The geothermal fluid has therefore been used in many countries for this purpose. The Blue Lagoon for example is a major tourist attraction in Iceland. The Lagoon has a warm pool and two steam baths, all believed to have therapeutic effect on the users (Figure 10 and 11).

A steam sauna is proposed at the Eburru to utilize the naturally occurring geothermal steam from the shallow steam wells or from the fumaroles.

Figure 10. A steam sauna at the Blue Lagoon, Iceland.

Figure 11. Geothermal warm spa at the Blue Lagoon, Iceland.

Besides being a great form of relaxation, steam bathing has a lot of health as well as beauty benefits. A steam bath relaxes overworked and stressed muscles, reducing aches and pains.

Aquaculture

Aquaculture refers to growing of aquatic creatures using a controlled environment. Many of the farmed species grow faster and larger in warmer-than-ambient water. Geothermal fluids can be used to control the temperatures of the aquatic ponds to enhance productivity hence faster growing fish, allow production in the winter and cold seasons when it would otherwise not be possible resulting to greater economic gains.

Chicken Hatchery and Brooders

Incubators and brooders in poultry industry act as a substitute for hens. This often results in higher hatch rates due to the ability to control both temperatures and humidity. The simplest incubators are insulated boxes with an adjustable heater, typically going up to 60˚C to 65˚C, though some can go slightly higher (generally to no more than 100˚C). Geothermal heat can be utilized to provide adequate and constant heat for such uses. The Eburru project will involve design and fabrication of a commercial hatchery.

CASCADED USE OF GEOTHERMAL ENERGY

Cascade Uses Depending on Temperature

In many countries direct utilization of geothermal energy is from low to medium temperature geothermal systems (Lindal, 1973). The temperature of the fluid dictates the applications the fluid (Figure 12). For medium to low temperature geothermal systems the fluids have very low dissolved salts and pose no major scaling problem hence temperature can be lowered significantly (Ballzus et al, 2000). Figure 13 shows the proposed cascaded use of geothermal energy at the Eburru project.

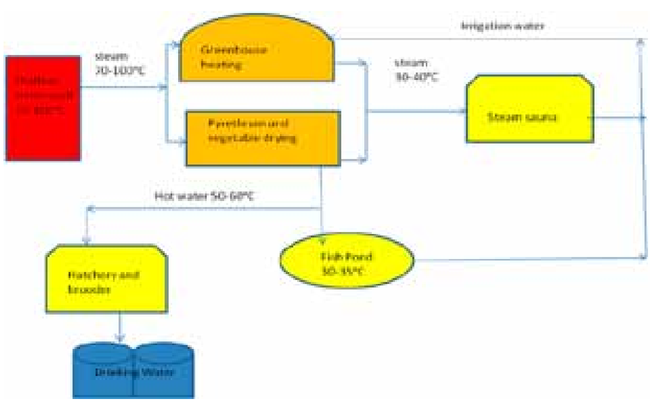

Figure 13. Proposed cascaded use at Eburru direct utilization demonstration center.

When using geothermal brine from high temperature resources, the limiting factor is the brine re-injection temperature to ensure no scaling of amorphous silica in the surface equipment and in the re-injection wells. High temperature geothermal brine of Nesjavellir power plant, Iceland is used for hot water supply with minimal problems. Controlling the flow rate of the brine in the heat exchanger significantly reduces the possibility of silica scaling but reduces the heat transfer (Arnorsson, 2000). A detailed design takes into account all conflicting factors ensure utilization is both technically and economically feasible (Orme, 2003)

The steam from the two shallow wells has been condensed and used as potable water by the local community at Eburru due to lack of water. There are no comprehensive studies to show the effect of exploitation of the two shallow wells to the reservoir. The current proposal does not consider reinjection of the fluid since the condensed steam, after heat extraction, will be used as potable water. However, there will be comprehensive monitoring of the reservoir to monitor the effect.

