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LOW-TEMPERATURE RESOURCE ASSESSMENT PROGRAM
BACKGROUND INFORMATION

Howard P. Ross June 4, 1999

The initial national geothermal resource assessment took place from 1975-82 as a joint effort supported by the U.S. Geological Survey and the Department of Energy (initially ERDA). In an effort coordinated by UURI, state geothermal resource teams were identified and funded to do geothermal resource assessment activities for all states with geothermal resource potential (the State-Coupled Program). In addition to individual state team reports and widely used state resource maps, the national survey results for low-temperature resources were organized and summarized in a much-referenced publication, USGS Circular 892, "Assessment of Low-Temperature Geothermal Resources of the United States - 1982", Marshall J. Reed, editor.

Realizing that the low-temperature resource inventory was badly out-of-date, and that these resources were greatly under utilized, P.M. Wright (UURI), L. Roy Mink (IWRRI), and Paul Lienau (OIT-GHC) proposed a new low-temperature assessment program in 1990-91 which was funded by Congress in 1991. Nine State Geothermal Resource Teams were identified by UURI and subcontracts for $30,000 to $55,000 for each state (total funding to states was $355,000) were issued through OIT-GHC for a major resource assessment update. IWRRI was funded directly by DOE for the resource assessment of that state, bringing the total number of states participating in the program to ten (10). The resource assessment activities of the state teams were coordinated and managed by UURI and final reports were submitted to OIT-GHC. OIT-GHC performed a computer-based collocation study of the geothermal resources and potential user communities. The results of this program are summarized in "Final Report, Low-Temperature Resource Assessment Program" by Paul J. Lienau and Howard P. Ross, OIT-GHC report to DOE, February 1996, and in journal publications.

Funding limitations restricted the program to the 10 states judged to have the highest potential to improve the total resource base, and those with the highest potential to bring new direct use projects on line because of the probable higher collocation of resources with potential user communities. The participating states selected for this program were:

> Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, and Washington **(AZ, CA, CO, ID, MT, NV, NM, OR, UT, WA)**

Several other states were initially considered for participation in the program, but not included when the level of funding available to the states became apparent. The other states with significant resource potential and potential low-temperature users were:

> Alaska, Arkansas, Hawaii, Nebraska, North Dakota, South Dakota, Texas and Wyoming. **(AK, AR, HI, NB, ND, SD, TX, WY)**

Considerations relating to the potential for new resource use, state of the last DOE supported geothermal studies, possible Principal Investigators (P.I.'s), etc. for these states follow.

Alaska

The Geothermal Resource Assessment (GRA) map was published in 1983. Numerous specific resource assessment studies were funded by DOE during the 1980's. The most recent study was "The Geothermal Resources of the Aleutian Arc" by Roman J. Motyka (P.I.), Shirley A. Liss, Christopher J. Nye, and Mary A. Moorman. This study includes all of the resources on the Aleutian Islands and the Alaska Penninsula, includes several high quality resource maps and is an excellent comprehensive study, and was published in 1993. The data should be considered current for these areas. There is some possibility for database improvement for mainland Alaska, but our earlier evaluation was that population centers are very few and the collocation of possible direct heat users and resources would not be substantially changed from earlier studies. Dr. Motyka and/or Shirley Liss would be likely candidates for the P.I. to complete any new resource evaluations.

Arkansas

Arkansas has relatively few geothermal resources, and these appear to be well known and well developed as a spa and recreation industry. DOE funded one additional resource study which was concluded in July 1987, "Final Report, Heat Flow in Arkansas", by Dr. Douglas L. Smith, P.I., University of Florida, a final report submitted to DOE, UURI with heat flow data submitted to Dr. David Blackwell for inclusion in his national heat flow map. The new heat flow data revealed the Ozarks to be a low heat flow province. New resource studies should be given a very low priority, and either Dr. Smith or Dr. Blackwell should be considered the P.I. for any new work.

Hawaii

The Hawaii GRA map was published in 1983, and most subsequent studies were directed toward high temperature resources. Dr. Donald Thomas was the P.I. for the last study which involved high temperature silica solubility and control, a study completed in June 1991. Perhaps because of the warm climate, there appears to be limited interest in direct heat utilization, other than for spent fluids from geothermal power production. This situation may change, but the likelyhood of major direct use interest is considered to be low.

Nebraska

The Nebraska GRA was published in 1982 and relatively little interest has been shown in the low temperature stratabound geothermal resources of this state. Dr. William D. Gosnold, Dept. Geology, University of North Dakota, has been the P.I. for resource assessment projects in Nebraska, North Dakota, and South Dakota, and is the undisputed geothermal expert for resource occurrence in these three states. The resources occur in major, stratabound aquifers (Dakota, Madison, etc.) and the distribution of these units, and their depth is well known. There seems to have been little interest in developing these resources in Nebraska. There could be substantial improvement in the well database which would define the resource.

North Dakota

The GRA map of North Dakota was published in 1981 and DOE has funded a number of subsequent studies by Dr. Gosnold, Department of Geology, University of North Dakota. From 1988-90 Dr. Gosnold was funded to complete a study "Stratabound Geothermal Resources in North Dakota and South Dakota". The studies include evaluations of fluid chemistry, depth to the thermal aquifers, and net potential for direct heat use. Relatively little improvement in the database would be expected from a new study.

South Dakota

The Geothermal Resource Assessment of South Dakota was completed by Dr. Gosnold with reports from 1987 to a final resource map received by DOE in 1992. We expect relatively little change in the resource definition since that time, but Dr. Gosnold would have the better opinion of this topic. A collocation of resources and communities would be expected to change little.

Texas

The GRA map of Texas (and accompanying study) was published in 1982. DOE funded a drilling and evaluation for direct use at Lackland AFB (1983-85?) but (to our knowledge) the project ended without utilization of the low-temperature thermal fluids. Another potential direct use project for air conditioning at Williams AFB in Arizona was also considered not to be economic. Texas has a number of identified low-temperature geothermal resources, but the relatively low temperatures (30-60 degrees C), depth of production horizons (500 - 1000 m) and water quality, coupled with a warm climate, have limited interest in direct heat projects. Perhaps it is time, however, for another in-depth study of potential for direct heat projects. Earlier DOE geothermal projects were completed by scientists from the Texas Bureau of Economic Geology, and we have not funded any P.I.'s there for several years. Dr. David Blackwell, Southern Methodist University is one of the nation's heat flow experts, and he should be considered as a potential P.I. for any new geothermal project in Texas.

Wyoming

The GRA map of Wyoming was published in 1982. Dr. Henry P. Heasler, Department of Geology and Geophysics, University of Wyoming, has directed a number of more detailed resource oriented studies since 1982, including the "Geothermal Resources of the Green River Basin, WY" (1985), "Geothermal Resources of the Wind River Basin, WY" (1985), Geothermal Resources of the Southern Powder River Basin, WY" (1985), and most recently "Geothermal Modeling of Jackson Hole, Teton County, WY" (1987). Wyoming is a state with many geothermal resources, and these are important to the recreational industry at Thermopolis and Cody. Several years have elapsed since the last resource assessment, and it may well be productive to complete a new statewide resource assessment such as those completed by the 10 State Teams in the last Low-Temperature Resource Assessment.

Evaluation of Proposed OIT-GHC Task 3 - Extent Low-Temperature Assessment Program

I was very impressed by the results of the previous Low-Temperature Assessment Program, and I am most supportive of DOE and OIT efforts to expand the utilization of our widespread low-temperature resources. Nonetheless, I believe that there are several flaws in the OIT Task 3 as proposed, and some of these should be apparent from the summary and background information presented earlier.

I strongly believe that Resource Assessment activities should be carried out by professional geologists or hydrologists familiar with the local or regional geology, the appropriate State regulatory agencies regarding water usage and drilling, oil and gas drilling, commercial drilling firms, etc. The concept of State Geothermal Resource Teams that complete these assessments has been successful in the past, but it does require some level of funding directly to the state or university agency. The tasks also require a substantial amount of verification using a basic knowledge of geologic unit depths, water chemistry, etc. to arrive at a solid, usable result. Task 3 as proposed does not provide for funding for state resource teams, nor for adequate time to complete a reasonable resource assessment update.

The Final Report of the Low-Temperature Resource Assessment Program (Lienau and Ross, 1996) identified 48 high-priority sites where communities and resources were collocated. Recommendations from the 10 participating states called for exploration, drilling, hydrologic testing, comprehensive assessment, and district and industrial heating feasibility studies as the next logical step to make more widespread use of the identified resources. The work proposed in Task 3 does not address these recommendations.

EGI

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FAX MESSAGE

TO: Willettia Amos	FROM: Howard Ross
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DATE: 06/04/99	_ URGENT ___ Reply Needed __ FYI
Page 1 of 5	

Willettia,

Here is a quick response to your request from today's review meeting. I will save the file, perhaps revise it, and ~~can~~ send it via Email next week if you wish.

Sincerely,

Howard Ross

LOW-TEMPERATURE RESOURCE ASSESSMENT PROGRAM

Objectives

- Update the inventory of low to moderate temperature resources
- Initially 10 western states
- Perform a collocation study of resources and communities
- Prioritize best resources for in-depth studies
- Establish resource databases
- Evaluate geothermal heat pump (GHP) performance
- Educate the public about GHPs

Program Participants

- Oregon Institute of Technology (OIT)
- University of Utah Research Institute (UURI)
- Idaho Water Resources Research Institute (IWRRI)
- State Resource Teams

Approach

- State geothermal resource teams review and update geothermal resource inventories
- Collocation of resources and communities by state teams and OIT
- Prioritization of resources for in-depth studies by state teams, UURI and OIT
- Recommendations for new work when funding is available
- Study and document GHP use
- Prepare Fact Sheets for GHP case histories

LOW-TEMPERATURE PROGRAM

Program Duration

- FY-93, FY-94
- Future funding (?)

Some Preliminary Results

State	Low-Temperature Wells 1982	Low-Temperature Wells 1993	Commercial Direct Heat Areas 1982	Commercial Direct Heat Areas 1993
CA	486	551	56	65
CO	120	170	28	28
UT	209	572	15	16
WA	338	936	–	–

Deliverables

- New state geothermal resource maps - black and white; 1:1,000,000
- Digital database for wells and springs
- 10 new fluid chemical analyses, each state
- GHP fact sheets and case histories
- Presentations and teleconferences

ALTERNATIVE FUELS and the ENVIRONMENT

Edited by
Frances S. Sterrett

LEWIS PUBLISHERS
Boca Raton Ann Arbor London Tokyo

Library of Congress Cataloging-in-Publication Data

Alternative fuels and the environment / edited by Frances Sterrett.
p. cm.
Includes bibliographical references and index.
ISBN 0-87371-978-6
1. Energy development—Environmental aspects. I. Sterrett, Frances S.
TD195.E49A44 1994
621.042—dc20 94-25419
CIP

Lewis Publishers is an imprint of CRC Press

International Standard Book Number 0-87371-978-6
Library of Congress Card Number 94-25419
Printed in the United States of America 1 2 3 4 5 6 7 8 9 0
Printed on acid-free paper

Chapter 2

Environmental Compatibility of Geothermal Energy

Marshall J. Reed and Joel L. Renner

CONTENTS

INTRODUCTION

Geothermal energy is one of the cleaner forms of energy now available in commercial quantities. The use of this alternative energy source, with low atmospheric emissions, has a beneficial effect on our environment by displacing more polluting fossil and nuclear fuels. Rapidly growing energy needs around the world will make geothermal energy exceedingly important in several developing countries. In the production of geothermal energy, wells are used to bring hot water or steam to the surface from underground reservoirs. The thermal energy carried in the produced fluid can be used for direct heating in residential, agricultural, and industrial applications; or the thermal energy of higher temperature systems can be used to produce electricity.

Geothermal energy provides an enormous resource for low-temperature applications such as heating and cooling buildings, drying agricultural products, and process heating for industry. For example, geothermal heat pumps can be installed in almost all areas of the U.S. to provide greater efficiency in heating and cooling of buildings and supplying hot water than either all electric systems or systems with air-source heat pumps. Only a modest part of the potential of geothermal energy has been developed because the service industry is small and the price of competing energy sources is low. Electrical power production is the most profitable use of geothermal energy and has grown the most. Our discussion of the environmental aspects of geothermal energy utilization will concentrate on the production of electricity.

The U.S., Japan, and the European Community are continuing experiments in the extraction of thermal energy from high-temperature, subsurface zones with low initial permeability (often called "hot dry rock"). In these investigations, one deep well is used for the injection of water, at high pressure, into artificially fractured rock, the water extracts heat from the fracture surface, and a second deep well produces steam and hot water. This method of energy production is not yet economic, and the presently commercial geothermal operations depend on naturally occurring hydrothermal systems.

The U.S. Department of Energy (DOE) conducted research into the extraction of energy from the geopressured (very high pressured) brines in the Gulf Coast area of Texas and Louisiana, and concluded that even the extraction of methane as a byproduct did not make this energy source economic. Experiments were also conducted by the DOE to investigate the recovery of thermal energy from magma systems. The technique considered for energy extraction involved the injection of water to cool the magma to a fractured glass and then the continued injection and production of water to carry heat to the surface.

Geothermal energy performs a small but important role in the supply of energy for electric power generation in the U.S., and geothermal electricity plays an even greater role in some developing countries (the Philippines, Mexico, Indonesia, El Salvador, Kenya). In 1991, geothermal electrical production in the U.S. was 15,738 GWh (gigawatt hours), and the generation of this electricity provided approximately $1 billion dollars in revenue.[1] This use of geothermal energy displaces the equivalent of over 30 million barrels of imported oil per year.

The U.S. geothermal electric-power industry has grown to be the largest in the world, with over 2100 MW (megawatts electricity) generating capacity operating at over 90% availability. Slightly over half, 1100 MW generating capacity, is from The Geysers geothermal field in California. The magnitude of development in the U.S. is followed by the Philippines with 890 MW, Mexico with 700 MW, Italy with 545 MW, and New Zealand with 460 MW.[1] Iceland has the unique situation of an overabundance of hydroelectric potential, and most geothermal energy is used to provide heating and hot water for commercial and residential customers.

Geothermal energy use avoids the problems of acid rain, and it greatly reduces greenhouse gas emissions and other forms of air pollution. Geothermal reservoirs, either dry steam or hot water, are naturally occurring hydrothermal convection systems. Natural fluids are usually complex chemical mixtures, and geothermal waters exhibit a wide range of compositions and concentrations of solutes. The concentrations of solutes generally increases with the temperature of the geothermal system, and higher concentrations of some elements often require remedial action for protection of the environment. Potentially hazardous elements (Hg, B, As, and Cl) produced in geothermal brines are largely injected back into the producing reservoir. A continuing strong market for geothermal electrical generation is anticipated as a result of the increasing interest in controlling atmospheric pollution and because of the spreading concern about global warming. Geothermal development will serve the growing need for energy sources with low atmospheric emissions and proven environmental safety.

Land use for geothermal wells, pipelines, and power plants is small compared to land use for other extractive energy sources such as oil, gas, coal, and nuclear. Low-temperature geothermal applications are usually no more disturbing of the environment than a normal water well. Geothermal development projects often coexist with agricultural land uses, including crop production or grazing.

GEOTHERMAL ENERGY APPLICATIONS

HIGH-TEMPERATURE ELECTRICAL USE

The production of electricity requires a greater concentration of energy than other applications. Many geothermal systems contain water or steam at temperatures above 175 °C, and temperatures up to 400 °C have been recorded. If hot fluid is available in great enough quantities, a geothermal power plant can be installed that uses the produced steam directly to drive a turbine generator system.

In 1960, The Geysers in northern California became the first U.S. geothermal field to produce electricity, and this remains the only commercial development in the U.S. that

Department of Energy
Washington, DC 20585

November 7, 1994

Dear Colleague:

Joel Renner and I considered it of value to author this contribution on the environmental compatibility of geothermal energy. We hope that this work makes information on geothermal energy more generally available to the public.

We would appreciate any comments or suggestions you might have.

Sincerely,

Marshall Reed

Marshall Reed, Program Manager
Geothermal Reservoir Technology
Geothermal Division, EE-122

is classified as a dry-steam geothermal system. In this low-pressure, single-phase system, dry steam is the pressure-controlling medium filling the fractured rocks. The pressure increases only slightly with depth due to the density of the steam. Initial conditions in The Geysers reservoir at a depth of 1.5 km (kilometers) included temperatures near 250 °C and pressures near 3.3 MPa (megapascals). Over 30 years of production, the pressure has dropped to less than 1 MPa in the areas of production wells, but the temperature has remained constant. Early developers found that this dry-steam type of geothermal system is very rare.

Most geothermal fields are water-dominated, where liquid water at high temperature, but also under high (hydrostatic) pressure, is the pressure-controlling medium filling the fractured and porous rocks. The pressure increases along a hydrostatic gradient in water-dominated reservoirs, and the temperature will often increase along the boiling point (liquid-vapor equilibrium) curve with depth. In water-dominated geothermal systems, water comes into the wells from the reservoir; and, in the flashed-steam power-plant technology, the pressure decreases as the water moves toward the surface, allowing part of the water to boil. Since the wells produce a mixture of flashed steam and water, a separator is installed between the wells and the power plant to separate the two phases. The flashed steam goes into the turbine to drive the generator, and the water is injected back into the reservoir.

The water-dominated geothermal system in Dixie Valley, Nevada has several features that are common to many of the geothermal fields in eastern California, Nevada, and western Utah. The water contains 0.45 weight percent dissolved solutes, and these constituents are in chemical equilibrium with the reservoir rocks. At a depth of 2 km, the temperature is 240 °C and the fluid pressure is 24 MPa; this is the hydrostatic pressure from the overlying column of water.[2] At these conditions, the geothermal fluid is liquid water. The production wells penetrate permeable zones along the active Stillwater fault, which is the physical boundary between Dixie Valley and the Stillwater Range. Steam is allowed to flash in the wells and is separated at the surface to drive the turbines. The separated water is injected to maintain reservoir pressure.

