Geothermal Direct-Use and Geothermal Greenhouse Operations

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Main Categories

- Electrical Power
- Agriculture
- Industrial
- Heating & Cooling
- Cascaded Energy Use
- Ground-Coupled Heat Pumps
- Combined Heat & Power (CHP)

Geothermal Education Office
www.geothermal.marin.org
IMPORTANT PARAMETERS

- Land
  - Location and Infrastructure
  - Ownership
  - Institutional Setting

- Water
  - Sufficient for reservoir sustainability
  - Adequate for surface requirements

- Temperature

- Economics

NPS, Saguaro National Monument
DEVELOPMENT INFRASTRUCTURE

- PRODUCTION WELLS
- INJECTION WELLS
- HEAT EXCHANGERS
- PIPE LINES

Drilling Masson Federal 36, Radium Springs, New Mexico, Masson Geothermal Greenhouse,

Drilling AmeriCulture State 2, Animas Valley, New Mexico, AmeriCulture Geothermal Tilapia Farm
PURPOSE OF GEOTHERMAL GREENHOUSING

THE PRIMARY OBJECT OF GEOTHERMAL GREENHOUSING IS TO GROW THE BEST QUALITY CROP PROFITABLY WITH ENERGY SAVINGS
WHY USE GEOTHERMAL?

DRAWBACKS

1) up front capital costs
2) approach unfamiliar
3) acceptance of risk
4) can require more effort
WHY USE GEOTHERMAL?

ADVANTAGES

1) significant savings in energy cost
2) energy costs are stable and predictable over the long haul
MOST IMPORTANT REQUIREMENTS

• SOUND BUSINESS PLAN

• EXPERT GROWER AND GREENHOUSE MANAGER

• MARKETS TO SELL PRODUCT
GEOTHERMAL GREENHOUSING REQUIREMENTS

CO-LOCATION OF
1) suitable land
2) geothermal resource
3) fresh water source
4) labor force
GEOTHERMAL SYSTEM COMPONENTS

- Geothermal production wells
- Geothermal pump
- Geothermal pipe line
- Heat exchangers
- Geothermal injection well
- Proper sizing and materials selection
HEAT EXCHANGERS

- Prevent scaling and corrosion
- Isolate geothermal fluids from heating equipment and environment
- Plate and frame heat are very efficient

NMSU

Haslego and Polley (2002)
GEOTHERMAL GREENHOUSE HEATING

- CENTRAL HOT WATER SYSTEM
- A GEOTHERMAL WELL AND HEAT EXCHANGER REPLACE A CONVENTIONAL FOSSIL FUEL BOILER
GEOTHERMAL GREENHOUSE HEATING

WHERE TO HEAT?

1) floor heating and soil heating
2) bench top heating
3) overhead heating
4) perimeter heating
5) crop irrigation water
HEATING EQUIPMENT

• Circulation pumps
• Fan-coil unit heaters
• Plain pipe
• Finned pipe
• Plastic tubing for bench top heating
• Small tube heat exchanger for heating irrigation water
OVERHEAD HEATING

• Fan-coil heating unit
• Unobtrusive installation
• Efficient
• Assists with snow melt
PERIMETER HEATING

FINNED PIPE

Prevents cold spots

Can be used in first stage heating

Use with other heating such and floor, overhead and benchtop heating
DRILLING OVERVIEW

- ELEMENTS
- METHODS
- TYPES OF WELLS
- MANAGEMENT
• DRILL RIG (STABLE PLATFORM)