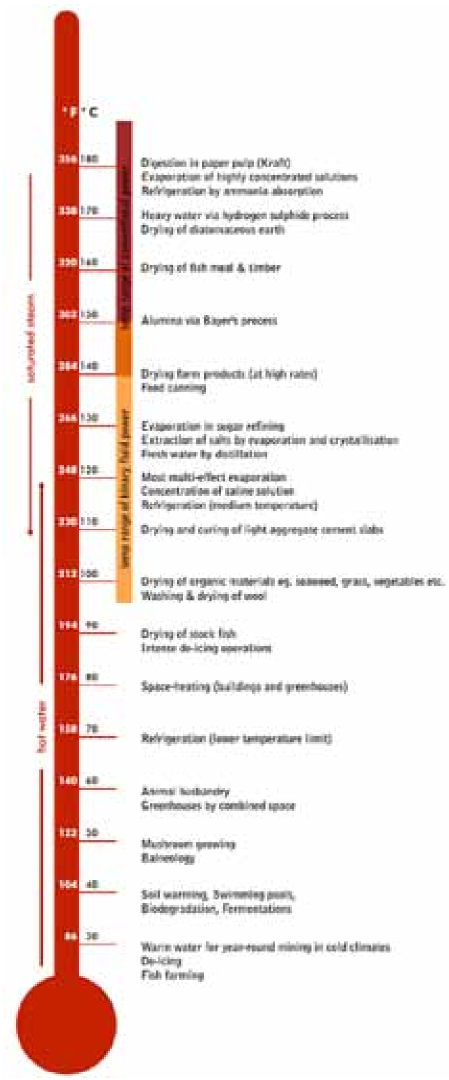

Figure 12. Utilization of geothermal energy at different temperatures (Lindal, 1973).

Proposed Cascade at the Eburru Project

The cascaded use of the geothermal energy will involve different applications as shown in the schematic diagram (Figure 13). Technical evaluation of the well's depth, temperature, chemistry of the fluid and the energy potential of the two shallow wells, need to be done to establish the optimum applications.

Technical Data Collection and Presentation

Technical data collected at one of the shallow wells (the drier well) on March 22, 2011 (Figure 14).

- Atmospheric temperature 21.8˚C
- Well Head Temperature 89.6˚C
- Drier inlet 78.0˚C
- Drier exhaust 56.8˚C
- Chamber pipe 74.0˚C
- Inside of chamber 40.0˚C
- Water pipe at tank entry 38.9˚C

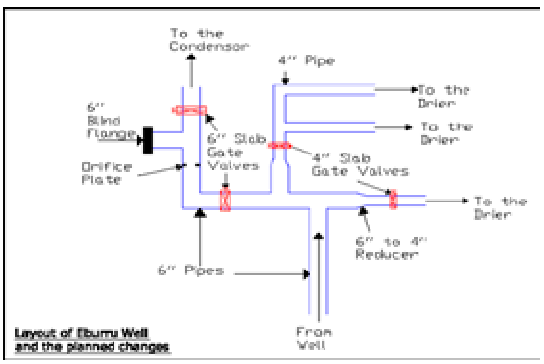

Figure 14. Schematic diagram of the drier well mechanical parts.

In order to establish the energy potential of the wells, the technical team established that the wellhead valves have to be replaced since they are worn out and are stuck in open position. The following items are being procured.

- M/S 6" Class 150 Slab gate valve – 2 Pcs
- Brass gate valve 4" – 2 Pcs
- M/S Reducers 6" x 4" - 2 Pcs
- Flanges 6" class 150 – 2 Pcs
- Bolts
- 3/8" ball valve
- Accessories

Other equipment and resources required are:

- Portable welding set
- Welding gas cylinders
- Grinder and accessories
- Transport for equipment and personnel

CONCLUSIONS

A cascaded use of geothermal energy at the current drier and water condensation site at Eburru field is hereby proposed.

- The project is to comprise of the following:
- Pyrethrum/crop dyer
- Greenhouse heating
- Honey purification
- Steam sauna
- Fish pond

Before the cascaded use is implemented, there is a need to carry out technical energy evaluation exercise to establish the energy available from the two shallow steam wells. To do so, the old worn-out wells need to be rehabilitated i.e. replace worn-out valves, pipes and other accessories in order to allow for testing.

The current proposal does not consider reinjection of the fluid since the condensed steam, after heat extraction, will be used for drinking. However, there will be a comprehensive monitoring program of the reservoir to monitor the effect once the project is implemented. The appropriate decision will be made depending on the monitoring observations.

RECOMMENDATIONS

- Set up a cascaded use of geothermal energy near the Eburru drier/water harvesting community project. This will act as a demonstration center for the direct utilization of geothermal energy.
- Evaluate the energy potential from the two existing shallow steam wells.
- Undertake a comprehensive monitoring program of the reservoir and the well output once the project is implemented.
- Hold a meeting with the community representatives and the larger community to establish the land ownership and assess the acceptability of the project by the local community.
- Evaluate the possibility of drilling a new well near the existing well to supplement the existing energy.

EDITOR'S NOTE

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THE USE OF PORTABLE GEOTHERMAL WELLHEAD GENERATORS AS SMALL POWER PLANTS TO ACCELERATE GEOTHERMAL DEVELOPMENT AND POWER GENERATION IN KENYA