BINARY-PLANT ELECTRICAL GENERATION

Most water-dominated reservoirs below 175 °C are pumped to prevent the water from boiling as it is circulated through heat exchangers to heat a secondary liquid. In these binary power systems, heat is transferred to an organic compound with a low boiling temperature (commonly propane or isobutane), and the resulting organic vapor then drives a turbine to produce electricity. Binary geothermal plants have no emissions because the organic fluid is continuously recirculated in a closed loop, and the entire amount of produced geothermal water is injected back into the underground reservoir. A higher conversion efficiency is required to economically use lower-temperature water for electrical production, and the binary equipment has a higher capital cost to achieve this greater efficiency. The identified reserves of lower-temperature geothermal fluids are many times greater than the reserves of high-temperature fluids, providing an economic incentive to develop more efficient binary power plants.

LOW-TEMPERATURE DIRECT HEAT USE

Warm water, at temperatures above 20 °C, can be used directly for a host of processes requiring thermal energy. Thermal energy for swimming pools, space heating, and domestic hot water are the most widespread uses, but industrial processes and agricultural drying are growing applications of geothermal use. In a 1990 inventory, the U.S. was using over 5×10^{12} kJ (kilojoules) of energy annually from geothermal sources for direct heating of commercial and residential installations.[3] In Iceland, more than 95% of the buildings are supplied with heat and domestic hot water from geothermal systems, and this heat has directly replaced the burning of fossil fuels. The cities of Boise, Idaho; Elko, Nevada; Klamath Falls, Oregon; and San Bernardino and Susanville, California; have geothermal district-heating systems where a number of commercial and residential buildings are connected to distribution pipelines circulating water at 54 to 93 °C from the production wells.[4] There is believed to be a high potential for growth in district heating because numerous geothermal resources are co-located with population centers, especially in the western half of the U.S. The U.S. Department of Energy currently is funding a comprehensive inventory of low-temperature geothermal systems with special emphasis on co-location with population centers. Preliminary results indicate that there may be twice the number of systems that have been identified previously.

Typical direct-use applications are either closed systems with the produced fluids being injected back into the geothermal reservoir, or systems where the produced water is pure enough for beneficial use or disposal to surface waterways. Experience has shown that it is worthwhile to inject as much of the cooled geothermal water back into the reservoir as possible to maintain pressure and production rates. The direct use of geothermal energy for heating offsets the carbon dioxide production from combustion of fossil fuels — usually oil or gas — in a large number of residential or commercial furnaces.

GEOTHERMAL HEAT PUMPS

The use of geothermal energy through ground-coupled heat pump technology has almost no impact on the environment and has a beneficial effect in reducing the demand for electricity. Geothermal heat pumps use the reservoir of constant temperature, shallow groundwater as the heat source during winter heating and as the heat sink during summer cooling. Shallow groundwater is normally about 5 °C above the mean annual air temperature for any locality in the U.S. Because of this constant temperature, the energy efficiency of geothermal heat pumps is about 30% better than that of air-coupled heat pumps and 50% better than electric-resistance heating. Depending on climate, advanced geothermal heat pump use in the U.S. reduces energy consumption and, correspondingly, power plant emissions by 23 to 44% compared to advanced air-coupled heat pumps, and by 63 to 72% compared to electric-resistance heating and standard air conditioners.[5] The need for electrical generation capacity at the central power station is reduced by 2 to 5 kW for each residential installation and by about 20 kW for average commercial installations. Thus, for each 1000 homes with geothermal heat pumps, the utility can avoid the installation of 2 to 5 MW of generating capacity.

Geothermal heat pumps can be used in a variety of installations. A system is comprised of 1) the heat pump mechanical unit, 2) the closed-loop or open-system ground heat exchanger, and 3) the building water loops. In closed-loop systems, water or a mixture of water and an environmentally safe antifreeze solution is circulated through a pipe to remove heat from, or reject heat to the ground. There is thus no contact between the solution in the closed-loop pipe and the groundwater or soil. In a vertical installation, the heat exchanger loop is a U-shaped pipe inserted in a hole 50 to 150 m (meters) deep. In horizontal installations, the heat exchanger loop is either rigid or flexible pipe laid in trenches about 2 m deep. Flexible tubing shaped in a spiral (often called a "slinky") and placed in a trench can be used to increase the effective heat exchange surface area of a horizontal loop and to reduce the length of trenching by 40%. The open vertical system uses a water well to provide groundwater to the heat pump, and, depending on need, the water can be used within the building, can be discharged at the surface, or can be injected in a second well. In single-well, open installations, water can be withdrawn from the bottom of the well, circulated through the heat pump, and returned to the top of the well. This method depends on the open communication with the groundwater system, is often a lower cost option, and is used in large commercial applications where space is limited.

The use of heat pump technology is associated with disturbance of soil during installation; however, since this application is normally associated with the simultaneous construction of homes and industrial buildings, there is only a small and transient surface disturbance. Geothermal heat pumps require less frequent maintenance and repair; refrigerants are installed in sealed systems at the factory (like a refrigerator) and no field connections are required. Equipment has a much longer lifetime since no part of the heat pump is outside the building and exposed to the elements. During operation, there are no emissions from closed-loop systems because the ground-loop heat-exchange fluid (usually water) is contained. If an antifreeze is needed, environmentally compatible antifreeze such as potassium acetate can be used so that there is no risk of accidental release of polluting compounds to ground or surface waters.

ENVIRONMENTAL CONSIDERATIONS

AIR QUALITY

All known geothermal systems contain the equilibrium distribution of carbonate, bicarbonate, and aqueous carbon dioxide species in solution; and, when a steam phase separates from boiling water, carbon dioxide is the dominant (over 90% by weight) noncondensible gas. Most hydrothermal systems have very low oxygen activity, and these systems commonly contain the reduced species H_2S, NH_3, and CH_4 in the steam phase. In most geothermal systems, noncondensible gases make up less than 5% by weight of the steam phase. Thus, for the same output of electricity, carbon dioxide emissions from geothermal flashed-steam power plants are only a small fraction of emissions from power plants that burn hydrocarbons. Binary geothermal power plants do not allow a steam phase to separate, so carbon dioxide and the other gases remain in solution and are reinjected into the reservoir, resulting in no atmospheric emissions. For each megawatt-hour of electricity produced in 1991, the average emission of carbon dioxide by plant type in the U.S. was: 990 kg from coal, 839 kg from petroleum, 540 kg from natural gas, and 0.48 kg from geothermal flashed-steam.[6]

Hydrogen sulfide can reach moderate concentrations in the steam produced from some geothermal fields, and some systems contain up to 2% by weight of H_2S in the separated steam phase. This gas presents a pollution problem because it is easily detected by humans at concentrations of less than 1 ppm in air. Development of technology to remove H_2S was the first major research effort for joint industry-government funding in the National Geothermal Program. H_2S control became a pressing problem at The Geysers because of increasingly more stringent environmental standards promulgated by the California Air Resources Board. Now, either the Stretford process or the incineration and injection process is used in dry-steam and flashed-steam geothermal power plants to keep H_2S emissions below 1 ppb.

The efficiency of these processes in removing over 99.9% H_2S from the air emissions has resulted in Lake County, California (containing part of The Geysers geothermal field) receiving the Outstanding Performance award in 1992 from the California Air Resources Board for compliance with the California Clean Air Standards.[7] Use of the Stretford process in many of the power plants at The Geysers results in the production and disposal of about 13,600 kg sulfur per megawatt of electrical generation per year. Figure 1, based on the diagram of Henderson and Dorighi,[8] shows the typical equipment used in the Stretford process at The Geysers. Some of this sulfur is contaminated with vanadium (the Stretford catalyst) and must be washed before disposal.

The incineration process burns the gas removed from the steam to convert H_2S to SO_2, the gases are absorbed in water to form SO_3^{2-} and SO_4^{2-} in solution, and iron chelate is used to form $S_2O_3^{2-}$.[9] Figure 2, derived from the diagram of Bedell and Hammond,[9] shows the incineration abatement system. The major product from the incineration process is a

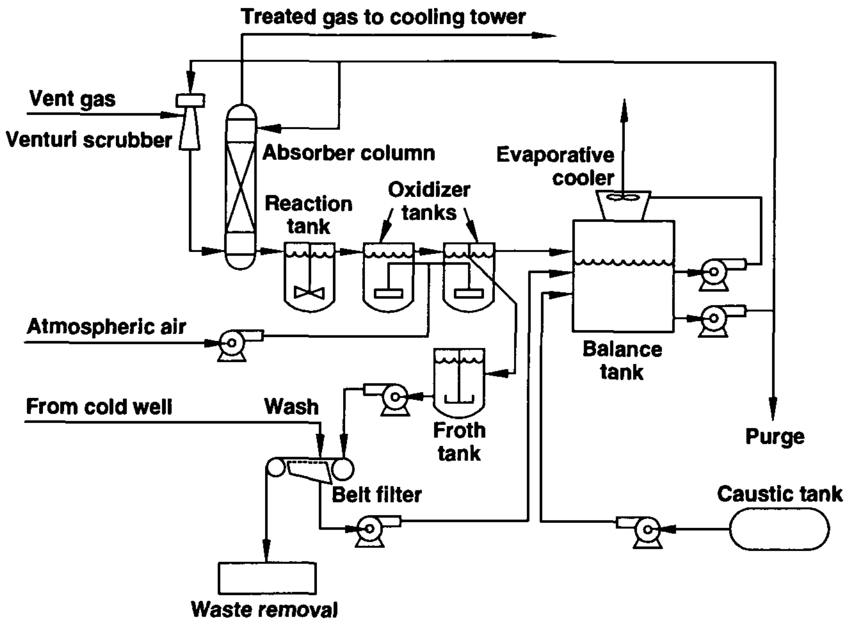

Figure 1 Typical equipment used in the Stretford process for hydrogen sulfide abatement at The Geysers geothermal field. (*From Henderson, J. M. and Dorighi, G. P., Geothermal Resources Council Trans., 13, 593, 1989, with permission.*)

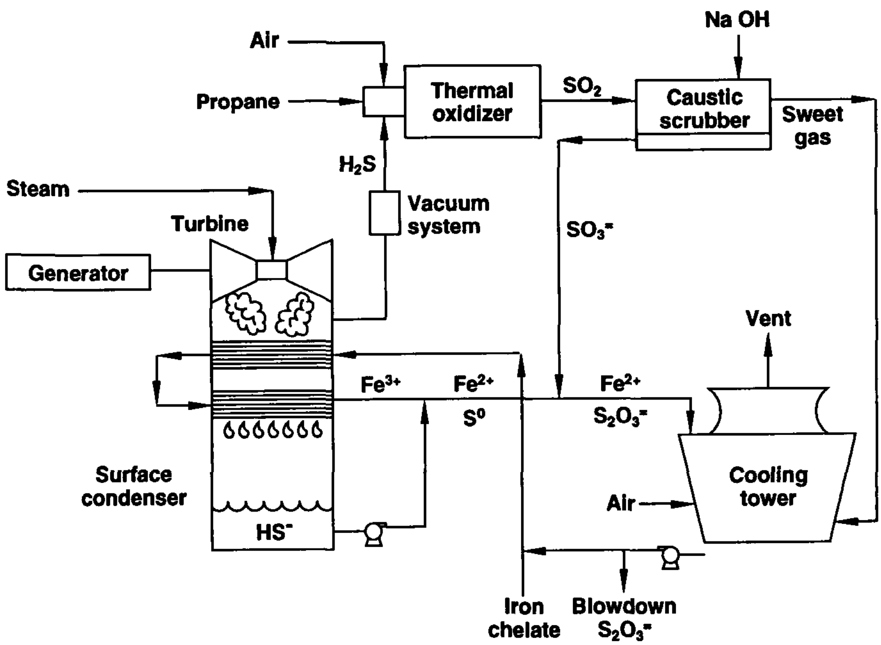

Figure 2 Equipment used in the incineration process for hydrogen sulfide abatement at The Geysers geothermal field. (*From Bedell, S. A. and Hammond, C. A., Geothermal Resources Council Bull., 16, 3, 1987, with permission.*)

soluble thiosulfate that is injected into the reservoir with the condensed water used for the reservoir pressure maintenance program. Recent advances in the use of an oxidizing biocide to remove H_2S from cooling tower circulating water have the potential to decrease cost and increase efficiency of removal.[10]

The environmental effects of H_2S and SO_2 are quite different but, at a distance of 5 km downwind from the source, studies have shown that all of the H_2S has been oxidized by the air to SO_2. For discussions of air emissions, we have converted the H_2S to SO_2. Sulfur emissions from geothermal flashed-steam power plants are only a small fraction of emissions from power plants that burn solid or liquid hydrocarbons. For each megawatt-hour of electricity produced in 1991, the average emission of SO_2 by plant type in the U.S. was: 9.23 kg from coal, 4.95 kg from petroleum, and 0.03 kg from geothermal flashed-steam (from data of Colligan[6]).

Ammonia occurs in small quantities in many geothermal systems; but, in flashed-steam geothermal power plants, the ammonia is oxidized to nitrogen and water as it passes into the atmosphere. Because the high pressures of combustion are avoided, geothermal power plants have none of the nitrogen oxides emissions that are common from fossil fuel plants. For each megawatt-hour of electricity produced in 1991, the average emission of nitrogen oxides by plant type in the U.S. was: 3.66 kg from coal, 1.75 kg from petroleum, 1.93 kg from natural gas, and zero from geothermal (from data of Colligan[6]).

WATER QUALITY

The waters in geothermal reservoirs range in composition from 0.1 to over 25 weight percent dissolved solutes. The compositions and concentrations of geothermal waters depend on the rock type of the reservoir, the temperature, and the pressure. Systems in sedimentary rocks seem to have higher concentrations than those in volcanic or granitic rocks, but there is wide variability within a single reservoir rock type. Temperatures up to 380 °C have been recorded in geothermal reservoirs in the U.S., and many chemical species have a significant solubility at high temperature. For example, all of the geothermal waters are saturated in silica with respect to quartz. As the water is produced, silica becomes supersaturated; and, if steam is flashed, the silica becomes highly supersaturated. Upon cooling, amorphous silica precipitates from the supersaturated solution.

The high flow rates of steam and water from geothermal wells usually prevent silica from precipitating in the wells, but careful control of fluid conditions and residence time is needed to prevent precipitation in surface equipment. Silica precipitation is delayed in the flow stream until the water reaches a crystallizer or settling pond. There the silica is allowed to settle from the water, and the water is then pumped to an injection well. It is necessary to inject the geothermal water back into the reservoir to maintain the pressure and flow rate at the producing wells. Precipitated silica is removed from the water so that the solid material does not clog the injection well or reservoir. The most soluble of the other species in solution remain in solution and are injected. Other species, which have precipitated, are washed from the silica and injected with the wash water. The removed silica requires disposal, but research is underway to find a commercial use for the silica produced. Many of the solids removed from geothermal processes require drying before disposal to reduce both volume and mass.

The Salton Sea geothermal system in the Imperial Valley of southern California has presented some of the most difficult problems in brine handling. Water is produced from the reservoir at temperatures between 300 and 350 °C and concentrations between 20 and 25% solutes by weight. This brine is in equilibrium with the mineral phases in the reservoir, but the concentration that occurs when 20% of the mass is allowed to vaporize leaves the brine supersaturated with respect to several solid phases. To remove solids from the steam, crystallizers are used upstream of the turbines, and to remove solids from the injection water, both clarifier and thickener tanks are needed. Figure 3, modified from

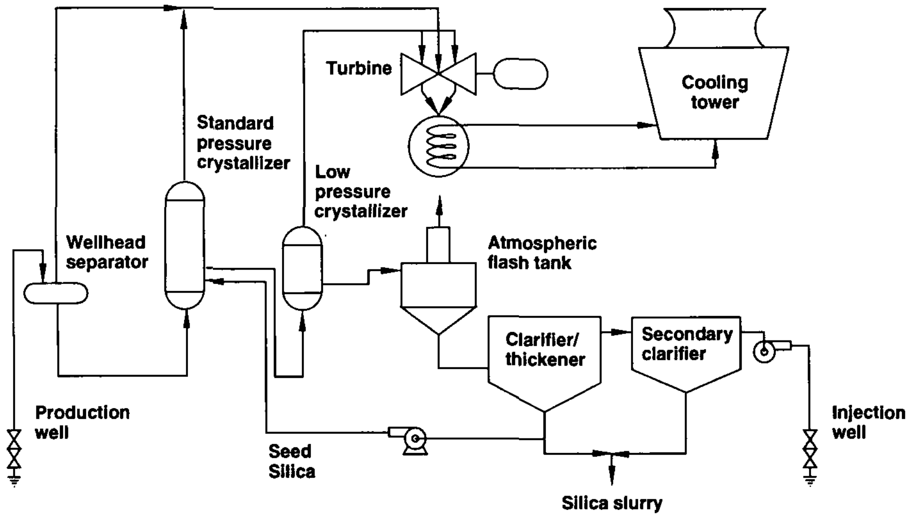

Figure 3 The flow stream for removal of solids from the vapor and brine in typical power plants in the Salton Sea geothermal field. (*From Signorotti, V. and Hunter, C. C., Geothermal Resources Council Bull., 21, 277, 1992, with permission.*)

the diagram of Signorotti and Hunter,[11] shows the flow stream for removal of solids from the vapor and brine. As an alternative, one power plant in the Salton Sea geothermal field uses the addition of acid to lower the pH and keep the solutes in solution.[11] The output from the crystallizers and clarifiers is a slurry of brine and amorphous silica. The methods used to de-water the salt and silica slurry from Magma Energy operations in the Salton Sea geothermal system are described by Benesi.[12]

Some geothermal systems, such as Dixie Valley in Nevada, form a high pH water through the evolution of carbon dioxide from solution.[1] This high pH permits the silica concentration in solution to remain at much higher levels without causing the precipitation of amorphous silica. At high pH, some of the silica in solution forms an ionic complex ($H_3SiO_4^-$) reducing the concentration of the neutral complex ($H_4SiO_4^0$) that controls polymerization and precipitation as amorphous silica.