• DRILL STRING

• DRILLING FLUIDS

• CASING

• WELL CONTROL

• STORAGE FACILITIES

• SUPPLIERS AND VENDORS

• KEY PEOPLE

• SITE PREPARATION

ESSENTIAL ELEMENTS OF DRILLING
DRILL RIG

• STABLE PLATFORM

• ENGINES AND COMPRESSORS FOR MECHANICAL OR HYDRAULIC DRIVE OF ROTARY DRILL STRING AND DRAW WORKS

• STRUCTURALLY SOUND MAST FOR DRAW WORKS AND TEMPORARY STORAGE OF DRILL STRING

• PUMPS FOR DRILL FLUID AND CEMENT

• WORKING PLATFORM WITH DRAW WORKS AND CONTROLS
ROTARY DRILLING

NGWA
ROTARY TABLE DRIVE

- MECHANICAL
- MOST COMMON ON OLDER AND LARGER DRILLING RIGS
ROTARY TOP HEAD DRIVE

- HYDRAULIC (PNUEMATIC) DRIVE
- GREATER SENSITIVITY IN DRILLING CONTROL
DRILL STRING

• TRANSFERS MECHANICAL ENERGY FROM SURFACE TO THE BIT IN A METHODICAL, PREDICTABLE, AND CONTROLLED MANNER

• DRILL STRING ELEMENTS
  DRILL PIPE
  COLLARS AND STABILIZERS
  BIT AND REAMERS
DRILL PIPE

- **O. D. FLUSH**
- **UPSET**
COLLARS AND STABILIZERS

- COLLARS
  - WEIGHT

- STABILIZERS
  - DIRECTION

NGWA
DRILL BITS

- DRAG BITS (BLADE BITS)
- ROLLER BITS (TRI-CONE)
- HAMMER BITS
- DIAMOND BITS
- SPECIAL PURPOSE BITS (CORING, REAMING, ETC)
DRILLING FLUID (MUD)

- Cool and lubricate bit and drill string
- Control formation pressures
- Remove cuttings from hole
- Reduce corrosion
- Stabilize hole (prevent caving)
- Seal hole (heal lost circulation)
- Inhibit (swelling clays)
TYPES OF DRILLING FLUID

- WATER OR AIR
- BENTONITE/WATER
- POLYMER/WATER
- LOST CIRCULATION MATERIAL (LCM)
- OTHER (SODA ASH, BARITE, DETERGENT, ETC)
CASING

• STABILIZES HOLE

• PROVIDES HOUSING FOR WELL EQUIPMENT (PUMPS, ETC)

• ASSISTS IN WELL CONTROL
CASING ELEMENTS

• PIPE (VARIETY OF MATERIALS WITH DIFFERENT STRENGTHS AND CONNECTIVE CONFIGURATIONS)

• CEMENT (VARIOUS TYPES DEPENDING UPON TEMPERATURE, FLUID CHEMISTRY, PURPOSE, AND RATE OF CURING OR SETTING)

• CASING SHOES AND CEMENTING SHOES OR CEMENT CHECK VALVES

• CENTRALIZERS
TYPES OF CASING

- **CONDUCTOR**
- **SURFACE**
- **INTERMEDIATE**
- **PRODUCTION**
WELL CONTROL

- CASING
- DRILL FLUID
- BOPE (BLOWOUT PREVENTION EQUIPMENT)
- DISCHARGE MANIFOLDS
- MUD PUMPS AND AIR COMPRESSORS
- DRILLING WELL HEAD WITH KILL AND DISCHARGE LINES
DRILLING WELL HEAD

- KILL LINE
- DISCHARGE LINE
- FLANGE FOR ANNULAR BOPE
- MAY ADD A GATE VALVE
STORAGE FACILITIES

- TANKS AND PITS FOR DRILLING FLUIDS
- STORAGE TANKS FOR WATER AND FUEL
- PIPE RACKS
- TOOLS AND ASSORTED SUPPLIES AND PARTS
SUPPLIERS AND VENDORS

- WATER
- MUD
- CASING
- BITS AND DRILLING SUPPLIES
- SITE PREPARATION
- CASING CREWS
- CEMENT OPERATIONS
- GEOPHYSICAL LOGGING
- MUD LOGGING AND ENGINEERING SUPPORT
- GEOLOGIC LOGGING
- HYDROGEN SULFIDE MONITORING AND ALARMS
- DRILL FLUIDS DISPOSAL
KEY PEOPLE

- COMPANY MAN
- TOOL PUSHER
- DRILLER
- HELPERS
- CASING CREW
- MUD ENGINEER
- MUD LOGGER
- GEOLOGIST
- GOVERNMENT MAN
SITE PREPARATION