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ABSTRACT

Geothermal electricity is generated from geothermal energy. Technologies used to convert the geothermal energy to electricity include dry steam power plants, flash steam power plants, binary cycle power plants and lately wellhead generator units. Wellhead units can be connected to wells with output of up to 10-15 MW, with shorter steam lines compared to a central power plant which characteristically have long steam lines. They have modular construction, usually the turbo generator modules are factory assembled on a single sled. As matter of fact, the demand for electric power has been increasing due to economic and industrial growth therefore expanding the demand for small size geothermal power plants. Small size geothermal power plants are generally used for the following purposes: satisfaction of electricity demand in an isolated area, remote areas off-the national grid, power source during resource development, auxiliary or emergency power source for main geothermal generating plant and simplification of steam transmission lines. Wellhead power generator units are standardized. Special consideration is given to easy transportation, easy operation including start and stop, maintainability, high efficiency and high reliability. This paper defines the merits associated with portable wellhead generators, its effects to the electricity market with respect to Geothermal Development Company (GDC) agenda in Kenya, growth of small geothermal power projects around the world, the impact/significance of wellhead generators to; investors, off grid power for remote areas and use during geothermal exploitation stage. Geothermal portable wellhead generators can be applied to accelerate geothermal development and power generation in Kenya with immense opportunities for both the country and investors.

INTRODUCTION

Demand for electricity in Kenya is expected to increase rapidly due to; a growing rural and urban economy, expansion of rural electrification programme, the advent of county governments and Kenya's concerted efforts to be a medium sized economy by 2030. Therefore, securing stable energy supply, developing and establishing power plants that meet this demand is a priority for the Kenyan power sector if the economic growth is to be sustained in the future.

Kenya presents various attractive advantages for investment in power generation such as; dynamic electricity markets, abundant indigenous resources (e.g. hydro, wind, coal, solar and geothermal), and relatively low political risks.

Substantial opportunities for power generation exist both in large and small scales. However, opportunities for small scale power generation are more abundant from various sources. These sources include mini-hydro projects, solar, wind and small geothermal projects. The government interventions and initiatives have encouraged the application of small scale generation. Of particular interest are small scale geothermal projects which can be developed independently in remote areas or as part of a larger geothermal project in an early generation concept. Widespread use of small geothermal plants demonstrates the technological feasibility of small geothermal systems (Vimmerstedt, 1998).

In this paper, small geothermal power plant is defined as one with up to 20 megawatts (MWe) capacity.

Small geothermal power plants, which could be in the form of wellhead units, play an important role in the development of geothermal energy. Transmission of high temperature steam over long distances is a challenge, and hence the nearer the power plant the more effective the resource. The biggest challenge to the deployment of the wellhead units is their economic viability (Leeds et al 1979), when compared to a large central plant. However, the wellhead units possesses unique characteristics that make it very attractive for certain applications, these include; portability, re-usability, modest capital investment and rapid power production capability. The most promising applications of small geothermal plants include; onsite industrial use, electricity supply in remote areas, as a geothermal field development tool and peaking units for larger utilities.

ENERGY STATUS, FUTURE PROJECTION AND INTERVENTIONS IN KENYA

Energy Status in Kenya

Kenya energy mix consists of both renewable and non-renewable sources. The current electricity demand stands at 1,191 MW against an installed capacity of 1,429 MW. The generation capacities from the various sources are as shown in Table 1.

For a long time, Kenya has relied on hydro-electricity with perennial power outages forcing the government to invite emergency power producers who use thermal sources to generate electricity. This stop-gap measure not only lead to an increase in the cost of electricity, but also contributed in a major way to air pollution since it uses fossil fuel. The government therefore identified the country's untapped geothermal potential as the most suitable indigenous source of electricity.

Table 1. Kenya energy mix (SREP, 2011)

Item	Energy Source	Generation Capacity (%)
1.	Hydro	52.1
2.	Geothermal	13.2
3.	Baggase (Co-generation)	1.8
4.	Wind	0.4
5.	Thermal sources (Fossil)	32.5

Energy Demand Projections in Kenya

Going forward, the peak load is projected to increase to about 2,500 MW in the year 2015 and 15,000 MW in 2030 (SREP, 2011).

Accelerating power generation and distribution is at the core of the Kenya's government commitment in keeping with the Millennium Development Goals (MDG), to reduce by 50% the access to modern energy services, by 2015. Access to affordable energy is essential in achieving economic growth in Kenya. Hence the government has set-up the necessary policies, regulations and institutions to ensure increased electricity generation.

Similarly, The Vision 2030 (Kenya's long term development strategy that covers the period 2008 to 2030), considers energy as a significant enabler for economic acceleration in Kenya. Consequently, the government of Kenya through the Rural Electrification Master Plan is committed to ensure 100% countrywide connectivity through grid extensions and off-grid systems. However, to achieve all these developmental objectives there is a need to expand energy infrastructure and increase the supply of power to the grid.

In a view to address the ever increasing power demand, the government through the LCPDP (Least Cost Power Development Program) process, endeavors to expand the expansion and inclusion of renewable sources of energy in the national energy mix. The LCPDP planning process estimates future energy requirements and identifies suitable least cost sources of energy to meet the projected demand. Figure 1, shows a comparison of the cost of various renewable energy sources in Kenya. It is observed from the figure that geothermal sources generate energy at the least cost.