In the U.S., only the lower-temperature geothermal waters that are of drinking-water quality are allowed to flow into streams or lakes. All other geothermal applications require that the cooled water be injected back into the reservoir. To protect potable ground waters in shallow aquifers, both the production and injection wells are lined with steel casing pipe and cemented to the surrounding rock. This type of well completion prevents the loss of geothermal water to any freshwater aquifers and confines the injection to the geothermal reservoir. Repeated examination of casing and cement, using sonic logging instruments, assures that no leakage occurs.

The production and injection system for geothermal water also prevents any contamination of surface waters. Water injection in the hotter geothermal systems does not require any pump pressure at the surface, since the cold injection water drops under the influence of gravity into the less dense, hot water of the reservoir. Cooler geothermal systems or those with rocks of lower permeability will require some pump pressure to inject the water into the reservoir. Geothermal power plants in the U.S. use cooling towers to condense the turbine exhaust fluid (either steam or organic fluid), and no waste heat is dumped into rivers or the sea. Waste heat disposal from fossil and nuclear power plants can cause disruption of the biota in local water bodies.

LAND USE

The actual land used in geothermal operations is fairly small, and other applications such as crop growing or grazing can exist in proximity to the roads, wells, pipelines, and power plants of a geothermal field. The average geothermal plant occupies only 400 m^2 (square meters) for the production of a gigawatt hour over 30 years.[13] If the entire life cycle of each energy source is examined, the energy sources based on mining such as coal and nuclear require enormous areas for the extraction and processing in addition to the area of the power plant. The disturbed surface from open pit mining is an area with no plant life to participate in the carbon cycle or in evapotranspiration to replenish the water in the atmosphere.

ACKNOWLEDGMENTS

The authors express their appreciation for useful suggestions and critical comments in reviews from Phillip M. Wright and John E. Mock. This study was supported by the Geothermal Division of the U.S. Department of Energy, partially under DOE Idaho Operations Office contract DE-AC07-76ID01570 with EG&G Idaho, Inc.

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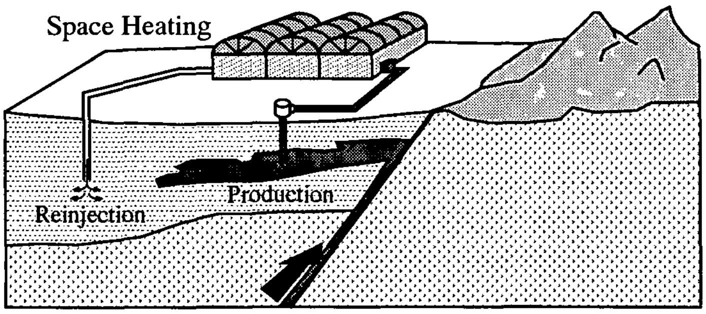
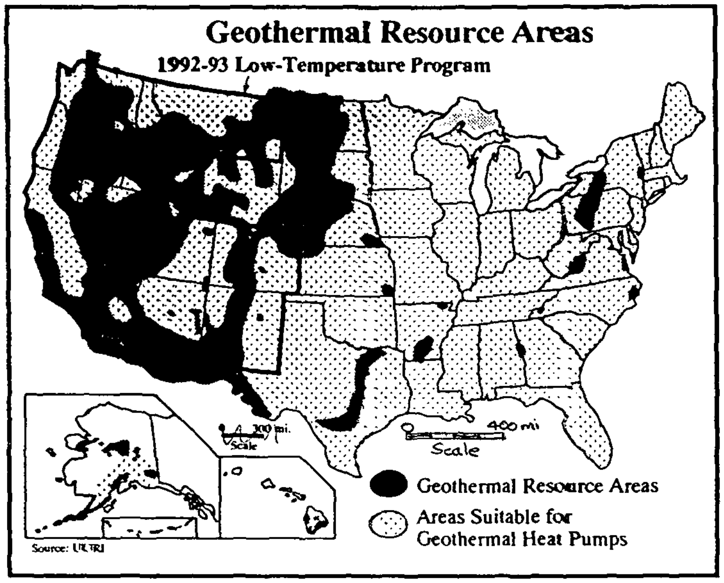

Space Heating
Production
Reinjection



Geothermal Resource Areas
1992-93 Low-Temperature Program
300 mi.
Scale
400 mi
Scale
Geothermal Resource Areas
Areas Suitable for
Geothermal Heat Pumps
Source: UURI

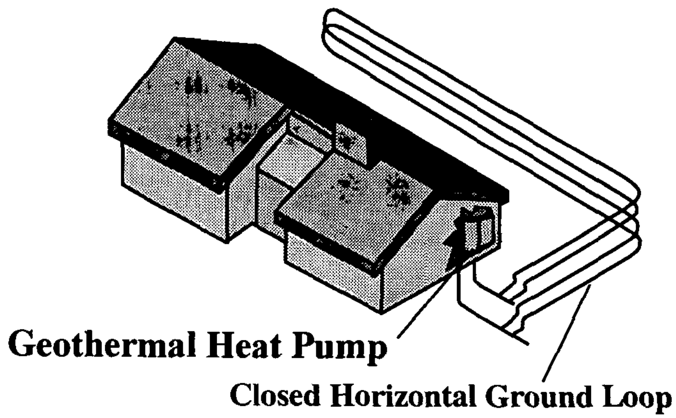
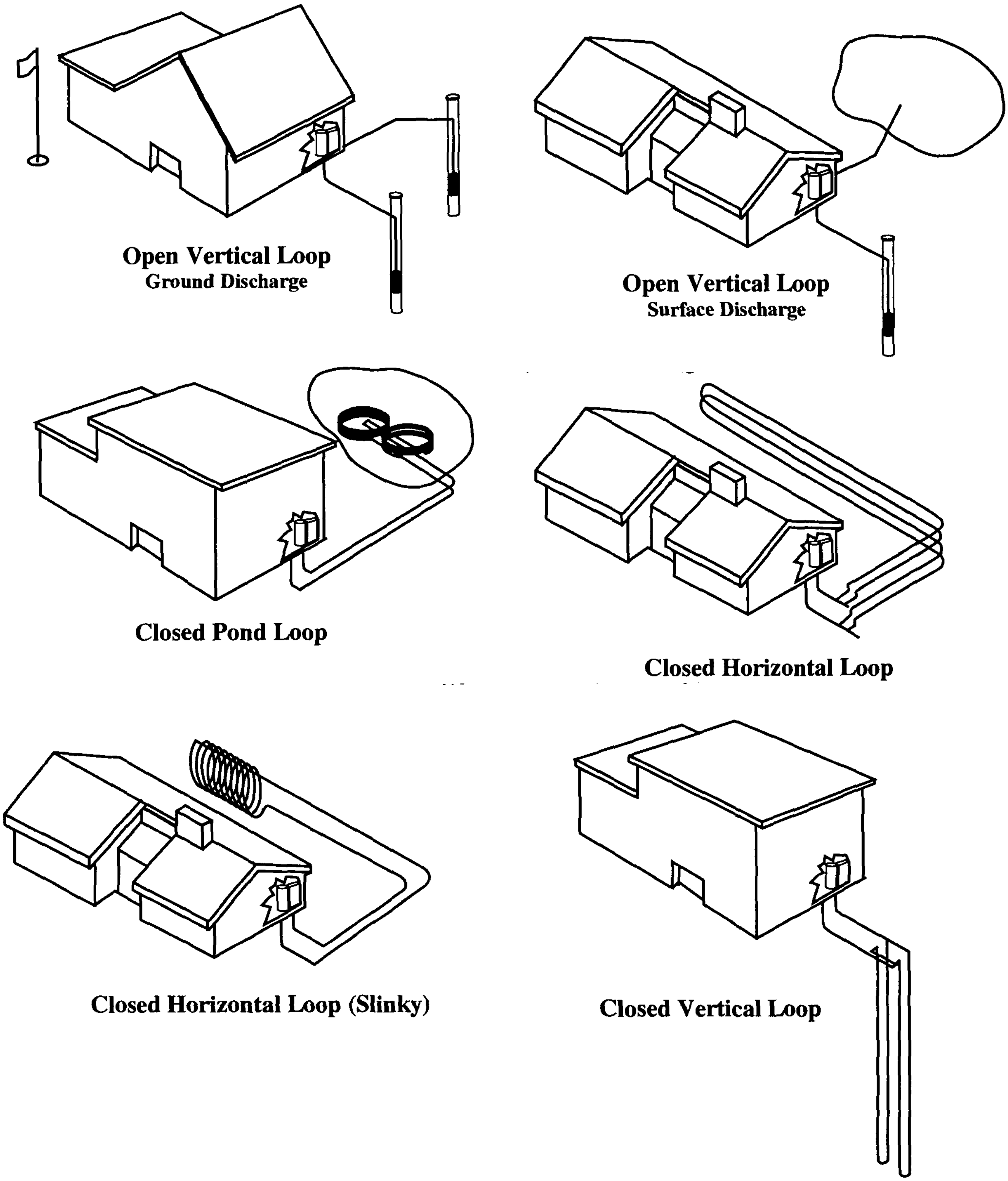

Geothermal Heat Pump
Closed Horizontal Ground Loop

Figure 4


Open Vertical Loop
Ground Discharge
Open Vertical Loop
Surface Discharge
Closed Pond Loop
Closed Horizontal Loop
Closed Horizontal Loop (Slinky)
Closed Vertical Loop

ADDENDUM TO STANDARD CONTRACT AGREEMENT
for
STATE GEOTHERMAL ENERGY RESEARCH,DEVELOPMENT,
AND DATABASE COMPILATION

between

THE OREGON STATE SYSTEM OF HIGHER EDUCATION
OREGON INSTITUTE OF TECHNOLOGY

and

THE COLORADO GEOLOGICAL SURVEY

STATEMENT OF WORK

1.0 INTRODUCTION

The United States Department of Energy - Geothermal Division (DOE/GD) supports the development of indigenous and environmentally advantageous energy alternatives to the traditional fuels. There is a very large, nearly unused supply of low- and moderate-temperature geothermal resources in the United States that could be brought on line over the next decade. The increased use of Geothermal Heat Pumps (GHPs) could also reduce the need for traditional fossil fuel consumption for space heating and cooling.

The U.S. Congress has appropriated funds for a program of Low-Temperature Geothermal Resources and Technology Transfer and DOE/GD has funded EG&G, Idaho to establish contracts with the Oregon Institute of Technology - Geo-Heat Center (OIT-GHC), the Idaho Water Resources Research Institute (IWRRI) and the University of Utah Research Institute (UURI) to implement this program.

Important parts of this program are to bring the inventory of the nation's low- and moderate-temperature resources up to date, to complete a collocation study of these resources and communities and other potential users, and to collect and disseminate information necessary to expand the use of GHPs. OIT-GHC will have the lead role in the collocation study and will establish subcontracts with the state resource teams. UURI will work with the State Teams on gathering, documenting, and assembly of low- and moderate-temperature hydrothermal resource data and will assist in technical monitoring of the State Team efforts and publications. IWRRI will be responsible for establishing the hydrothermal resource data for Idaho and for performing geothermal reservoir evaluations throughout the western United States.

The technical tasks described herein may be considered Phase I of the Low-Temperature Geothermal Resources and Technology Transfer program. If Phase I proves successful, and additional funds are appropriated by Congress, the program may be expanded and continued. Phase II would likely include detailed resource evaluations of priority areas identified in Phase I.

Funding for the Low-Temperature Geothermal Resources and Technology Transfer Program is limited, and the success and continuation of the program is dependent upon a productive Phase I effort. Participating State Teams are encouraged to seek state or organization cost shares (in cost or in-kind) to enhance this contract effort.

2.0 TECHNICAL TASKS

The following technical tasks will be accomplished under this subcontract.

2.1 Complete an updated inventory of low- and moderate-temperature resources for the State of Colorado, current to June 1, 1992. Review drilling records and other information to identify new resources and verify temperatures and flow rates of springs and wells which may have changed substantially since the previous statewide geothermal resource inventory. Identify geological, geophysical, geochemical, and hydrologic studies which relate to these resources. The minimum temperature for a low-temperature resource is defined to be 10°C above the mean annual air temperature at the surface and should increase by 25°C/km. Occurrences to 150°C will be included.

2.2 Conduct a fluid geochemistry study of the more important resource areas for which existing data are questionable or unavailable. UURI will provide up to ten (10) quantitative fluid chemical analyses for each state in support of this study.

2.3 Complete a computer database listing compatible with Lotus 123 format tabulating for each occurrence: name, location (T,R,S), county, longitude, latitude, depth, flow, temperature, chemistry, and other data as appropriate and available.

2.4 Review OIT-GHC geothermal resource and demographic data for the State of Colorado for accuracy and completeness, as part of the collocation study.

2.5 Assist OIT-GHC, UURI, and IWRRI in studies to prioritize low- and moderate-temperature resource areas for new development. Develop conceptual geologic models and groundwater data for selected resources.

3.0 REPORTS, DATA, AND OTHER DELIVERABLES

3.1 A geothermal database listing in hardcopy and diskette form will be submitted to UURI. The listing will include all known low- and moderate- temperature spring and well occurrences in the State of Colorado. Principal facts will include location, depth (well), flow rate (if known), etc.

3.2 Letter reports and memoranda reviewing collocation data and priority rankings will be submitted to OIT-GHC and UURI.

3.3 A final summary report, not to exceed 50 pages, describing all tasks and their results, and documenting any new temperature, geologic, geochemical or geophysical data will be submitted to UURI, OIT-GHC, and IWRRI. This report may incorporate interim letter reports and memoranda as appendices. The report will include a geothermal resource occurrence map of the state, black and white, scale 1:1,000,000 or acceptable alternative.

3.4 Interim progress reports will be submitted to UURI and OIT quarterly.

4.0 SCHEDULE OF PERFORMANCE AND REPORTING

4.1 The period of performance for this agreement will terminate December 31, 1993, unless modified by letter agreement and signed by the Colorado Geological Survey, OIT-GHC, and UURI.

4.2 A review of the OIT-GHC collocation study will be completed and a letter report or memorandum of comment submitted to OIT-GHC and UURI within one month after receipt of the draft document from OIT-GHC.

4.3 A preliminary database listing of geothermal resource occurrences will be submitted to UURI within four months after the execution of this agreement.

4.4 A final database listing of geothermal resource occurrences will be submitted to UURI within twelve months after the execution of this agreement.

4.5 A final report documenting all new data and activities completed under this agreement will be submitted to UURI not later than December 31, 1993.

5.0 RESPONSIBLE PARTIES

5.1 The Principal Investigator for this agreement will be James A. Cappa, Colorado Geological Survey.

5.2 The Technical Project Managers for this agreement will be Howard P. Ross, UURI and Paul J. Lienau, OIT-GHC.

5.3 The Contracting Officer for this agreement will be Douglas Yates, OIT.

6.0 FUNDING

This contract agreement provides for funding not to exceed $35,000.00 for the completion of all technical tasks and submittal of all required deliverables.

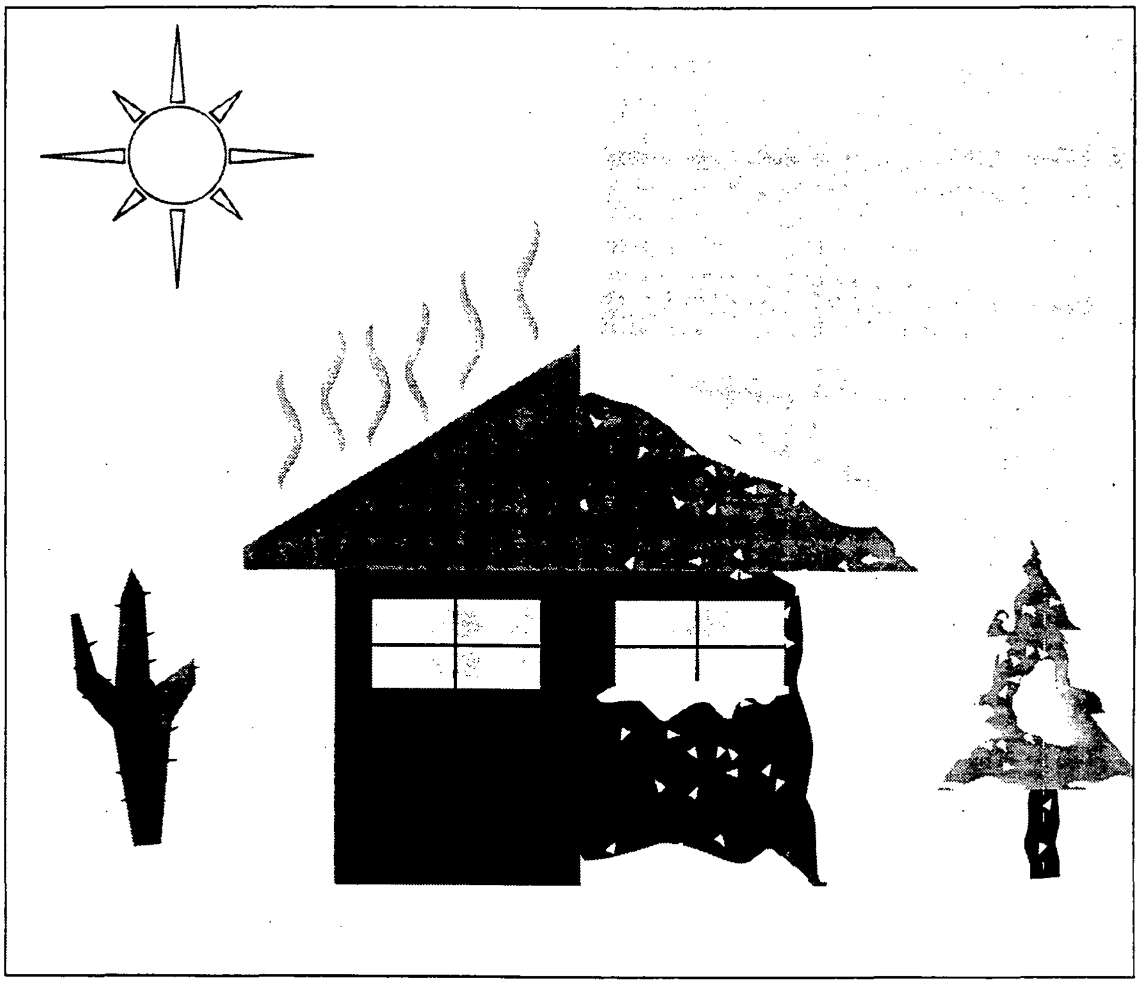
Howard Ross

United States Environmental Protection Agency | Air and Radiation (6202J) | EPA 430-R-93-004 April 1993

EPA

Space Conditioning: The Next Frontier

The Potential of Advanced Residential Space Conditioning Technologies for Reducing Pollution and Saving Consumers Money



Space Conditioning: The Next Frontier

The Potential of Advanced Residential Space Conditioning Technologies for Reducing Pollution and Saving Consumers Money

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Michael L'Ecuyer
Cathy Zoi
John S. Hoffman

Office of Air and Radiation
U.S. Environmental Protection Agency
Washington, DC, 20460

APRIL, 1993

Space Conditioning: The Next Frontier
The Potential of Advanced Residential Space Conditioning Technologies for Reducing Pollution and Saving Consumers Money

REPORT'S MAIN FINDINGS

1. <u>Advanced residential space conditioning equipment can save consumers money.</u>

   - In most climates, **EMERGING GROUND SOURCE HEAT PUMPS** and **ADVANCED AIR SOURCE HEAT PUMPS** save consumers hundreds of dollars annually over standard electric technologies, even when their higher first costs are factored in.