- ACCESSIBLE FOR ALL EQUIPMENT AND SUPPLIERS
- ADEQUATE SIZE FOR OPERATIONS
- MINIMAL ENVIRONMENTAL IMPACT
- ALL WEATHER SUITABILITY
DRILLING METHODS

- MUD ROTARY
- AIR ROTARY
- CABLE TOOL
CABLE TOOL

- SLOW!
- INEXPENSIVE
- GOOD IDENTIFICATION OF WATER BEARING ZONES
- MINIMAL FORMATION DAMAGE
- GOOD MOBILITY
- MAY NOT BE SUITABLE FOR HIGHER TEMPERATURE (>100 °C)
MUD ROTARY DRILLING

• BEST AVAILABILITY

• MODEST COST

• CAN DRILL TO GREAT DEPTH

• MAY CONTRIBUTE TO FORMATION DAMAGE (DRILL MUD INFILTRATION INTO TO RESERVOIR OR AQUIFER)
REVERSE MUD ROTARY

• MINIMAL FORMATION DAMAGE

• GOOD SAMPLE RETURNS

• NOT READILY AVAILABLE

• HIGHER TEMPERATURE DRILLING MAY NOT BE FEASIBLE (>100 °C)

NGWA
AIR ROTARY

- MINIMAL FORMATION DAMAGE

- MAY BE LIMITED IN DEPTH BY WATER COLUMN PRESSURE

- MAY USE DOWN HOLE AIR HAMMER
DOWN HOLE AIR HAMMER

• EFFICIENT DRILLING OF HARD FORMATIONS

NGWA
TEMPERATURE GRADIENT AND HEAT FLOW HOLES

Temperature Gradient/Heat Flow Drilling
Safford, Arizona

- SHALLOW (100 TO 300 ft)
- 6 in OR SMALLER HOLE IS TYPICAL
- ONLY REQUIRES A SMALL DRILL RIG
- COMPLETE WITH 1-2 in PVC OR BLACK IRON PIPE FILLED WITH WATER AND ANNULUS BACKFILLED
- MAY BE ABLE TO DRILL AND COMPLETE TWO OR THREE WELLS PER DAY
- COSTS ($15 TO $35/ft)
- CAN DRILL 3 TO 10 HOLES FOR COST A RESISTIVITY SURVEY

Witcher
SLIM-HOLE EXPLORATION HOLES

- SMALLER DIAMETER ROTARY HOLES
- 500 TO 5,000 ft DEPTH
- CONTINUOUS WIRE-LINE ROTARY CORE DRILLING
- COSTS ($75 TO $150/ft)
PRODUCTION WELLS AND INJECTION WELLS

AmeriCulture #2, Lightning Dock, Animas Valley, New Mexico

- LARGER DIAMETER
- DESIGNED TO HOST PUMP EQUIPMENT
- DRILLED TO MINIMIZE FORMATION DAMAGE
- COST HIGHLY VARIABLE ($75 TO $400/ft)

Witcher
RESERVOIR TESTING AND MONITORING

- Determine reservoir hydraulic properties
- Obtain water chemistry and isotopic data
- Estimate long-term drawdown (sustainability)
- Manage reservoir
  - Monitor chemistry
  - Monitor water levels
  - Monitor temperature
  - Record production

Pump Test, AmeriCulture 1, Lightning Dock, Animas, New Mexico
MANAGEMENT FRAMEWORK

• PLAN AHEAD
  Match geology, drilling method, contractor availability and budget.

• COSTS
  Track costs.
  Understand cost inflection points, drilling costs are not linear

• REGULATORY COMPLIANCE

• SUPPLIERS AND VENDORS

• OPERATIONS
  Maintain good coordination and communication.
  Require drillers keep tally books of tools in hole.
  Have driller, geologist, and engineer maintain a detailed log.