The amount of power generated from the various sources envisioned to meet the increasing demand in the country include; 5,000 MW from geothermal, 1,000 MW from hydro, 2,000 MW from wind, 3,600 MW from thermal, 2,000 MW from imports, 2,400 MW from coal and 3,000 MW from other sources (SREP, 2011).

Therefore going forward in the future, power generation from geothermal sources will play a major role in reducing the energy deficiency in the country.

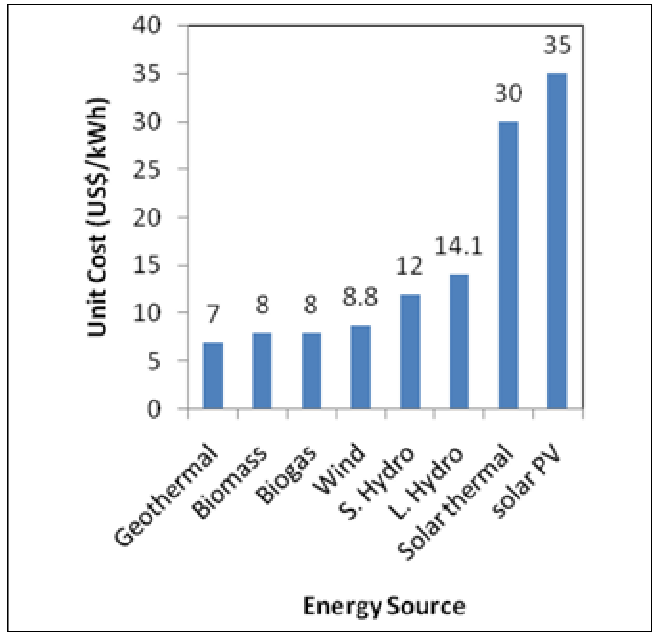

Figure 1. Comparison of generation cost for various renewable energy sources (SREP, 2011)

Geothermal Energy Interventions

The Sessional paper No. 4 of 2004 institutionally restructured the energy sector in Kenya. In the restructuring, GDC (Geothermal Development Company) was formed as a Special Purpose Vehicle to fast track the development of geothermal resources in the country and generate in excess of 5,000 MW of electricity from geothermal sources by the year 2030. Geothermal energy is an indigenous, abundant, reliable and environmentally- friendly source of energy.

The exploration and development of geothermal energy started as early as 1957 in Kenya. But this has so far yielded 209 MW only against a massive potential estimated at between 7,000 MW to 10,000 MW.

There are more than 14 geothermal sites in Kenya (Figure 2). The potential sites are spread along the Kenyan Rift. Other locations include: Homa Hills in Nyanza, Mwananyamala at the Coast and Nyambene Ridges. Currently only Olkaria has been developed, while Menengai is at the appraisal drilling stage.

Evidently, the speed of harnessing and developing geothermal resources in Kenya has been slow necessitating the creation of GDC.

GDC is expected to drill about 1,400 steam wells to provide steam for the generation of 5,000 MW of geothermal power by 2030.

To achieve the objective of developing geothermal energy, the government through GDC has started and progressing with the development 400 MW in the Menengai geothermal field to be completed in 2015 (SREP, 2011).

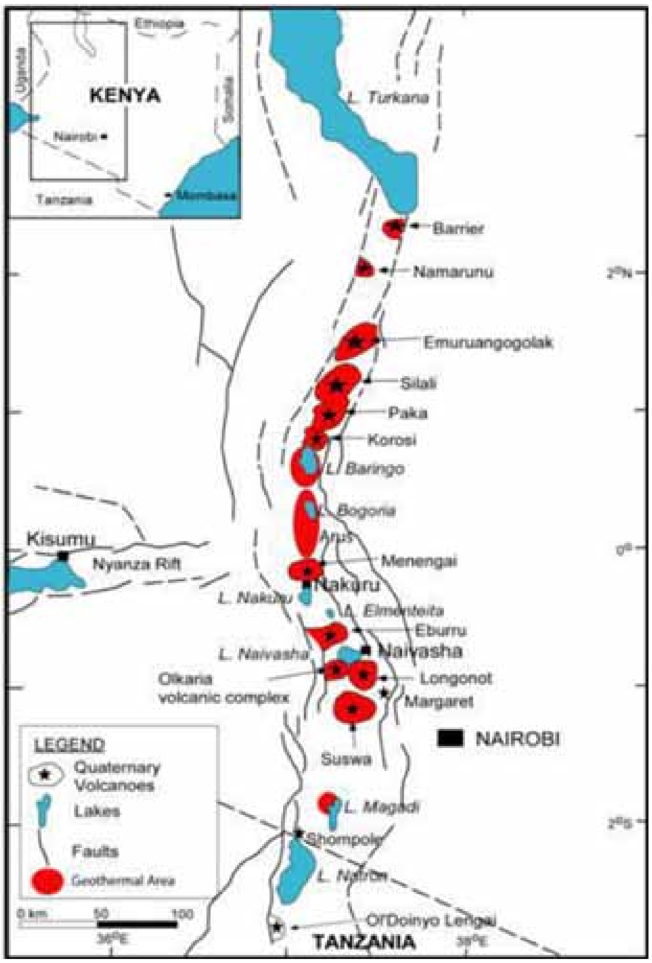

Figure 2. Geothermal Sites in Kenya

GDC currently has two rigs drilling at the Menengai field. Figure 3 shows one of the rigs on site, while Figure 4 shows the first exploration well in the Menengai field discharging vertically.