   - New, emerging **GAS-FIRED HEAT PUMPS** were also found to have lower total annual costs than **STANDARD GAS FURNACES** in many locations, again despite higher first costs.

CO_2: 25,000,000 t
SO_2: 85,000 tons
NO_x: 44,000 tons

2. <u>Advanced residential equipment can reduce emissions significantly.</u>

   - Under most electricity generating scenarios, the **EMERGING GROUND SOURCE HEAT** the lowest CO_2 emissions of all technologies analyzed, and the lowest overall environm
     - ★ Its emissions were 55-60% less than **STANDARD AIR SOURCE HEAT PUMPS.**

   - Among gas equipment, the **GAS-FIRED HEAT PUMP** was the lowest CO_2 emitter emissions generally by one-fourth to one-third over standard gas furnace and air c combinations.
     - ★ Its NO_x emissions were higher than other gas equipment. The industry will be (work to reduce NO_x emissions as this technology is introduced in 1994.

33,900 MWe

   - If American electric and gas utilities aggressively promoted advanced residential space conditioning technologies, they could reduce national CO_2 emissions by 25 million metric tons, SO_2 emissions by 85,000 metric tons, and NO_x emissions by at least 44,000 metric tons by the year 2000.

3. <u>Advanced residential space conditioning technologies can be highly cost-effective for utility conservation programs.</u>

   - As utility conservation measures, the most advanced **GROUND SOURCE HEAT PUMPS, AIR SOURCE HEAT PUMPS**, and the **GAS-FIRED HEAT PUMPS** are all generally very cost-effective when replacing standard technologies, in all areas where they offset needed electricity generation capacity. **ADVANCED GAS FURNACES** were similarly cost-effective everywhere but in the South.

   - By aggressively promoting these technologies wherever they are cost-effective, utilities could save 28 billion kilowatt-hours of electricity and offset the need for 113 typically-sized (300 MW) electric power plants in the year 2000. They could also reduce annual gas demand by over 3 billion therms.

4. <u>Strategic partnerships are the best way to promote advanced residential space conditioning equipment.</u>

   Working together, utilities can most effectively promote advanced space conditioning technologies by:

   - creating coordinated programs in which many utilities target the same efficiency levels;
   - offering incentives that reward continuing efficiency improvements by manufacturers;
   - working with national organizations and universities to develop a competitive, national infrastructure of advanced equipment dealers and contractors.

   EPA and other organizations can compliment these efforts by:

   - helping utilities coordinate their programs, and urging utility commissions to approve them;
   - researching new products with advanced components and alternative refrigerants; and
   - identifying superior equipment through the EPA **ENERGY STAR** product identification program.

Space Conditioning: The Next Frontier
The Potential of Advanced Residential Space Conditioning Technologies for Reducing Pollution and Saving Consumers Money

EXECUTIVE SUMMARY

BACKGROUND

Residential space conditioning equipment is responsible for about 9% of total U.S. end-use energy consumption. Through the combustion of fossil fuels, both in the home and at the power plant, space conditioning accounts for 423 million metric tons (MMT) of CO_2 emissions annually. It also results in 1.2 MMT of sulfur dioxide (SO_2) and 830,000 metric tons of nitrogen oxides (NO_x), as well as significant emissions of carbon monoxide, particulates, volatile organic compounds and lead.

Expenditures associated with residential space conditioning are significant; approximately one-half of residential energy expenditures are related to space conditioning, and in 1987 this amounted to about $46 billion.

Due to the long life of space conditioning equipment, the choices that American homeowners, landlords and builders make over the next decade regarding space conditioning equipment will have important environmental and economic ramifications lasting well into the next century. Some existing and emerging technologies hold great promise for significantly reducing the emissions and costs associated with residential space conditioning.

In this report, EPA explores advanced alternative space conditioning equipment and the opportunities each provides for cost-effective energy savings and pollution prevention. Unless existing market barriers are removed, however, these opportunities will not be realized. EPA has identified some methods by which utilities can address the market barriers and improve the productivity of home heating and cooling systems.

COMPARATIVE ANALYSIS OF ALTERNATIVE SPACE CONDITIONING SYSTEMS

EPA compared the performance and cost of emerging high-efficiency space conditioning equipment with equipment already on the market. Since climate affects the performance of space conditioning equipment, comparisons were made for six locations representing the range of major climate zones in the U.S. The six locations analyzed were: (1) Burlington, Vermont; (2) Chicago; (3) the upper New York City metropolitan area; (4) Portland, Oregon; (5) Atlanta; and (6) Phoenix. For the sake of consistency, the same prototypical single-family house was used for each location.

Exhibit ES-1 lists each of the space conditioning technologies that were examined. All comparisons were based on source energy performance taking into account losses associated with all stages of energy use, i.e., energy production, transmission, and distribution. Also, because the advanced heat pumps provide water heating as well as space conditioning, water heating cost and performance were also included in the analysis.

Exhibit ES-1
Space Conditioning Systems Compared in Report

Electric Equipment

System	Description
Electric Resistance/Standard Air Conditioning	Air Conditioner complies with standard -- has Seasonal Energy Efficiency Ratio (SEER) of 10.
Standard Air Source Heat Pump	SEER of 10, Heating Season Performance Factor (HSPF) of 6.85.
High Efficiency Air Source Heat Pump	Scroll compressor, larger heat exchanger and better controls: 12.5 SEER and 8.1 HSPF.
Advanced Air Source Heat Pump	Variable speed compressor, microprocessor control, better heat exchanger, and demand water heating. 14 SEER and 9 HSPF.
Standard Ground Source Heat Pump	Single speed unit; 13.2 EER at 70° F inlet water temperature and a Coefficient of Performance (COP) of 3.1 at 50° F inlet temperature.
Advanced Ground Source Heat Pump	Single speed scroll compressor, variable speed fans; desuperheater uses waste heat to heat water. EER of 17 at 70° F and COP of 4.4 at 50° F.
Emerging Ground Source Heat Pump	Two-speed scroll compressor; fully integrated demand water heat. Two-speed system saves about 10% heating and cooling energy over advanced technology.
Gas Equipment	
Standard Gas Furnace/Standard Air Conditioner	Typical, 80% efficiency furnace; 10 SEER AC.
Advanced Gas Furnace/ High Efficiency AC	Pulse condensing furnace, 96% efficient, with 12 SEER AC.
Emerging Gas-Fired Heat Pump	To be introduced in 1994; lean-burn, single cylinder engine drives vapor compression and heat recovery cycles. Can perform desuperheating.
Oil Equipment	
Advanced Oil Furnace/Efficient AC	Power oil burner and power vent controller; 85% efficient, with 12 SEER air conditioner.

Some of the high-efficiency technologies listed above, such as two-speed or variable-speed compressors could also be incorporated into central air conditioning systems. However, these and other air conditioner options, including evaporative and dessicant cooling, were not explicitly studied in this report.

PERFORMANCE AND COST

- Source Heating Performance: The **EMERGING GROUND SOURCE HEAT PUMP** had the highest source heating season performance factor (SPF) in all locations[1]. The next-best performers, the **GAS-FIRED HEAT PUMP** and the **ADVANCED GROUND SOURCE HEAT PUMP**, had similar source heating performance in all locations.

- Source Cooling Performance: The **EMERGING GROUND SOURCE HEAT PUMP** also had the highest cooling SPF in all locations, followed by the **ADVANCED GROUND SOURCE HEAT PUMP** and then the **ADVANCED AIR SOURCE HEAT PUMP**. The **GAS-FIRED HEAT PUMP** and the **ADVANCED AIR SOURCE HEAT PUMP** had comparable performance.

- Water Heating Performance: The **GAS-FIRED HEAT PUMP** had a performance advantage in water heating mode in all locations except for Portland, OR (where its performance was closely matched by the **ADVANCED AIR SOURCE HEAT PUMP**).

- Annual Operating Costs: In all locations either the **EMERGING GROUND SOURCE HEAT PUMP** or the **GAS-FIRED HEAT PUMP** had the lowest annual operating costs, since they were the best-performing equipment. In order to get a more accurate view on costs, however, annualized capital costs had to be factored in. In milder climates or in areas where energy costs are low, the higher capital cost of more efficient equipment often negated the operating cost advantage.

- Comparison of Electric Equipment Annualized Costs: The **EMERGING GROUND SOURCE HEAT PUMP/SLINKY™ LOOP** system had the lowest total annual cost (including operating and annualized capital costs) among all electric equipment, except in Portland, where the **LOW-COST ADVANCED AIR SOURCE HEAT PUMP** had virtually the same annual cost.

- Comparison of Gas Equipment Annualized Costs: Among gas-fired equipment, the **GAS-FIRED HEAT PUMP** had the lowest total annual costs in three locations -- Burlington, New York and Phoenix -- based on current energy prices. In the other locations, (Chicago, Portland and Atlanta) the **STANDARD GAS FURNACE/STANDARD AIR CONDITIONER** system had lower annual costs. The **ADVANCED GAS FURNACE/HIGH EFFICIENCY AIR CONDITIONER** system did not have the lowest cost in any location.

- Opportunities for **ADVANCED AIR SOURCE HEAT PUMPS**: In the three warmest locations -- Portland, Atlanta and Phoenix -- the total annual cost of the **LOW-COST ADVANCED AIR SOURCE HEAT PUMP** was lower than the **EMERGING GROUND SOURCE HEAT PUMP/VERTICAL LOOP** system. Thus, in these warmer locations, there appears to be a clear opportunity for **ADVANCED AIR SOURCE HEAT PUMPS**, especially where ground loops installation are relatively costly or impractical -- if sufficient market demand arises to lower their costs significantly through economies of scale.

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[1] The net SPF is a ratio of the total Btus of energy consumed by an end-use equipment, either directly or indirectly, to the total Btus it delivers into service. The net SPF accounts for losses in the generation, transmission and distribution of energy before it arrives at the end use.

UTILITY COST-EFFECTIVENESS

Cost-effectiveness screening was performed to calculate the net benefits of replacing "standard" technologies with the higher-efficiency emerging technologies. The calculations utilized the Total Resources Cost (TRC) test, which is widely used by utilities and their regulators to screen demand-side management programs. The TRC test compares the incremental cost of an energy-saving technology -- both in terms of its extra market price and the administrative cost that the utility would face in promoting it -- to the energy and capacity benefits that the measure brings to the utility's system. Cost-effectiveness is measured both as a ratio of total benefits to total cost and as a net present value. Whenever the ratio is greater than one, or the net present value is positive, the technology is considered cost-effective.

The value of the electricity savings (kWh) in each location was based on avoided energy costs from representative local utilities. The value of the capacity benefit ($/kW) was assumed to be the same in each location, and was based on the cost to construct a natural-gas-fired combustion turbine power plant. In the four coldest locations -- Burlington, Chicago, New York area and Portland -- it was assumed that the utilities were "dual peaking," i.e., they have roughly equivalent summer and winter peaks. Thus, in these locations the value of the capacity benefit was split between the summer and winter peak.

In the two warmest locations -- Atlanta and Phoenix -- a summer-peaking utility was assumed, and the entire value of the peak benefits accrued from reductions in the summertime. The actual capacity benefits that would accrue in a location are in fact based on the local mix of end uses and the local utility's specific mix of generating resources and capacity needs, which can vary widely.

- **GROUND SOURCE HEAT PUMPS**: The **EMERGING** and **ADVANCED** systems were highly cost-effective in all regions as replacements for **ELECTRIC RESISTANCE** and **STANDARD AIR SOURCE HEAT PUMPS**. They also appeared very cost-effective compared to **STANDARD GAS FURNACES/STANDARD AIR CONDITIONING** in the milder climates (Portland, Atlanta, and Phoenix).

- **ADVANCED AIR SOURCE HEAT PUMPS**: The **ADVANCED AIR SOURCE HEAT PUMP** was cost-effective as a substitute for **ELECTRIC RESISTANCE** and **STANDARD AIR SOURCE HEAT PUMPS** in all locations. Its cost-effectiveness generally increased as the climate became warmer (in colder climates it requires electric resistance back-up). Under the **LOW-COST** scenario, the cost-effectiveness of this technology improved significantly. The **LOW-COST AIR SOURCE HEAT PUMP** had both high benefit/cost ratios and net present values relative to all other equipment in Atlanta and Phoenix. In the coldest locations, however, its net present value was not nearly as high as other advanced equipment.

- **GAS-FIRED HEAT PUMP**: The **GAS-FIRED HEAT PUMP** was cost-effective as a substitute for standard technologies in all locations, though its results were not as strong in the three warmer locations (Portland, Atlanta, and Phoenix) as in Burlington, Chicago and the New York area. In those latter locations, it produces a very high net present value, no matter which standard technology it is replacing.

- **ADVANCED GAS FURNACE/HIGH EFFICIENCY AIR CONDITIONER**: This system was most cost-effective in colder climates as a substitute for standard technologies. In warmer climates it was often only marginally cost-effective or not cost-effective. While the system as a whole has a benefit/cost ratio that is greater than 1 when replacing the **STANDARD GAS FURNACE** system in Atlanta and Phoenix, closer analysis reveals that the advanced gas furnace fails in these locations when considered alone.

ENVIRONMENTAL IMPACTS AND TOTAL SOCIETAL COSTS

EPA estimated and compared the CO_2, SO_2 and NO_x emissions resulting from the various alternative space conditioning systems. Four different generating scenarios were analyzed to estimate the air emissions in each region: (1) a regional generating mix based on a weighted average of the actual fuel mix in each area;[2] (2) a natural gas combined cycle generating plant as the marginal unit; (3) an advanced fluidized bed coal plant as the marginal unit; and (4) a natural gas combustion turbine. In order to make cross-pollutant comparisons and get a clear view of overall impacts, EPA assigned "externality" costs to each pollutant. These costs are assigned, on a dollar-per-kilogram basis, using estimates of the cost to control each pollutant, as compiled by the Union of Concerned Scientists et al in America's Energy Choices. Some of the key findings of this analysis were:

- EMERGING GROUND SOURCE HEAT PUMP EMISSION BENEFITS OVER OTHER ELECTRIC EQUIPMENT: Depending on the location, **EMERGING GROUND SOURCE HEAT PUMPS** can reduce energy consumption and, correspondingly, emissions by 23-44% compared to the **ADVANCED AIR SOURCE HEAT PUMPS**, and by 63-72% compared to **ELECTRIC RESISTANCE/STANDARD AIR CONDITIONING** equipment.

- REGIONAL FUEL MIX SCENARIO: Under **REGIONAL** utility generating fuel mixes as projected for 2000, the **EMERGING GROUND SOURCE HEAT PUMP** generally had lower CO_2 emissions than all other equipment. The only exception to this was the coal-intensive Midwest (Chicago), in which the **GAS-FIRED HEAT PUMP** had the lowest CO_2 emissions. In all locations, except for Chicago and Atlanta, the **EMERGING GROUND SOURCE HEAT PUMP** had the lowest overall environmental "costs" under the projected **REGIONAL** utility fuel mixes.

- ADVANCED FLUIDIZED BED COMBUSTION (AFBC) SCENARIO: If the marginal electric generating plant is assumed at all times to be an **ADVANCED FLUIDIZED BED COMBUSTION** coal plant, then **GAS-FIRED HEAT PUMPS** have the lowest CO_2 emissions.[3] However, this relative environmental advantage for the **GAS-FIRED HEAT PUMP** was offset by significantly higher NO_x emissions.

- NATURAL GAS COMBINED CYCLE (NGCC) SCENARIO: When it was assumed that the marginal generating plant was **ADVANCED NATURAL GAS COMBINED CYCLE**, (the lowest-cost option for new baseload electricity generation in most areas of the country), **GROUND SOURCE HEAT PUMPS** and the **ADVANCED AIR SOURCE HEAT PUMP** had the lowest CO_2 and NO_x emissions.

[2] Since the regional fuel mix scenarios utilize a weighted average of all fuels used in a particular region, the average emissions are relatively low for regions which rely heavily on baseload nuclear or hydro resources (e.g., the northwest). To the extent DSM programs reduce electricity consumption during peak periods, when coal or fossil plants are running, the actual emissions reductions would be greater than the "average" numbers represented in this report.

[3] If a conventional pulverized coal steam plant were the marginal unit, the relative CO_2 savings for the **GAS-FIRED HEAT PUMP** would be even greater.

- **NATURAL GAS COMBUSTION TURBINE (NGCT) SCENARIO**: When it was assumed that the marginal generating plant was a typical modern natural gas combustion turbine, the **EMERGING GROUND SOURCE HEAT PUMP** had the lowest CO_2 and NO_x emissions. The **ADVANCED GROUND SOURCE HEAT PUMP** also had lower or comparable CO_2 emissions than advanced gas equipment in most locations, while NO_x emissions were comparable to the **ADVANCED GAS FURNACE**. The **ADVANCED AIR SOURCE HEAT PUMP** had higher CO_2 and NO_x emissions than advanced gas equipment in the three coldest locations under this scenario.

- **COMPARISON OF GAS EQUIPMENT EMISSIONS**: The **GAS-FIRED HEAT PUMP** can reduce CO_2 emissions by 23-36% over **STANDARD GAS FURNACES** and by 7-25% over **ADVANCED GAS FURNACES**, assuming the **REGIONAL** electric fuel mix. However, because of relatively high NO_x emissions, the **GAS-FIRED HEAT PUMP** had higher environmental costs than advanced gas furnaces in several locations under various generating scenarios.

THE MARKET POTENTIAL FOR ADVANCED SPACE CONDITIONING EQUIPMENT

Based on the performance and cost analysis at representative locations, EPA estimated the potential for coordinated utility and other promotional programs to affect the space conditioning market. From the results of this analysis, EPA projected energy savings and emissions reductions that could accrue from such an effort. <u>No fuel switching between gas and electric heating was assumed.</u> The major findings include:

- **REGIONAL OPPORTUNITIES**: Most of the opportunities for **EMERGING GROUND SOURCE HEAT PUMPS** and **ADVANCED AIR SOURCE HEAT PUMPS** occur in warmer climates, reflecting the much higher historical penetration of electric resistance and heat pumps in these regions. Conversely, most of the opportunities for **G** **FIRED HEAT PUMPS** and **ADVANCED GAS FURNACES** occur in colder clim given high historical levels of gas penetration.

- **MARKET POTENTIAL FOR ADVANCED ELECTRIC HEAT PUMPS**: With aggressive utility conservation incentives, total U.S. market demand for **EMERGING GROUND SOURCE HEAT PUMPS** and **ADVANCED AIR SOURCE HEAT PUMPS** could increase from present sales levels of under 50,000 units annually to over 700,000 (about 300,000 **GROUND SOURCE HEAT PUMPS** and 420,000 **ADVANCED AIR SOURCE HEAT PUMPS**) by the year 2000. With increased consumer awareness and acceptance the market for **EMERGING GROUND SOURCE HEAT PUMPS** could grow further to over 400,000 by the year 2005 (with a corresponding reduction in demand for **ADVANCED AIR SOURCE HEAT PUMPS** to just under 400,000).

- **ENERGY AND CAPACITY SAVINGS FROM ADVANCED ELECTRIC EQUIPMENT**: **EMERGING GROUND SOURCE HEAT PUMPS** and **ADVANCED AIR SOURCE HEAT PUMPS** could save over 23 billion kWh per year and avoid about 18,000 MW of generating capacity in winter and 25,000 MW of summer capacity by the year 2000; by 2005 these savings could increase to 46 billion kWh, 38,000 MW of winter capacity, and 50,000 MW of summer capacity.

- **CO_2 BENEFITS FROM ADVANCED ELECTRIC HEAT PUMPS**: The potential savings from **EMERGING GROUND SOURCE HEAT PUMPS** and **ADVANCED AIR SOURCE HEAT PUMPS**, if realized, would reduce CO_2 emissions by over 17 million metric tons (MMT)/year in 2000 and by 34 MMT/year by 2005.

- **POTENTIAL MARKET FOR ADVANCED GAS EQUIPMENT**: As a result of utility efforts, demand for **GAS-FIRED HEAT PUMPS** and **ADVANCED GAS FURNACES** could increase by a factor of twelve over the estimated baseline to more than 750,000 units annually.

- **ENERGY AND CAPACITY BENEFITS FROM ADVANCED GAS EQUIPMENT**: Advanced gas technologies could save 5 billion kWh and 3 billion therms per year by the year 2000, reducing CO_2 emissions by about 7 MMT/year. These savings would increase to 12 billion kWh and 6 billion therms by 2005, reducing CO_2 by 15 MMT.

- **CHALLENGE FOR GAS-FIRED HEAT PUMPS**: While they are competitive in several areas and reduce CO_2 emissions, **GAS-FIRED HEAT PUMPS** increased NO_x emissions. The Gas Research Institute (GRI) plans to undertake additional work to cost-effectively reduce NO_x emissions, either by pollution controls on existing designs or by substituting new, lower-emission technologies.

OPPORTUNITIES FOR ENHANCING THE MARKET FOR ADVANCED SPACE CONDITIONING EQUIPMENT

As the above findings suggest, utility efforts and other promotional programs can play a key role in accelerating the market penetration of advanced space conditioning equipment. Given the unique barriers and challenges that face each technology, however, it will most likely require more than a typical utility rebate program to achieve anything close to full market potential. EPA has identified several steps that utilities could take to effectively enhance the market for space conditioning equipment:

- Form partnerships or coordinated residential programs with other utilities to pool the demand for advanced space conditioning equipment. A coordinated approach can communicate a much stronger market signal to manufacturers than individual utility efforts, and may be more effective at reducing the risk manufacturers face in commercializing new technologies.

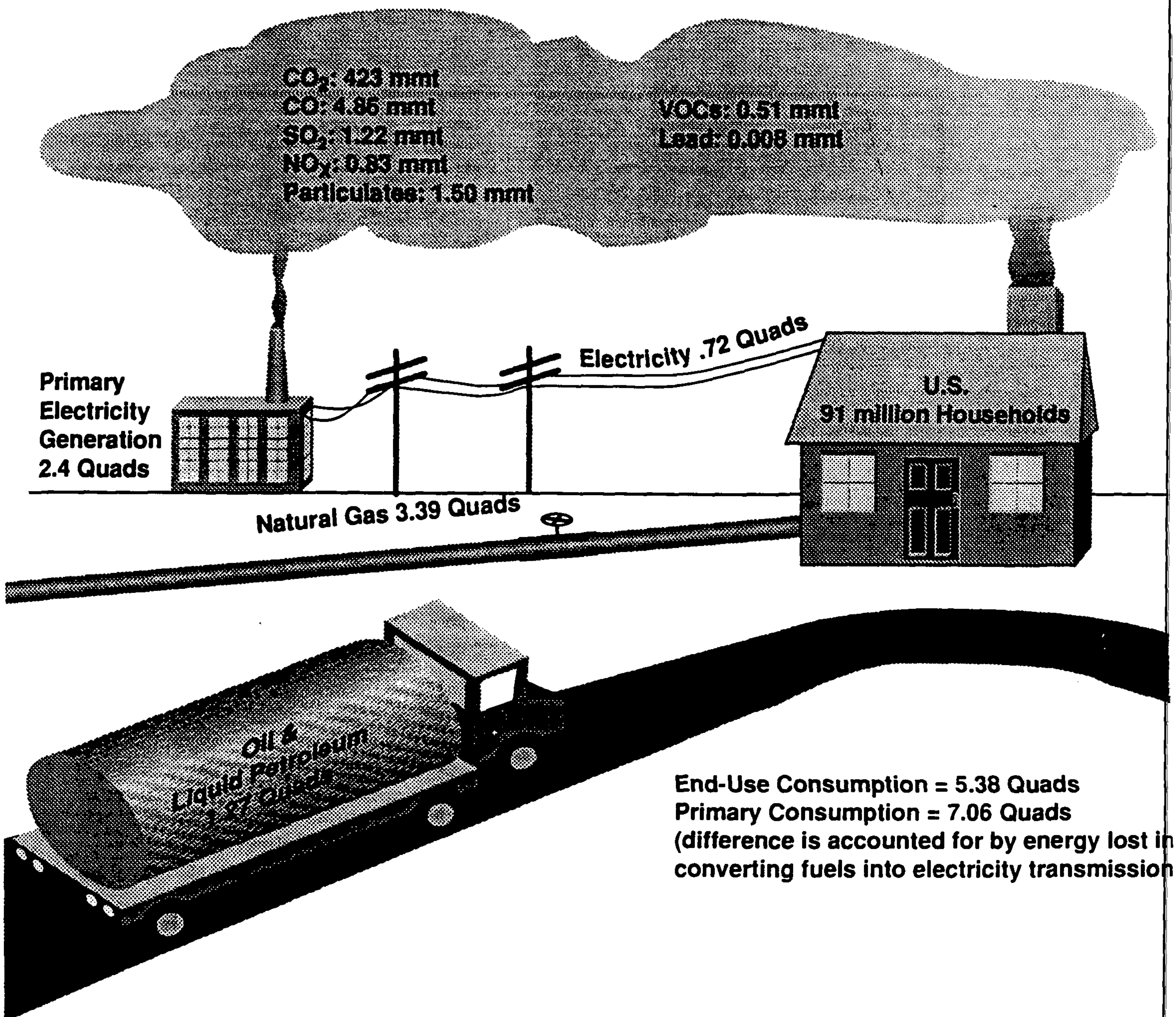
- Implement utility conservation programs over a sustained period of time, e.g., 5 years or more. This will demonstrate to manufacturers that there is a stable market for their new products, and will further reduce the risk associated with developing new product lines.

- Expend sufficient effort to develop strong marketing and installation networks in order to improve the local infrastructure. As contractors become more knowledgeable about the new technologies, the cost to install the equipment should fall and the quality of the installations should improve.

- Communicate with the industry to determine in which areas utility incentives would be most effective -- whether paid to the consumer, the dealer, or directly to the manufacturer. Manufacturer incentives might be preferable, since they have the greatest effect on reducing equipment costs. Manufacturer incentives communicate directly to the people who make the decisions about which equipment to produce and in what quantities.

- Structure incentives to allow larger payments for units with higher efficiencies. This would provide an incentive for manufacturers to continuously improve performance and to introduce even more efficient technologies.

Exhibit 1.1
Energy Usage and Emissions from US Residential Space Conditioning



CHAPTER ONE

THE ENVIRONMENTAL IMPACTS OF RESIDENTIAL SPACE CONDITIONING IN THE U.S.

INTRODUCTION

Space conditioning (heating and cooling) uses 5.39 quadrillion Btu ("quads") of energy, 8.82% of total U.S. end-use energy consumption[1]. In 1987, the nation's 90.9 million occupied households consumed a total of 4.93 quads for space heating and 0.45 quads for space cooling. Americans spent approximately $46 billion on space conditioning that year, more than half of total residential energy expenditures.[2]

Residential space conditioning resulted in 423 million metric tonnes (MMT) of carbon dioxide (CO_2) emissions in 1987.[3] When combined with water heating, residential space conditioning contributes more greenhouse gases to total U.S. emissions than all other activities other than driving automobiles -- more than commercial space conditioning and water heating combined, more than light and heavy trucks combined, and more than all industrial machine drives and electrolytics combined. Exhibit 1.1 summarizes the air pollution associated with fossil fuel combustion serving residential space conditioning demand.

The decisions that American homeowners, landlords, developers and builders make about space conditioning over the next decade will have important economic and environmental ramifications lasting well into the next century.

BARRIERS AGAINST EFFICIENCY IN THE HEATING AND AIR CONDITIONING MARKET

Strong evidence exists that several market failures have prevented cost-effective space conditioning products from capturing an economically optimal share of the residential market.

The higher first cost of more efficient equipment has made consumers reluctant to buy efficient products or install conservation measures even though these measures provide higher rates of return than consumers receive for their savings accounts and investments.

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[1] Number of households comes from Bureau of the Census, U.S. Department of Commerce, Statistical Abstract of the United States, 1991, Table 1281. Space heating and electric air conditioning consumption figures come from Energy Information Administration (EIA), Annual Energy Review 1990, Table 17. Space cooling consumption figure presented here also includes 0.01 quads of gas-fired air conditioning, inferred from Table 17. Total U.S. end-use energy consumption (61.1 quads) comes from EIA, Table 7.

[2] EPA estimate derived from Statistical Abstract, 1991, Table 954 and ICF, Inc., 1991 data on the breakdown of energy consumption by residential end-use.

[3] EPA estimate, based on the following rates of CO_2 formation: natural gas, 51.3 kg/MMBtu; electricity, 468.9 kg/MMBtu (based on national average fuel mix for electricity production and national average heat rate); oil, 78.5 kg/MMBtu, and liquified petroleum gases, 63.3 kg/MMBtu. Rates for natural gas, electricity and oil are from ICF Resources, 1991; rate for liquified petroleum gas is taken from EPA, Office of Policy, Planning and Evaluation, "Emissions and Cost Estimates for Globally Significant Anthropogenic Combustion Sources of NO_x, N_2O, CH_4, CO, and CO_2," May 1990, p. 99.

Another barrier is the landlord-tenant relationship. One-third of households occupy rented housing.[4] Since landlords do not generally pay the heating and cooling bills, they have little incentive to invest in energy efficiency. Tenants are reluctant to make investments when they occupy dwellings for short periods of time.

Recognizing these barriers, policy makers on the federal, state and local level have devised regulatory mechanisms -- building codes and appliance or equipment efficiency standards -- that assure that minimal levels of energy efficiency are attained.

However, developing and implementing regulations is time-consuming, adversarial and politicized. Regulations often lag behind the development of, or fail to reflect, the most cost-effective or environmentally benign technologies. Furthermore, to optimize decisions through regulations would require complexity and raise administrative costs. Non-regulatory mechanisms may be a more efficient way to promote the development and selection of the most efficient technologies.

UTILITIES: THE NEW PLAYERS IN THE SPACE CONDITIONING APPLIANCE MARKET

Utilities have become significant "players" in the purchase decisions of space conditioning and appliances. Utility commissions throughout much of the United States have begun to require utilities to evaluate a full mix of "resources." That is, when a utility decides how to meet its customers' energy services it must now consider conservation and load reducing measures as well as more traditional resources, such as new generating facilities, wholesale power purchases, and transmission and distribution equipment.

In order to fully implement these "least-cost, integrated resource planning" (IRP) policies, many utility commissions have instituted ratemaking procedures that allow utilities to recover the costs of conservation measures and earn an attractive rate of return through their rates.

"Decoupling" of utility revenues from sales is one such mechanism. In traditional ratemaking, the utility would have a rate set for each unit of energy sold within a rate class, such as for each kiloWatt-hour (kWh) sold. Rates would be set based on a forecast of sales, such that the utility's costs would be covered and an allowed rate of return would be earned. The more kWhs sold relative to the forecast, the more profits the utility made. Of course, this means that the converse -- the less kWhs sold, the less profit made -- presented a natural barrier to effective conservation. Decoupling of revenues and hence profits from sales allows utilities to maintain their earnings while actually decreasing the number of kWhs they sell.

"Shared savings" is another commonly employed recovery mechanism for conservation. This approach allows utilities to "share" the savings that have resulted from a particular conservation investment through their rates.

Shared savings recovery mechanisms can be applied broadly throughout entire classes of customers, or they can be applied strictly to program participants. In the latter case, the utility provides the customer with a subsidy for a conservation measure, and then recovers the capital and a profit through an adder on the customer's bill. If effectively implemented, the customer benefits overall because the amount paid back to the utility is less than the reduction in his/her bill.

Whatever the recovery mechanism, conservation measures are justified whenever the cost of implementing them is less than the marginal cost of producing an equal amount of new energy

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[4] Bureau of the Census, Statistical Abstract of the United States, 1991, Table 1281.

supplies (including the cost of transmission and distribution to end users). Marginal cost of new supplies, or the utility's "avoided cost," is the benchmark by which conservation measures are usually evaluated.

THE ENVIRONMENTAL COSTS OF ENERGY

Given the significant contribution of energy usage to air pollution, utility regulators are increasingly -- now in fifteen states -- requiring utilities and other power suppliers to include consideration of the environmental costs associated with power generation in their resource decisions.[5] In fact, some states have even gone so far as to require that utilities include environmental "adders," dollar amounts associated with pollution from different options, in their marginal costs.

In particular, CO_2 emissions associated with the energy industry have come increasingly under scrutiny. In June of 1992, the United States signed an historic international treaty on climate change at the Earth Summit in Rio de Janeiro. Key provisions of the new United Nations Convention on Climate Change include:

2(a) "Each of these Parties shall adopt national policies... recognizing that the return by the end of the decade to earlier levels of anthropogenic emissions will contribute to [the mitigation of climate change]."

2(b) "... each of these Parties shall communicate... detailed information on its policies and measures... with the aim of returning individually or jointly to 1990 levels."

Fossil fuel power generation facilities owned by utilities and non-utility generators (NUGs) now face substantial risk that future policies might be implemented to mitigate CO_2 emissions. This potential risk has not been lost upon commissions practicing least-cost IRP. As the California Public Utilities Commission stated on April 22, 1992:

> "...it is... prudent to adopt future resource procurement policies recognizing that owners of existing coal-fired generation in the future may be required to take actions to abate their carbon emissions significantly, or to pay for emission rights. This raises the concern that the owners may try to pass on the costs for such actions to their customers....
>
> "Given the uncertainty over policy addressing climate change, we ... believe it essential that utilities obtain appropriate assurances from any prospective supplier ... that it alone will bear the cost of meeting any future costs resulting from a carbon tax, acquisition of tradeable emission permits, retrofits, or any other carbon emission control strategy or regulation applicable to the supplier's plant(s)." [6]

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5 Cynthia Mitchell, "Integrated Resource Planning Survey: Where the States Stand," Electricity Journal, V.5, N.4 (May, 1992), pp. 10-15. "Advanced" IRP was identified by the presence of the following elements: financial incentives to encourage utility demand-side management (DSM) investments; evidence of DSM acquisition; competitive bidding; incorporation of environmental externalities; and gas utility IRP.