The expansion of the Olkaria field to accommodate a 280 MW power plant is underway.

The government's involvement in the development of geothermal energy is mainly to mitigate on the risks inherent in the early stages of geothermal development in the view of reducing the gestation period of the projects to about five years, and hence make it more attractive to investors.

Currently, funding for the geothermal projects in Kenya is sufficient since the government committed to finance the early stages of the projects.

The country can benefit immensely with accelerated power generation from ongoing geothermal projects through installation of wellhead generation units in an early generation concept.

Kenya geothermal industry offers competitive and attractive advantages for investment in power generation. These unique advantages include;

1. Dynamic electricity markets,
2. Abundant geothermal resources
3. Relatively low political risks
4. Government and institutional support
5. In-country expertise
6. Active geothermal development

Figure 3. A GDC rig at Menengai Geothermal Prospect, GDC 2011.

Figure 4. Well MW-01 in the Menengai geothermal field discharging vertically.

Characteristics that Make Portable Wellhead Generators Attractive

Geothermal wellhead generator unit possess special features that make it attractive for a small geothermal power plant application. These unique features could be the much needed interventions the power sub-sector in Kenya requires to mitigate some of the challenges that limit its development.

The challenges identified to retard electricity development in Kenya include the following:

1. Slow rate of capacity addition hence inadequate supply;
2. Over-reliance on hydropower
3. High cost of power
4. Weak transmission and distribution network
5. Long lead times in the development of power infrastructure
6. Low investments in power sector by private investors
7. High cost of rural electrification
8. Low countrywide electricity access and connectivity

The special features built into the portable wellhead generators include:

No Need for Power Source to Start

Portable wellhead generators can be started without any auxiliary power source except a battery for instrumentation.

The unit has steam turbine driven oil pump and mechanical-hydraulic control system. Therefore the unit can be installed without considering any electric network of the area.

Attracting Investment

The units enable developers, utilities and independent power producers to significantly shorten the time between exploration and revenue generation in geothermal projects and thereby accelerate the growth in the geothermal development in Kenya.

Optimal Energy Utilization

The independent wellhead power plant unit enables optimum power to be produced from each individual well regardless of their differing outputs and characteristics. The concept negates the needs of traditional power plants for well redundancy or an excess steam buffer to cater for well failures and allows all wells to be utilized. The wellhead generating unit is modular in design also makes it possible to generate electricity from remote wells that are outside the topographical reach of large traditional plants.

Rapid Deployment

Portable Wellhead generator modular design, based on standard manufactured components, allows for significantly reduced lead times and early power online. Today, manufacturers can deliver power online within 12 months of ordering the portable modular wellhead power plant and thereafter rapid deployment, at a rate of one modular portable wellhead unit plant per month, can be achieved (GEG website: www.geg.no/news).

Lower Risk

With modular flexibility, the wellhead turbine power plant is delivered in standard containers and each module is ready made at the factory allowing for quick installation. It is designed to operate independently for each well, but can be organized in power farms to provide a similar power output to large traditional geothermal power plants. In the event of a well failure, the module is designed to be decommissioned, transported and redeployed on a second well, maximizing the return on investment. Equally importantly, the failed well can be returned to its original state thus preserving the environment.

Reduced Cost per Megawatt

The unit modular design like C64 from the Green Energy Group can generate over 6.4 MW (based on standard manufactured components; this enables a highly competitive capital price and allows for easy maintenance and access to spare parts. By focusing on the characteristics of each well independently, this module is able to adjust turbines to achieve a high level of power output efficiency, driving down electricity production costs.

Advance Control and Maintenance

Wellhead power generating units also deploy an advanced control system providing real-time operational data, allowing for early remediation action and preventative maintenance thus avoiding unnecessary downtime and associated costs.

Huge Investment Opportunity

Wellhead generators provides a big opportunity to power developers, utilities and independent power producers to significantly cut capital costs and shorten the time between exploration and revenue generation in geothermal projects. The wellhead generator can be used to test the geothermal field and in effect benefit from data already gathered.

TECHNOLOGIES FOR SMALL POWER PLANTS

Majority of small geothermal power plants currently in use are either binary or flash, although some are a hybrid of both. Both flash steam and binary technologies have their own proponents and each has its own set of advantages and disadvantages.