6 California Public Utilities Commission, "Interim Opinion, Resource Plan Phase: Bidding for New Generation Resources," Decision 92-04-045, April 22, 1992, pp. 27-29.

The Commission was directing California utilities to follow the example of the Bonneville Power Administration (BPA), which in an October, 1991 solicitation said it would require bidders of fossil fuel generation to assume all carbon-related financial risks; any future costs could not be passed along to the BPA and its customers.[7]

As the risks associated with new, polluting fossil fuel generation increase, demand-side-management (DSM) programs will continue to become increasingly attractive to regulators and utilities.

DSM FOR SPACE CONDITIONING AS PRACTICED BY UTILITIES

Utilities have taken various approaches to implement residential appliance and space conditioning programs. Some have relied on information to change consumer behavior. These have included energy audits, product information and labelling. Other utility programs go further to change behavior by providing financial incentives to dealers and consumers. Such measures as sales person incentive fees ("SPIFs") provide a bonus to a dealer for selling high efficiency equipment. Consumer rebates work on the other side of the transaction by reducing the extra first cost of high efficiency products to the consumer. The utility acts as a co-purchaser with the consumer -- in effect buying the extra energy efficiency. In some cases, utilities have included both SPIFs and consumer rebates in their appliance efficiency incentive programs.

While utility DSM programs have grown, they are not typically designed to promote the most advanced energy-efficient technologies that may be technically feasible. As a result, most programs are failing to capture all of the technically feasible and cost-effective energy-saving opportunities. These "lost opportunities" are occurring because most utility-sponsored DSM programs are short-lived, are not focused on promoting advanced, emerging technologies, and are not coordinated or consistent with programs of other utilities. Manufacturers, in viewing the entire national market, are thus faced with a "crazy quilt" of utility programs that come and go very quickly relative to their own commercialization schedules. As a result, equipment manufacturers are not sufficiently induced to develop the most advanced, energy efficient technologies.

EPA'S POLLUTION PREVENTION STRATEGIES

EPA has launched a variety of programs intended to stimulate market demand for high efficiency, pollution preventing equipment. These programs use different strategies and have been very successful at changing behavior in various markets (Exhibit 1.2).

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[7] Electric Utility Week, June 22, 1992, pp. 3-4.

EXHIBIT 1.2

EPA PROGRAMS AND RELATED EFFORTS FOR ENERGY EFFICIENCY AND POLLUTION PREVENTION

Strategy	Example Program	Success to Date
Change Corporate Purchasing	**Green Lights** Partners Agree To: · survey all domestic facilities · choose lighting upgrades that maximize energy saved while passing economic test · retrofit 90% of all facilities within five years; install efficient lighting in new facilities Vendor and Utility Allies also upgrade facilities and market program	over 800 members and 3 Billion ft^2 in program (over 3% of national office space) 50-75% reduction in consumption underway 81-203 billion kWh saved/yr. by 2000 62-183 million metric tons carbon dioxide avoided/yr. by 2000
Change Consumer Purchasing -- Product Identification	**Energy Star Computer Program** Partners Agree To: · produce high-efficiency personal computers (PCs) and work stations · EPA Energy Star Logo put on efficient products	55% savings expected 26.3 billion kWh/yr. saved by 2000 20 million metric tons CO_2 emission reductions by 2000 Success has led to development of similar initiative for printers
New Technology Acceleration through Long-Term Utility DSM Procurement	**"Golden Carrot[SM]" Super Efficient Refrigerator Program** · supported multi-utility effort to introduce advanced refrigerators through a competitive bid · promotes non-CFC unit that is 25-50% more efficient than 1993 standard · will help make 1998 efficiency standard-setting process less contentious and better-informed	At least 25 utilities participating $28 million incentive pool for manufacturer building best product 150,000 - 500,000 units by Mid-90's Coordinated utility approach better influences manufacturing decisions

WHAT THIS REPORT SEEKS TO ACCOMPLISH

This report assesses a variety of technologies available or potentially available in the residential space conditioning market (Exhibit 1.3). It provides information to different important participants in the process of determining space conditioning choices.

1) Electric utilities may find this report useful for:

  * recognizing the technological and economic potential of ground source heat pumps and other advanced technologies as featured DSM technologies;

  * deciding on key elements that are needed for an effective program; and

  * gauging the appropriate magnitude of investment.

2) Gas utilities may find this report useful for:

  * realizing the importance of similarly nurturing new high-efficiency gas heat pumps or other advanced technology through a DSM program approach.

3) Consortium for Energy Efficiency (CEE) or similar groups may find this report useful for:

  * deciding which aggregate or long-term DSM procurement ("Golden Carrot^{SM}") programs to initiate.

4) State Utility Regulators may find this report useful for:

  * evaluating integrated resource plans and rate filings with respect to the adequacy of proposals for advanced space conditioning technologies; and

  * assessing the proper rate treatment for utility Golden Carrot^{SM} programs for advanced space conditioning equipment.

5) Space conditioning equipment manufacturers may find this report useful for:

  * assessing products, prices, and marketing strategies; and
  * developing strategies for Golden Carrot^{SM} partnerships with CEE utilities, conservation groups, EPA and other public agencies.

6) The Gas Research Institute and the Electric Power Research Institute may find this report useful for:

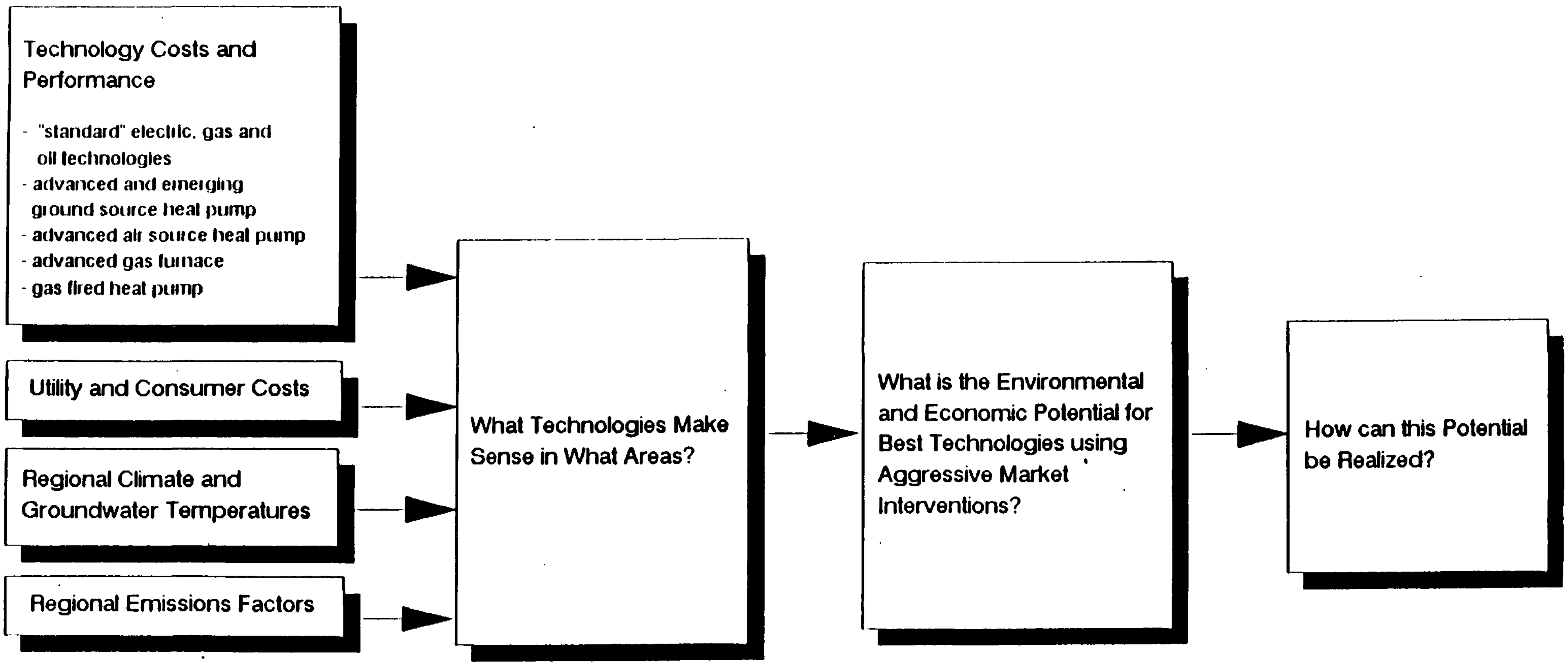
  * fashioning R&D targets in coordination with CEE's Golden Carrot^{SM} program goals.

7) The natural gas industry may find this report useful for:

  * developing marketing strategies for the mid-1990's and well beyond.

EPA hopes the report will initiate a dialogue between various parties that leads to a major shift toward vastly increased sales of higher value added, energy-efficient space conditioning products.

Exhibit 1.3
Analytical Flow Diagram for this Report



LOW-TEMPERATURE GEOTHERMAL RESOURCE ASSESSMENT AND GEOTHERMAL HEAT PUMP PROGRAM 1992 - 1993

This important program was funded as an addition to the Geothermal Budget by Congress in 1991. The objectives were (1) to update the inventory of geothermal resources useful for direct-heat applications (such as greenhouse heating and district heating), and (2) to develop data which would accelerate use of geothermal heat pumps (GHPs) in the U.S. This document provides a summary of accomplishments to date and discusses funding needs to complete the program.

LOW-TEMPERATURE GEOTHERMAL RESOURCES

Barriers to Widespread Use

Several barriers inhibit rapid development of geothermal resources for direct-heat application. The most troublesome of these barriers are:

- Limited knowledge of the resource.
- Limited infrastructure of experienced consultants and A&E firms.
- Cost of development.

Accomplishments to Date

To date, the resource assessment program has been concentrated in 10 states having high potential; Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah and Washington. Resource inventories of ten years ago had identified some 5,600 thermal wells and springs in these 10 states. The new database now includes 11,300 entries, giving an indication of the enormous potential for development of clean, domestic geothermal-heat resources.

Funding Needs

This program needs to be continued and strengthened. Funding would be used to stimulate development of low- and moderate-temperature resources through cost-sharing of demonstration projects to spur infrastructure development and bring costs down.

FUNDING NEEDED ($ millions)

FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000
5.5	5.0	5.0	4.5	3.0	2.0

Anticipated Results

At the conclusion of this program, we anticipate being able to increase the amount of direct-heat geothermal power on line from 670 thermal megawatts to 3,700 thermal megawatts. With displacement of fossil fuels, this would save the emissions of about 1,550,000 tons of carbon dioxide, 30 tons of sulfur dioxide and 1,400 tons of nitrogen oxides per year.

GEOTHERMAL HEAT PUMPS

Barriers to Widespread Use

Several barriers inhibit rapid introduction of geothermal heat pumps as an energy-saving measure. The most troublesome of these barriers are:

- Limited utility interest in demand-side management (DSM).
- Lack of promotion of geothermal heat pumps.
- Lack of an installation infrastructure in many parts of the country.

Accomplishments to Date

We have developed a map of areas in the United States most conducive to installation of GHPs. We have also developed case-study brochures for promotion of GHPs. Availability of this information will encourage utilities and their customers to consider the GHP option.

Funding Needs

This program needs to be continued and strengthened. Funding would be used for promotion of GHPs with the utilities and their customers through education and limited incentives. This would help build the infrastructure needed for GHP installation to accelerate on its own at the conclusion of this program.

FUNDING NEEDED ($ millions)

FY 1995	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000
5.0	4. 5	4.5	4.0	3.5	2.0

Anticipated Results

At the conclusion of this program, approximately 1,500,000 geothermal heat pump systems would be installed in homes, schools and other buildings in the United States. Savings over today's level of generating capacity for heating and air conditioning would be at least 5,000 megawatts. With displacement of fossil fuels this would save the emissions of about 20,000,000 tons of carbon dioxide, 2,300 tons of sulfur dioxide and 16,000 tons of nitrogen oxides per year.

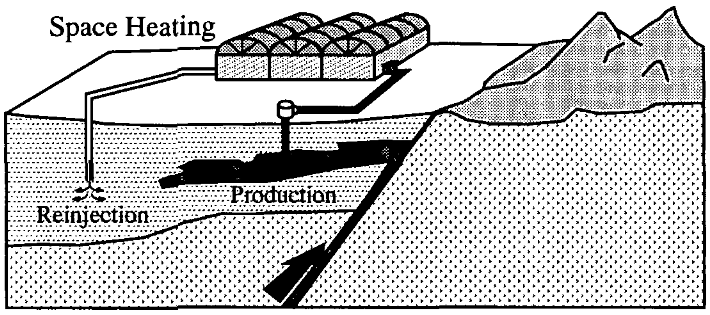
GEOTHERMAL ENERGY

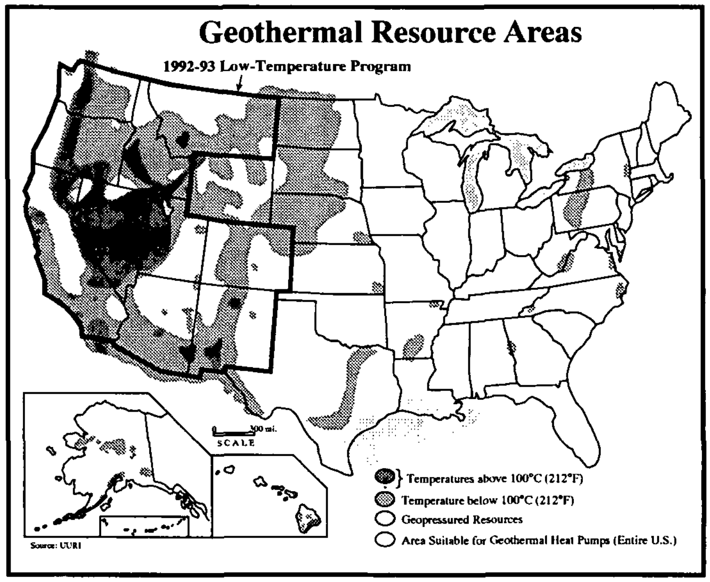
Geothermal energy is renewable heat energy from deep in the earth. Heated groundwater forms hydrothermal resources - naturally occurring hot water and steam. Use of geothermal energy has environmental and reliability advantages over conventional energy sources. Geothermal energy contributes both to energy supply, with electrical power generation and direct-heat uses, and to reduced energy demand, with savings in electricity and natural gas through use of geothermal heat pumps to heat and cool buildings.

Use of hydrothermal energy is economic today at some high-grade sites. A modest industry generates electrical power and supplies heat for direct uses. Only a small fraction of our geothermal reserves are in use today. Much more could be brought on line in the short term with appropriate research, development and incentives.

Hydrothermal resources are tapped by existing well-drilling and energy-conversion technology to generate electricity or to produce hot water for direct use. For direct-heat application, water at temperatues ranging from about 80°F to more than

300°F is brought from the underground reservoirs to the surface through production wells. The geothermal water is usually fed to a heat exchanger for extraction of the heat before being injected back into the earth. Heated domestic water from the output side of the heat exchanger is used for commercial and home heating, greenhouse heating, vegetable drying, aquaculture and a wide variety of other energy needs.





RESOURCE BASE

Low- and moderate-temperature geothermal resources are widely distributed throughout the western and central United States. Numerous resources occur in the areas indicated on the map, with individual reservoir areas one to ten square miles in extent. In the northern Great Plains, major aquifers with fluid temperatures exceeding 50°C (122°F) extend in a continuous manner for thousands of square miles. Geothermal resources also occur at certain locations in the East.

The last major effort in assessing the national potential of low-temperature geothermal resources occurred in the early 1980s. Since that time, substantial resource information has been gained through drilling for hydrologic, environmental, petroleum and geothermal projects, but there has been no significant effort to compile information on low-temperature geothermal resources.

While there has been a substantial increase in direct-heat utilization during the last decade, the large resource base is greatly under-utilized. Since the thermal energy extracted from these resources must be used near the reservoir, collocation of the resource and the user is required. Development of a user facility at the site of the hydrothermal resource is often economically feasible. Direct-heat resources are typically used by small businesses, various types of local industry, communities, and individuals. These users generally cannot afford to hire the technical expertise required to delineate and develop geothermal resources from scratch.

To expand utilization of the direct-heat resource, a current inventory of these resources is needed by potential users, together with the information necessary to evaluate the reservoirs and the economics of potential uses. To stimulate the development of an industry, it is necessary to reduce risks of development and this can be done by providing resource data and by cost-sharing of demonstration projects.

1992-1993 LOW-TEMPERATURE PROGRAM

In 1991, Congress appropriated money for the Department of Energy to begin a new program for the evaluation and use of low- and moderate-temperature geothermal resources. The program is addressing two major national goals: 1) reduced emission of greenhouse gases, acid rain-producing gases, and particulate matter to the atmosphere; and 2) reduced dependence on imported petroleum. The program has several components, including: (1) compilation of all available information on resource location and characteristics, with emphasis on resources located within 8 km (5 mi) of population centers; (2) development and testing of techniques to discover and evaluate low- and moderate-temperature geothermal resources; and (3) technical assistance to potential developers of these resources. Program participants include state government or university teams in ten western states. Program coordination is furnished by the Geo-Heat Center at the Oregon Institute of Technology (OIT-GHC), the University of Utah Research Institute (UURI), and the Idaho Water Resources Research Institute (IWRRI).