Flash Steam Plants

Flash steam plants are used where the geothermal resource produces high temperature hot-water or a two-phase fluid.

In the flash steam plant (either single or double flash) the hot-water or two-phase flow from the well is directed to a steam separator where the steam is separated from the water phase and directed to drive the turbine. In double flash system, the steam is flashed from the remaining hot-fluid of the first stage, separated and fed into a dual-inlet turbine.

This technology is competitive and economical for deployment in many locations and can be developed with capacities of between 10 to 50 MW (Meyers, 2002). A modular approach is also possible with this technology where standardized units are installed.

The flash steam systems can either be condensing or non-condensing. In a non-condensing flash system, as shown in Figure 5, the steam is separated from the geothermal discharge and fed through a conventional axial flow steam turbine which exhausts directly to the atmosphere. This plant is the simplest and the cheapest in capital cost of all geothermal cycles. The condensing flash system, shown in Figure 6, is a thermodynamic improvement on the non-condensing design. Instead of discharging the steam from the turbine to the atmosphere it is discharged to a condensing chamber that is maintained at a very low absolute pressure- typically about 0.12 bar-a. Because of the greater pressure drop across a condensing turbine more power is generated compared to atmospheric exhaust.

Non-condensing turbines are less efficient than condensing turbines. They demand about 12 tons of steam per Megawatt-hour (MWh), compared to around 8 tons per MWh required for condensing turbines. But when used for testing new wells they are very attractive in an economic sense (Hiriart, 2003).

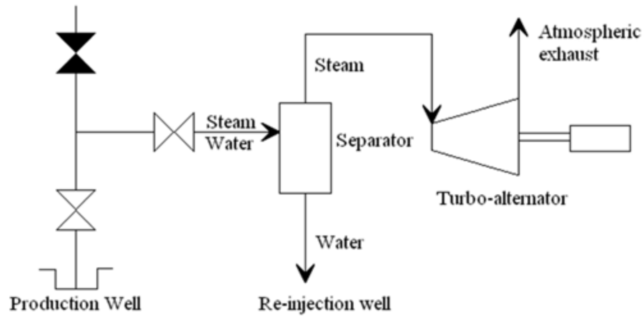

Figure 5. Atmospheric exhaust cycle simplified schematic

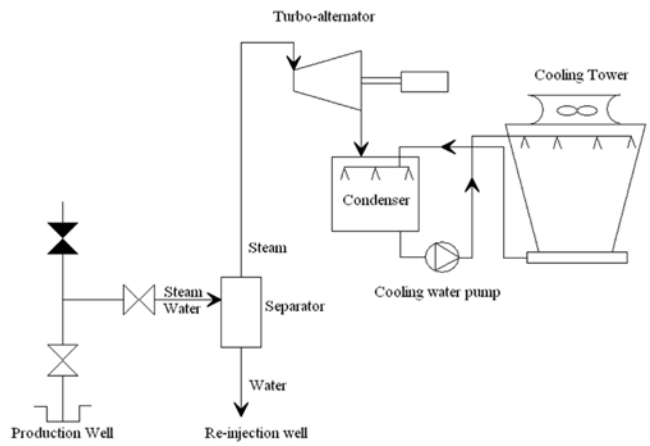

Figure 6. Condensing cycle simplified schematic

Examples of small flash plants can be found in, Japan, Mexico and Guadalupe.

In Japan, a small flash facility was installed at the Kirishima International Hotel in Beppu, Kyusha in 1983. The 100 kW non-condensing unit operates on the output of two production wells and has an inlet temperature of 127°C at 2.45 bars (Bloomquist, 2005).

In Mexico, a 5-MW wellhead non-condensing turbine (Los Azufres Unit 8) was used to test the behavior of the Los Azufres geothermal reservoir. This plant was later moved to the Los Humeros geothermal field (Hiriart, 2003). This example demonstrates the significance of wellhead units in geothermal development.

Binary Plants

The binary cycle plant is used with low and medium enthalpy resources.

In a binary plant, shown in Figure 7, the thermal energy of the geothermal fluid is transferred to a secondary working fluid via a heat exchanger for use in a conventional Rankine Cycle or Kalina Cycle. The vaporized working fluid, e.g. isopentane, propane, Freon or ammonia drives the turbine before being condensed and returned to the heat exchanger in a closed loop. Cooling is generally provided through the use of air coolers.

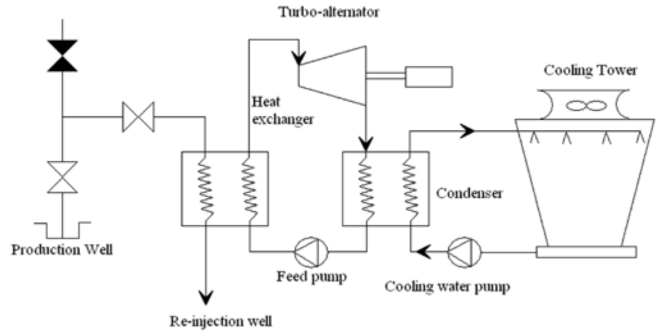

Figure 7. Binary cycle simplified schematic

Geothermal binary plants are widely used and the technology is very feasible. Normally modular configuration and systems are applied to achieve higher plant availability factors of over 98% (Meyers, 2002).

EXISTING SMALL GEOTHERMAL POWER PLANTS

Amedee Geothermal Venture Binary Power Plant (Lund and Boyd, 1999)

Amedee Geothermal Venture binary plant, located in northern California near Susanville, became operational in 1988. The plant consists of two units of 1-MW each with a total net output of 1.5 MW. The resource temperature is 219˚F (104˚C), and well depth of 850 ft (260 m) with a maximum flow rate of 3,200 gpm (205 l/s). The plant uses R-114 working fluid and cooling ponds for makeup water. The units were designed by Barber-Nichols Engineering Company of Arvada, Colorado. They have an availability is 90% and the system is remotely monitored by telephone line. Geothermal fluids from two wells are used to operate the plant, and surface discharge is used to dispose of the spent fluid. This is possible because the geothermal fluids have a very low salinity and a composition the same as area hot spring water.

Tarawera Binary Plants, Kawerau, New Zealand (Lund and Boyd, 1999)

They were commissioned in late 1989 and officially opened in early 1990 after a record short construction time of 15 months. The two ORMAT energy convertors (OEC) receive waste water from Kawerau 21 flash plant at about (172˚C) and 8 bar. Heat rejection from the plant is by a forced draft air condenser situated above the OEC units. Each unit has a gross output of 1.3 MW; a total of 2.6 MW, of which about 13% is used by auxiliaries, pumps, fans, etc., giving approximately 2.2 MW available for the Bay of Plenty Power Board (BOP) grid. The monitoring system allows unattended operation that ensures that unscheduled outages can be quickly reported. The plant performance is also monitored by the manufacturers in Israel, who provide weekly reports directly to the BOP offices in Whakatane. Tilson, et al., (1990) reported no deposition in the heat exchangers and, with little maintenance required, load factors for the first six months of operation were over 90%, with 96.6% availability. The unit average output was about 1,800 MWh per month for the initial operation.

2 MW Nominal Geothermal Power Plant, Lake Naivasha, Kenya

Geothermal Development Associates (GDA) designed, assembled and installed a 2 MW nominal geothermal steam turbine generator and related power plant auxiliary components at the Oserian flower-growing facility near Lake Naivasha in Kenya.

GDA shipped the plant to Kenya in June 2007. The time from contract signature to readiness for shipment of the plant was 10 months. The plant was commissioned in November 2007. The complete geothermal power generation system (turbine generator set, gearbox, oil lubrication system and electrical control system) was manufactured and assembled in the U.S. The plant is now operational.

Eburru Wellhead Geothermal Pilot Power Plant, Kenya

Geothermal Development Associates (GDA) has also been contracted for the design, supply, and commissioning of a wellhead geothermal pilot power plant at Eburru geothermal field in Kenya. The equipment supplied will include a 2.5 MW steam turbine generator set complete with auxiliary systems and controls. The contract was signed on October 2009. The construction of the plant started in early 2011 and completed within the same year. The plant is waiting commissioning. The Eburru geothermal field is along the flanks of the Ol Doinyo Eburru Volcano and is situated 11 km northwest of Lake Naivasha.

The trend with the small geothermal plants discussed above is the short time the power plant takes to come online. This is the greatest advantage of wellhead generators, which allows them to be deployed rapidly.

THE IMPACT AND SIGNIFICANCE OF APPLICATION OF PORTABLE WELL HEAD GENERATORS TO THE INTEGRATION OF SMALL GEOTHERMAL POWER GENERATION IN KENYA

The period after which geothermal projects in Kenya are expected to start generating electricity can be reduced further to two or three years by installing wellhead generators on the already drilled productive wells. This strategy will not only generate power for project implementation by providing power to the drilling operation, but also provide opportunities for other direct uses.

Early Generation for Geothermal Development

Geothermal sites in Kenya are found in remote locations; off-grid (Outside national power network) and hence diesel generators are used to provide power to the drilling rigs. For instance, Menengai wells 03 and 04 have used diesel to power the drilling rig, base camp and associate equipment of over Kenya shillings 100 million (USD 1.2 million) which is about 25% of the total cost of drilling the well. Menengai well 01 and 04 can produce over 10 MW peak loads for our 2000 horsepower rigs is 1.5 MW. By connecting these wells to wellhead generators producing over 10 MW, we can save over a quarter of drilling and base camp facility costs. Moreover, procurement and logistics period required before obtaining the diesel fuel will be eliminated hence reducing the drilling period significantly. This is notwithstanding the fact that diesel generators require maintenance periodically. Oil filters; oil and fuel filters alongside labor required for maintenance are eliminated by use wellhead generators.