PRELIMINARY RESULTS - RESOURCE EVALUATION

State geothermal resource teams (State Teams) initiated their resource evaluation and database compilation efforts in late 1992 and early 1993 and have now updated their resource inventories. Table 1 summarizes the catalog of more than 11,000 thermal wells and springs for these 10 western states, more than twice the number on the previous assessment in 1983. More than 900 low- to moderate-temperature resource areas are indicated, and perhaps a greater number of isolated (singular) thermal wells or springs. Direct-heat use of geothermal fluids is documented at more than 250 sites, including commercial and municipal buildings, rapidly expanding greenhouse and aquaculture industries, and major space-heating districts in California, Oregon, Nevada, Idaho, and Colorado. More than 40 high-priority resource study areas have been identified, along with high potential for near-term direct-heat utilization at 150 new sites. Preliminary estimates indicate that 254 cities in 10 western states could potentially displace 64 trillion Btu per year (17 million BOE) with geothermal district heating. The number of commercial and residential direct-heat users and the total energy use have increased dramatically in one decade. Table 1 indicates the tremendous potential for expanded utilization of these resources, and is a compelling argument for continued funding of this productive program. Each state team is producing a new geothermal resource map showing thermal wells and springs for their state.

Table 1. State Geothermal Database Summary: 1992-93 Low Temperature Program

	State PGA	AZ 1982	CA 1980	CO 1980	ID 1980	MT 1981	NV 1983	NM 1980	OR 1982	UT 1980	WA 81
Thermal Wells and Springs	**1993**	**543**	**979+**	**157**	**1,935**	**346**	**3,300**	**247**	**2,135**	**713**	**971**
	PGA	501	635	125	899	68	1,376	312	998	315	368
Moderate Temp. Wells	**1993**	**0**	**73**	**0**	**20**	**0**	**50**	**10**	**88**	**3**	**1**
(100°C<T< 150°C)	PGA	0	48	0	0	0	35	3	79	3	1
Low Temp. Wells/Springs	**1993**	**543**	**906**	**157**	**1,915**	**97**	**1,000**	**237**	**2,047**	**710**	**970**
(20°C<T<100°C)	PGA	501	587	125	899	58	700	309	925	312	367
Low Temp. Resource Areas	**1993**	**29**	**58**	**93**	**28**	**16**	**300**	**29**	**275**	**161**	**17**
(20°C<Tres<150°C)	PGA	29	56	56	28	15	300	24	151	64	10
Direct-Heat Utilization Sites	**1993**	**3**	**72**	**28**	**29**	**15**	**21**	**7**	**29**	**16**	**4**
(Commercial, district, resorts)	PGA	0	54	24	20	2	8	0	23	9	0
Greenhouses, Aquaculture, Industrial Processes	**1993**	**5**	**17**	**4**	**17**	**4**	**8**	**6**	**7**	**6**	**0**
Areas, Potential Near-Term Direct Heat Utilization	1993	4	2	4	51	2	2	4	25	7	49+
Areas, High Priority Resource Study	1993	3	4	6	5	4	4	4	5	4	3

Comments: PGA = Previous Geothermal Assessment. Tres = Estimated reservoir temperature
The minimum low-temperature criteria is typically 20°C, but varies with climate.

The Geo-Heat Center (OIT) and UURI are working with state teams to evaluate the collocation of resources with communities and potential users, and to establish priorities for more detailed resource studies. Some highlights from selected states are:

California. The California Division of Mines and Geology reports more than 979 thermal wells and springs. Some 58 low-temperature resource areas have been identified with an additional 194 "singular" thermal occurrences. The 71 commercial direct-heat users include six district-heating systems, 48 resorts/spas, and 13 greenhouse, aquaculture or industrial concerns.

Idaho. The Idaho Water Resources Research Institute (IWRRI) lists 1,935 thermal wells and springs, more than twice the 899 reported in the 1980 inventory. Although district heating is well established at Twin Falls and Boise, there is high potential at about 50 sites for new direct-heat utilization, as well as some potential for electrical power development.

Nevada. The Nevada Bureau of Mines and Geology (NBM&G) includes over 3,000 entries in a preliminary database. More than 300 separate resource areas may be present in Nevada. Direct heat is utilized at 20 establishments, including the Moana and Elko district-heating systems.

New Mexico. The Southwest Technology Development Institute (SWDI) reports 247 thermal wells and springs. Twenty-nine low-temperature resource areas and perhaps 151 isolated thermal occurrences have been identified. New Mexico currently leads the nation with the largest acreage of geothermally-heated greenhouses on line, and expansion continues.

Oregon. The new Oregon Department of Geology and Mineral Industries (DOGAMI) database includes 2,135 entries. More than 200 thermal areas have been identified. Geothermal fluids are used for heating over 625 buildings by businesses, organizations, and homeowners. Several greenhouses, aquaculture sites and industrial processes also use geothermal energy. Five high-priority resource study areas have been identified by DOGAMI and perhaps 25 businesses or organizations could utilize geothermal heating in the near term.

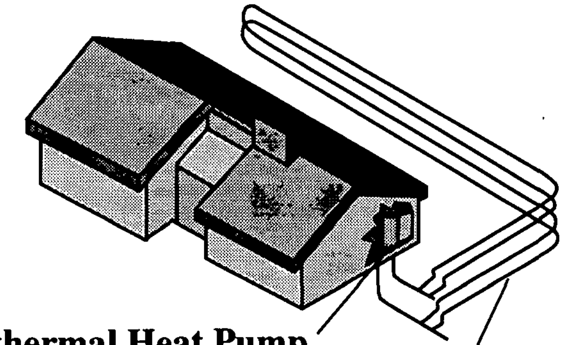
Washington. A detailed study by the Washington State Department of Natural Resources (WDNR) team has identified 971 thermal wells/springs, 264% of the 1981 inventory, and perhaps seven newly recognized low-temperature resource areas. Geothermal resource utilization is currently very low, but three counties are regarded as priority study areas, and as many as 49 potential users (commercial, private, or municipal) are collocated with promising resources.

1992-1993 GEOTHERMAL HEAT PUMP PROGRAM

Geothermal heat pumps (GHPs) use normal-temperature earth or groundwater for heating during the winter, cooling during the summer, and supplying hot water year around. Because of their high efficiency, GHPs save significant amounts of electricity and natural gas compared to other heating and cooling systems. They are a preferred technology of the EPA.

DOE has been working to increase the use of GHPs throughout the country. OIT has been collecting and interpreting engineering data on the performance of residential and commercial installations of geothermal heat pumps from throughout the nation. In addition, it has been investigating utility demand-side management (DSM) programs to determine: (1) the most effective and successful utility marketing and incentive programs to expand GHP markets; (2) barriers to market entry; (3) the benefits to utilities from reduced peak demand and higher annual load factors; (4) the number of GHP units installed in utility areas; and (5) suitability of GHPs for northern climates. IWRRI has focused on identifying those portions of the country which have particular favorability for installation of earth-coupled and groundwater heat pumps. IWRRI has shown that well over one-half of the country, particularly the central and the southeast, possess the hydrogeologic characteristics necessary to make the ground water heat pump a very viable option. UURI has completed GHP fact sheets documenting residential and commercial GHP system performance, economic analysis and benefits, and distributed these widely.

The next step in this program will be to begin work with utilities to provide them with updated information on GHPs and to induce them to adopt this technology to help achieve their DSM programs in a lasting way.



Geothermal Heat Pump

Closed Horizontal Ground Loop

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ISSN 0276-1084

VOL. 15, NO. 1 AUGUST 1993

GEO-HEAT CENTER *Quarterly Bulletin*

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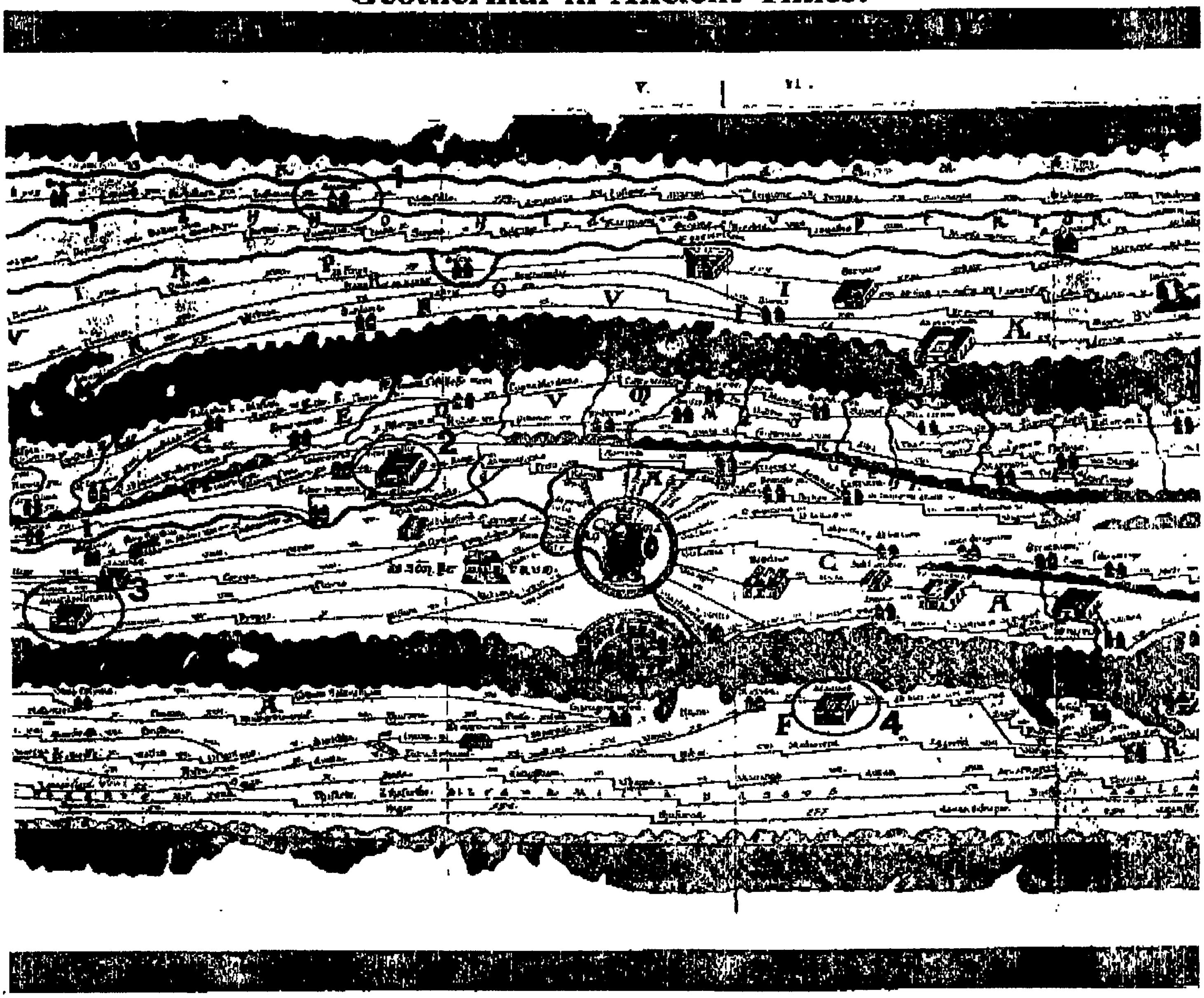
Geothermal in Ancient Times:



LOW-TEMPERATURE RESOURCE ASSESSMENT PROGRAM UPDATE

Paul J. Lienau
OIT Geo-Heat Center

Howard Ross
University of Utah Research Institute

INTRODUCTION

The U.S. Department of Energy - Geothermal Division (DOE/GD) started a new two-year program in 1992 to encourage wider use of low-temperature geothermal resources. Two main objectives of the program are: (1) to update and compile databases for wells and springs in 10 western states with temperature ranges of 20° to 150°C, and (2) to collect and interpret information on utility geothermal heat pump programs and energy use patterns of typical residential and commercial installations, along with energy savings and life-cycle costs.

State Resource Assessment Teams are compiling databases for wells and springs in Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, and Washington. Each record in the databases consist of fields which include location of the well or spring, its physical characteristics, chemical analysis of water samples, and its current utilization. The databases are being modeled after a system developed by the Utah Geological Survey for uniformity in presentation. They are being developed for use on personal computers and can be accessed by spreadsheet or text-editor type software. The information can be used for geochemical, statistical, and resource studies and 5 to 10 sites in each state will be prioritized for more detailed resource assessment and utilization feasibility studies in Phase 2 of the program.

Much of the recent interest in developing direct-heat resources may be attributed to a Department of Energy initiative, the State Coupled Program, which began in 1977. Data developed by State Teams during this period was incorporated into GEOTHERM, a computer-based system of databases and software used to store, locate, and evaluate information on geothermal systems for the U.S. Geological Survey's (USGS) Geothermal Research Program. GEOTHERM received data until 1983, when it was taken off-line. GEOTHERM data was presented on geothermal resource maps, compiled and distributed for 18 western states. The maps, typically printed at a scale of 1:500,000, identify wells and springs with anomalous temperatures, and were released from 1980 to 1983. These maps, and the data and reports upon which they were based, have been extremely useful to the more aggressive developers, and form an important starting point for the current update assessment study.

A geothermal heat pump (GHP) takes advantage of the earth's relatively constant ground temperature to provide heating or cooling as well as water heating for both residential and commercial buildings. A GHP delivers 3 to 4 times more heat energy than it consumes, since electricity is used primarily to transfer heat, not produce it and is considered the most efficient heating or cooling technology available today. The objective of the GHP part of this program is to collect and interpret data and information on the performance of residential and commercial installations. Utilities are also being contacted to obtain information on incentive programs, market barriers and benefits to utilities for demand-side management (DSM).

COMPILATION OF DATA ON HYDROTHERMAL RESOURCES

State geothermal resource teams are reviewing and updating their geothermal resource inventories which were completed as part of the USGS-DOE national assessment from 1977-1983. Each state is preparing a comprehensive digital database in table format and a resource map at a scale of 1:1,000,000. UURI and OIT are providing technical guidance and coordination, and UURI will complete 10 fluid chemistry analyses for each state. Table 1 identifies the state agencies and principal investigators involved with the project.

Table 1. State Resource Assessment Teams

State	Agency	Principle Investigator
California	Division of Mines and Geology	Leslie Youngs
Colorado	Colorado Geological Survey	James Cappa
Idaho	Water Resources Research Institute	Leland Mink
Montana	Bureau of Mines and Geology	Wayne Van Voast
New Mexico and Arizona	New Mexico State University	James Witcher and Rudi Schoenmackers
Nevada	Bureau of Mines and Geology	Larry Garside
Oregon	Dept. of Geology and Mineral Industries	George Priest
Utah	Utah Geological Survey	Robert Blackett
Washington	Division of Geology and Earth Science	Eric Schuster

The compilations include resources in the temperature range of 20° to 150°C (68° to 300°F) many of which have potential to supply energy to collocated cities within approximately 8 km (5 miles) of a resource as well as greenhouses, aquaculture, mining, and other process applications.

The State Teams, under subcontract to OIT and with guidance from UURI, are reviewing drilling records and other information to identify new resources and verify temperatures and flow rates of springs and wells which may have changed substantially since the previous statewide geothermal resource inventory. The databases are organized into tables linked by common data-fields, using the preliminary database from the Utah Geological Survey as a model for uniformity in presentation (Blackett, 1993). Information to be contained in the tables is listed below:

Table 2. Description: ID number, source name, country codes, latitude and longitude, type of source, temperature (°C), flow rate (L/min), depth of wells (m), current resource use, and references to relevant studies (geology, geophysics, geochemistry, hydrology) completed for the site.

Table 3. Geochemistry: ID number, source name, pH, TDS, major cations, major anions, cation-anion balance, chemical species that may cause scale and corrosion products, and light stable isotopes.

Tables 2 and 3 are examples of the database format and Figure 1 is a portion of the new map for Utah (Blackett, 1993).

Simultaneously, we will collect and interpret demographic and other data to evaluate potential heat loads, fossil-fuel displacement, utility electrical-demand reduction and load-leveling opportunities, and environmental benefits for potential geothermal direct-heat applications.

These two data sets, resource and demographic, will be jointly interpreted with the main objective of making a prioritized list of resources which have highest potential for economic development with significant benefit for in depth studies. The State Teams P.I.s are submitting a priority list of resource areas (5 to 10) for more detailed studies. Two general guidelines for inclusion on the list are areas with some development in place and a need for studies to protect the resource or to expand utilization; or high potential for near-term development. Collocation with potential users (community or industry) is an important but not mandatory, criteria. Specific criteria to be considered are listed below:

Criteria

- Proximity to user (within 8 km) for low-temperature use
- Probable reservoir temperature, and range of possible uses
- Potential for substantial flow

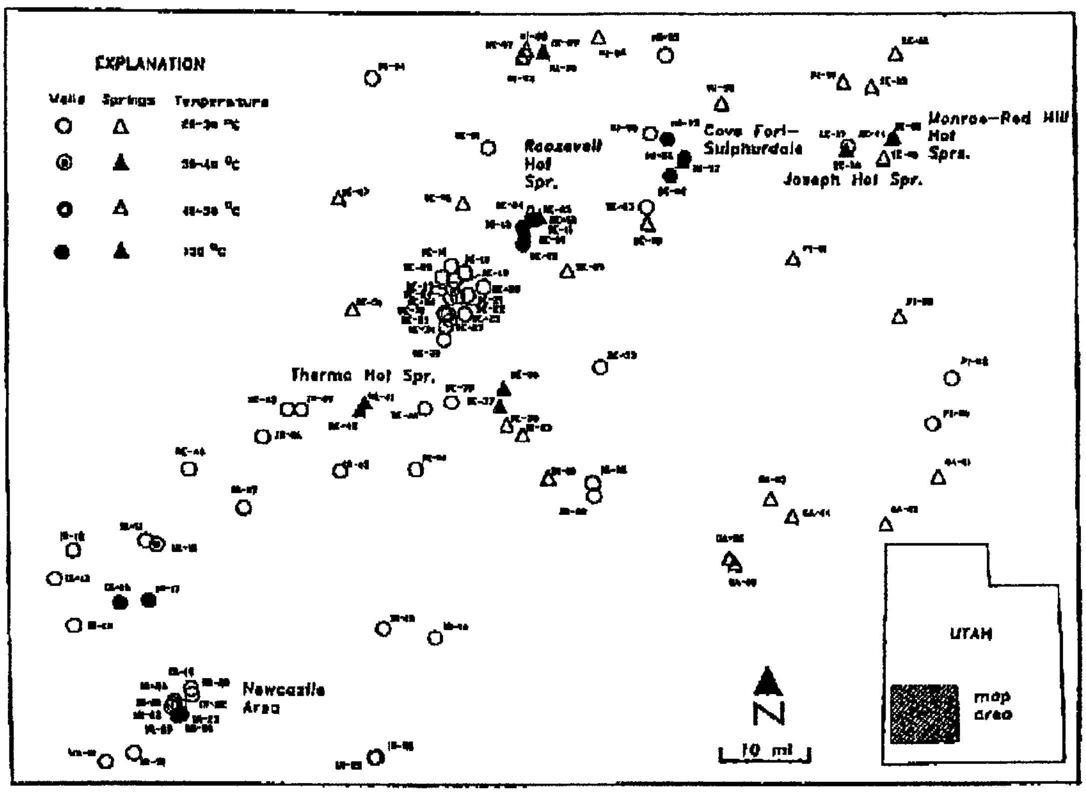


Figure 1.

Table 2. Example of Descriptive Information in the Database

NUMBER	SOURCE NAME	TYPE[1]	LOCATION[2]	TEMP (°C)	DEPTH (m)	STATUS[3] (P/F)	FLOW (L/min)	LEVEL[4] (m)	DATE
BE-30	Green Diamond Ranch	W	(C-28-11)25ddd	20.0	45.7	P	1817.00	6.7	22-Jul-87
BE-33	Beaver School Dist.	W	(C-29-08)25cac	20.0	76.2	P	26.50	3.7	03-Jun-82
BE-34	J. Mayer	W	(C-29-11)01add	20.0	19.5	P	1741.29	9.4	09-Jun-81
BE-35	unnamed	W	(C-29-11)12ddc	20.5	73.2	P	2119.83	10.7	21-Jul-87
BE-39	Neb Craw	W	(C-30-10)19abd	21.0	89.0		1785.00		
BE-40	Bureau of Land Mgmt.	W	(C-30-11)22ddc	22.5	50.0		34.00		
BE-41	Thermo Hot Spr. (north)	S	(C-30-12)21add	85.0			41.00		
BE-42	Thermo Hot Spr. (south)	S	(C-30-12)28acb	76.5			73.06		

1. W = well; S = Spring
2. Well and spring numbering system for Utah.
3. P = pumped; F = flowing
4. Depth (in meters) to static water level.

Table 3. Example of Water Chemistry Data in the Database

NUMBER	pH	Na	K	Ca	Mg	Fe	SiO2	B	Li	HCO3	SO4	Cl	F	TDSm	TDSc	ChgBal	δD	δO18
BE-30		0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.00					
BE-33	7.9	20.0	8.0	31.0	5.0	0.010	75.0	0.1	0.0	121.0	41.0	6.0	0.80	247	171	100		
BE-34	7.5	38.0	6.0	120.0	25.0	0.010	38.0	0.1	0.0	244.0	87.0	130.0	0.30	576	526	103		
BE-35		0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.00					
BE-39	7.5	18.0	5.0	34.0	8.8	0.010	47.0	0.1		144.0	50.0	25.0	0.30	291	232	102		
BE-40	8.2	65.0	2.3	7.3	1.2	0.000	45.0	0.2		117.0	34.0	36.0	0.90		204	91		
BE-41	6.8	378.0	52.0	78.0	10.0	0.000	87.0	1.0	1.3	401.0	476.0	222.0	4.90	1564	1420	98	-118.0	-14.3
BE-42	7.4	360.0	47.0	76.0	12.0	0.000	10.0	0.9		374.0	460.0	210.0	14.00	1490	1363	100		

values for pH in pH units
values for δD and δO18 in permil
charge balance (ChgBal) in percent cations/anions
all others in mg/L
TDSm = TDS measured
TDSc = TDS calculated

- Proximity to transportation infrastructure (major highways, railroads, airports, etc.)
- Proximity to agriculture centers
- Availability of cold water for irrigation and process water
- Local development trends
- Land status
- Legal considerations (water use conflicts, etc.)

At the same time, we will undertake R&D on better cost effective methods for locating low- and moderate-temperature geothermal resources and on siting successful test and production wells. Part of this work will encompass development of better well-testing methods and better hydrologic models of these hydrothermal resources. These tasks are expected to pay off in further discoveries of resources and in better methods to evaluate reservoir production and ultimate-development capacity at an earlier stage in the development cycle than is possible now.

GEOTHERMAL HEAT PUMP ANALYSIS AND USE

We are collecting and interpreting information on the performance of residential and commercial installations of geothermal heat pumps (GHPs). This will yield information on: (1) the most effective and successful utility marketing and incentive programs to expand GHP markets; (2) the benefit to utilities from reduced peak demand and higher annual load factors; (3) barriers to market entry; (4) the potential total national energy savings contribution from GHPs; and (5) suitability of GHPs for northern climates. Load data and energy-use patterns are being documented before and after installation of GHPs in typical residential and commercial situations, along with energy savings and life-cycle costs.

Based on contacts with 36 utilities, they see geothermal heat pumps as a peak reducing demand side management (DSM) tool and many offer incentives of some kind. Incentive programs offered by utilities to customers include: rebates of $125 to $500 per ton of installed capacity, low cost loans, discounts on electric rates for the heat pump system, and in some cases they install ground coupled closed loops. In some cases, heat pumps are seen as a means of retaining customers with all-electric homes built in the 1960s to early 70s who are now tempted to switch to cheaper natural gas. Barriers to market entry of GHPs are higher initial costs ($800 to $1000/ton) than other HVAC systems due to incremental cost of the ground loop heat exchanger installation and a lack of an infrastructure of ground loop contractors and dealers. Where there are good contractors and inspections, customer satisfaction has been good.

A preliminary performance analysis has been evaluated for two ground-coupled heat pump (GCHP) residential systems in Minnesota from data obtained from United Power Association, Elk River, MN (Connett, 1993). Data was collected on an hourly basis, monitoring ground loop supply and return temperatures, outside air temperature, compressor power, circulating pump power, and water heater power.

The first home (260 m^2 or 2800 ft^2) located in Stanchfield, MN was installed with a 4-ton heat pump using a vertical ground-coupling of five 45.7 m (150 ft) boreholes. Figure 2 shows a comparison of the geothermal heat pump with an air-source heat pump for a peak winter day when the outside temperature was at -28°C (-18°F). The geothermal heat pump had a 7.4 kW lower peak demand and 5,294 kWh lower annual heating and cooling energy than the air heat pump. The annual savings for the GHP was 11% for the cooling and 34% for the heating seasons compared to the air heat pump.

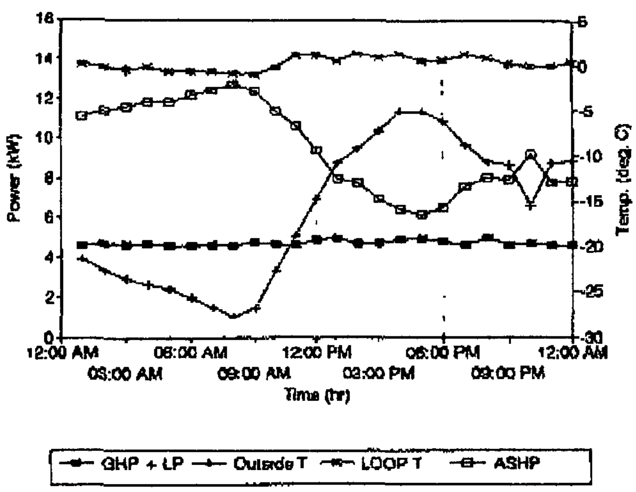


Figure 2. Demand comparison of a geothermal heat pump (vertical ground-coupled) with an air-source heat pump.

The second home (260 m^2 or 2800 ft^2) located in Zimmerman, MN was installed with a 5-ton heat pump using a horizontal ground-coupling of 671 m (2200 ft) of pipe. The GHP had a 5.7 kW lower peak demand than the air heat pump on the coldest winter day. Figure 3 shows a comparison of water temperatures in the loops for the vertical and horizontal configurations. A difference of about 6°C (10°F) in the winter and 11°C (20°F) in the summer will result in a better performance for the vertical ground-coupled heat pump.

In the course of the above work, we will identify weaknesses in the technology and data base, with the objective of describing needed R&D that would accelerate GHP use.

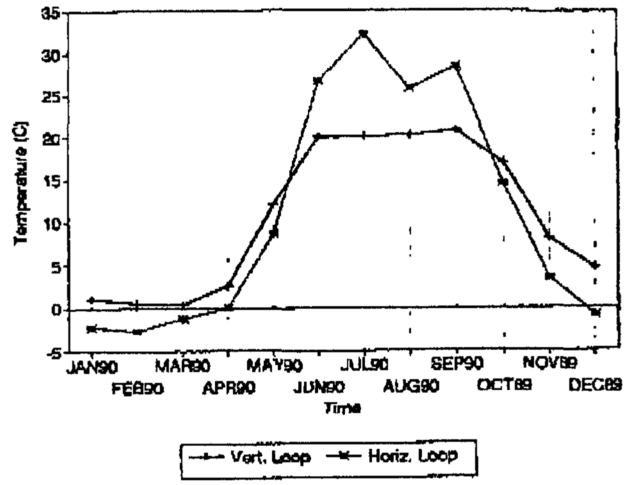


Figure 3. Loop supply temperature comparison for vertical and horizontal ground-coupled heat exchangers.

OUTREACH AND PUBLIC EDUCATION

All project personnel are working cooperatively and closely with state and local agencies, energy offices and other public entities. This network will bring information on geothermal resources and their uses to the public and to potential geothermal developers. We are also working closely with the Geothermal Resources Council, the National Geothermal Association, the Geothermal Education Office and other entities in the geothermal community. We are developing brochures on geothermal direct-heat, fact-sheets on GHPs and geothermal energy in general. We will also produce an informative video for general national distribution on geothermal energy and its advantages.

FUTURE PLANS

The state teams will complete their inventory, database listings, and resource occurrence maps in FY-93 and early FY-94. These will be reviewed and edited by UURI and OIT. OIT will complete the collocation study and with UURI and IWRRI, will prioritize resources for more detailed study. The results will be reviewed by and discussed with the appropriate state teams. UURI will complete fact sheets to inform Congress of the progress, and with OIT and IWRRI will solicit support for Phase 2 funding of additional states and detailed studies for the most promising resources for near-term development. We envision the present program to be the first part of an ongoing effort that will take possibly 5 years to complete.

Further information on this program can be obtained by contacting any of the authors, or Mr. Joel Renner, INEL, P.O. Box 1625-3830, Idaho Falls, ID 83415, or Mr. Marshall Reed or Mr. Lew Pratsch, U.S. Department of Energy - Geothermal Division, 1000 Independence Avenue SW, Washington, D.C. 20585.

ACKNOWLEDGEMENT

This work was supported by the U.S. Department of Energy under EG&G Subcontract C92-120253. Such support does not constitute an endorsement by the Department of Energy of the views expressed herein.

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MEMORANDUM

TO: Participants, DOE-GD Low-Temperature Geothermal Resources and Technology Transfer Program

FROM: Howard Ross and Paul Lienau

SUBJECT: More data for Low-Temperature Program Fact Sheets, and Standardized Format for State Team Final Reports

DATE: November 4, 1993

The 1993 Geothermal Resources Council meeting in Burlingame, CA provided an opportunity for several of us to meet and discuss the project status, efforts for Phase II funding, the need for subcontract time extensions, and future deliverables of this program. Some thoughts, suggestions, and requests resulting from this meeting are included here.

State Team Subcontracts - Time Extensions

Most State Team subcontracts were scheduled for termination on December 31, 1993. We understand that subcontract reviews and late signings, diversion of efforts to other projects, and problems with the old GEOTHERM database have slowed progress on the project for many teams and time extensions will be required. Please notify Paul Lienau if you need a time extension to bring your present subcontract to completion. Subcontracts will not be extended beyond June 30, 1994.

Efforts for Phase II Funding

There will be an opportunity through May, 1994 for some to speak to Congress with the hope that they will fund a continuation of this program. UURI is working on a two-page fact sheet which will describe the program and indicate the new resource potential identified from Phase I studies, as compared to the 1980-83 resource assessments. Although several teams responded to an earlier request for data for their states, the data received were not all comparable or complete. Therefore, we are asking again for numbers we can use for the fact sheet. Please complete the accompanying table "Geothermal Database Summary" for your state, estimating numbers as necessary, and forward it to Howard Ross at UURI, even if your new database is unfinished. We can modify our fact sheet with the revised numbers later with only minor changes to format. Please call Howard at (801) 584-4444 with questions or suggestions.

Our current thoughts are that three documents should be available to Congressmen or Staffers to inform them of the Low-Temperature Program: 1) a two-page fact sheet explaining and summarizing the results of Phase I; 2) a two-page fact sheet summarizing results, priorities and potential for energy savings for each state; and 3) the final report (and map)for each state (when available) as follow up for additional detail and interest.

Format for State Team Final Reports

Several people feel that the State Team final reports should each follow the same format as much as possible, and should be standardized. We have drafted an outline that should be appropriate for these reports and this outline and additional comments are enclosed. Please let us know if you have any problems with this format, or suggestions to improve it.

Database Entries and Mapped Wells

Many state teams are still involved with sorting out multiple well entries for a small area, multiple entries for the same well, how many wells to plot, etc. We recognize the problem and the need for completeness. Each state team is best prepared to make these decisions for their state. Feel free to talk to the other P.I.'s for their ideas on this problem.

Samples for Fluid Chemistry Analyses

Several teams have yet to submit fluid samples for analyses at UURI. Please plan ahead to submit samples so that they may be processed in an orderly fashion at UURI, and so the results will be available to you in time for inclusion in the database and in time to provide input to other aspects of the study. Ruth Kroneman, UURI chemist, notes that UURI receives many samples for fluid analyses and that all samples should be carefully labeled with a sample number, with an indication whether the sample is filtered or unfiltered, acidified or raw. All sample submittals should be accompanied by a sample list, perhaps on letterhead, with information relating to the samples. A handwritten list is adequate - no typing required. Ruth mentioned that she has received some sample bottles with sample i.d. partially rubbed off by the packing materials during shipping. Please do not hesitate to talk to Ruth at (801) 584-4434 with any questions.

Priority Areas for Additional Study

A reminder! State Team Principal Investigators should be prioritizing resource areas for future studies. Considerations include resource potential, collocation with users or stand alone location, types of data or studies needed, etc. UURI, OIT-GHC, and IWRRI would like to receive a preliminary list before November 30.

Response

Please try to complete Table 1 for your state and return it to Howard Ross by November 19.

FINAL REPORT FORMAT
LOW-TEMPERATURE GEOTHERMAL RESOURCE ASSESSMENT: 1993

Report Requirements: A final summary report, not to exceed 50 pages. Description of all tasks and results. Document new data. Geothermal resource map of state (1:1,000,000) or acceptable alternative.

CONTENTS

Cover Page
ACKNOWLEDGMENTS
DISCLAIMER (standard DOE statement)
ABSTRACT

1.0 INTRODUCTION
- Previous geothermal assessment
- Need for a new assessment
- Overview of program, funding route, etc.

2.0 DATA SOURCES
- Selection criteria
- Error and duplicate record checking
- Reference to/explanation of bibliography

3.0 DATA FORMAT
- General organization of tables or spreadsheets
- Methods of data entry (manual or imported from external files)
- Procedures for using the data (hardcopy and diskettes)

4.0 FLUID CHEMISTRY
- New samples, results, implications
- Observations from other database entries
  - (observations, interpretations, implications)

5.0 DISCUSSION
- Resource potential (qualitative discussion)
- Collocation of resources and users (preliminary observations)

6.0 SUMMARY

7.0 RECOMMENDATIONS
- Priority areas for Phase 2 studies
- Future studies needed

8.0 REFERENCES / BIBLIOGRAPHY

APPENDICES
- Tables, etc.

State Geothermal Resource Map (1:1,000,000 or acceptable alternative)
Other Figures: Histogram of occurrences v.s. temperature
State outline map, page size, with resource areas.

Table 1. GEOTHERMAL DATABASE SUMMARY

Database Result	State YPGA	AZ 82	CA 80	CO 80	ID 80	MT 81	NV 83	NM 80	OR 82	UT 80	WA 81
Total Database Entries (thermal wells, springs)	1993										
	YPGA										
Moderate Temp. Wells (100°C<T< 150°C)	1993										
	YPGA										
Low Temp. Wells/Springs (20°C<T<100°C)	1993										
	YPGA										
Low Temp. Resource Areas (20°C<Tres.<150°C)	1993										
	YPGA										
Direct Heat Utilization (Commercial or district)	1993										
	YPGA										
Greenhouses, Aquaculture, Industrial Processes (Number separate businesses)	1993										
	YPGA										
Areas, Multiple Residence Heating (not a district)	1993										
Areas, Potential Near-Term Direct Heat Utilization (Commercial Buildings)	1993										
Areas, Possible New Binary Power Development (110°C<Tres<150°C)	1993										
Areas, High Priority Resource Study	1993		*								

Comments: YPGA = Year of Previous Geothermal Assessment
Total Database Entries may include several representative wells in a single resource area.
Direct Heat Utilization: Total number of commercial space heating systems, etc.
Areas, Multiple Residence Heating: 1 or more residences
Tres = Estimated reservoir temperature

* singular resource occurrence