Since the use of diesel will completely be eliminated by the portable wellhead generators, the use of geothermal energy amount to use of green energy which environmental friendly, cheaper and clean.

Drilling, design and construction of a traditional geothermal power plant can take up to 7 years to complete (Green Energy Group website: www.geg.no/product-sheet). This involves the need for big capital injections while at the same time not being able to cater for the short term needs of energy. Well head manufacturers like Toshiba and Green Energy Group have developed a standardized module system which is in mass production today. The production capacity of each module is up to 15 MW and can be put together to produce a larger scale power station. It takes one year from module construction to it being installed and operational. The considerable time before power production can take place lies in the amount of wells that need to be drilled.

The portable geothermal units can be installed in the Menengai geothermal field especially to displace the diesel being currently used to run the rigs, compressors and auxiliary equipment in the field. The two already producing wells (well MW-01 and MW-04) can be harnessed to generate over 10 MW as well tests are ongoing. As more wells are drilled in the field, the number of wellhead plants can be increased to supply electricity to the grid. This is practical as the Menengai field is close to Nakuru town which will provide a ready market.

The same concept can either be applied to existing geothermal fields like Olkaria, where more wells are being drilled for expansion or new fields like Korosi-Paka-Silali block, as part of the geothermal field development program.

By implementing this concept, the subsequent early generation programs will benefit from the experiences of the first implementation and the reuse of the portable wellhead units.

Integration of Small Power Plants with Agribusiness and Tourism

The integration of small geothermal power projects with agribusiness and tourism is rapidly growing in popularity. This trend is a result of advancements in the generation of electricity from low to moderate temperature geothermal resources (100°C-150°C) and the economic advantage that full use of the resource provides.

Opportunities for integration of small geothermal plants with other direct uses exist in the Kenyan Rift where most of the viable geothermal sites are found, i.e.,, Nakuru, Baringo and Turkana counties.

The use of wellhead type generation coupled with agribusiness systems e.g. agriculture crop dehydration, greenhouses, milk processing and aquaculture in these remote regions of the Kenya will not only support the above processes but also supply power off grid. In addition, the infrastructure built in the process of developing the geothermal resources will promote tourism activities in these regions. Consequently, there will be a need to provide power off-grid and using the geothermal fluid for tourism activities like outdoor bathing, warm swimming pools and water heating for sauna baths. Table 2 summarizes some of the integrated direct uses of geothermal fluid from the small power plants.

Table 2. Opportunities for integrated geothermal power generation and direct uses in Kenya

Item	Area (county)	Type of integrated direct use
1	Nakuru	• Crop dehydration; maize, onions, wheat • Greenhouse use • Milk and pyrethrum processing
2	Baringo	• Crop dehydration; tomatoes, onions • Greenhouse uses • Tourism applications; swimming pools, outdoor bathing and heating of sauna baths
3	Turkana	• Fish drying • Greenhouse uses • Tourism applications; swimming pools, outdoor bathing and heating of sauna baths

The integration of small power production with agribusiness projects and off grid power supply in remote Kenya by use of portable wellhead turbine power generators can significantly improve the economic viability of using lower temperature geothermal fluids and can result in a much higher overall "fuel use efficiency" than can be achieved with stand-alone power or direct use projects.

Investment Opportunities

By embracing the early generation concept, the geothermal industry in Kenya will provide a great investment opportunity to the private sector. The portable wellhead technology will enable power developers, utilities and independent power producers to significantly reduce capital costs since this is no need for steam lines to connect many wells to the power plant as is the case in traditional power plants. The reduced time between exploration and revenue generation in geothermal projects will accelerate the growth in the geothermal development in Kenya. The investor can generate power from a single or more wells and generate revenue to invest in other fields being drilled. More significantly the government would have shielded the investor from the high risk initial stages of the field development and proved the existence of the resource, and hence enables the investor to concentrate on power generation.

CONCLUSION

Geothermal portable wellhead generator set is completely assembled on a common base then shipped to the site. Therefore installation and adjustment work are minimal. Pursuant to immense benefits related to their lower cost of installation, this would provide an economical alternative to the rather expensive conventional power plants in Kenya. Kenya which is a developing economy and having installed electricity capacity of only 1,330 MW in the whole country will benefit from the use of these units, especially during the resource development phase of geothermal energy and supply of electricity to off grid and remote areas of the Great Rift Valley where up to 10,000 MW of geothermal potential exists.

EDITOR'S NOTE

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GRC 2012 ANNUAL MEETING THEME PROMOTES GEOTHERMAL AS ENERGY SOLUTION

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