• TESTING AND SAMPLING
  Have a planned schedule and alert geophysical log contractors at various stages of drilling.
FINAL THOUGHTS

• DRILLING CREATES AN UNNATURAL AND HIGHLY EFFICIENT VERTICAL PATHWAY FOR FLUID FLOW INTO OR OUT OF THE BOREHOLE

• ALWAYS TRY TO UNDERSTAND THE GEOLOGY AND HYDROGEOLOGY AND POTENTIAL DRILLING PROBLEMS BEFORE DRILLING

• COMPLETELY PLAN THE DRILLING, TESTING, AND WELL COMPLETION OR ABANDONMENT

• HAVE CONTINGENCY PLANS, APPROACHES, AND BUDGET

• **DRILLING PROJECTS ALMOST NEVER PROCEED AS PLANNED**
GEOTHERMAL HEATING OF A LARGE COMMERCIAL GREENHOUSE
a case study

Masson Geothermal Greenhouse, Radium Springs, New Mexico

Williamson, NREL
Radium Springs
15 miles north
Las Cruces

South-central
New Mexico
(Rio Grande Rift)

4,000 ft Elevation

3,400 Degree
Heating Days

1,450 Degree
Cooling Days

Mean Annual
Temperature
15.5° C (60° F)
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Geothermal Heating Distribution Manifold, Masson Geothermal Greenhouse, Radium Springs, New Mexico

Williamson, NREL
SITE ATTRIBUTES

• Geothermal and fresh water supplies co-located

• Shallow reservoir and deep reservoir
  • Injection
  • Production

• Private surface

• Level land

Drilling Masson Federal 36, Radium Springs, New Mexico, Masson Geothermal Greenhouse
PRODUCTION AND INJECTION WELLS

PROBLEMS
• Production temperature decreases
• Injection wells not taking full production

SOLUTIONS
• Site production wells further from injection wells
• Add production from the deep parent reservoir
• Eliminate open hole completions for injection wells and add liners
• Use larger diameter injection wells
CORROSION

PROBLEMS
- Pitting of stainless steel heat exchangers
- Corroded well casing adjacent fluctuating water level

SOLUTIONS
- Titanium steel heat exchangers
- High temperature fiberglass casing

FLUID CHEMISTRY
TDS – 3,600 to 3,700 mg/L
Cl – 1,500 to 1,700 mg/L

Original plate and frame heat exchanger, Masson Geothermal Greenhouse, Radium Springs, New Mexico

Plate and frame heat exchanger dismantled for cleaning

Williamson, NREL

NMSU
HOT WATER STORAGE

PROBLEMS
• Slow heating response to rapid temperature/weather changes
• Continue optimal heating if one of the well pumps fails on a winter night

SOLUTIONS
• Use large 167,000 gallon insulated hot water storage tank to buffer heating system
• Use radiant floor heating
RADIANT FLOOR HEATING

ADVANTAGES

• Provides thermal mass and stabilized heating system
• Decreases geothermal well production
•Places uniform heat at plant roots
• Allows for flood irrigation

Construction of new 2-acre greenhouse range with radiant floor heating, Masson Geothermal Greenhouse, Radium Springs, New Mexico
FLOOD IRRIGATION

PROBLEM
• Irrigation water is treated with reverse osmosis (RO) to remove undesirable minerals and nutrients are added (important cost factors)

SOLUTION
• Flood irrigation conserves water by recycling excess water and nutrients and decreases costs and disposal needs

Completed 2-acre greenhouse range with radiant floor heating and flood irrigation, Masson Geothermal Greenhouse, Radium Springs, New Mexico
ECONOMICS

ANNUAL SALES (wholesale)
$325,000 to $850,000 per acre

EMPLOYMENT
4 to 8 employees per acre

ENERGY SAVINGS
$46,200/yr per acre
4,200 MMbtu/yr/acre at less than $1.50/MMbtu
Natural gas $12.50/MMbtu (boiler inefficiency included)

Masson Geothermal
Greenhouse, Radium Springs, New Mexico

Williamson, NREL
SUMMARY

- 3rd largest geothermal greenhouse in US (18 acres)
- Installed heating capacity $44.1 \times 10^6$ Btu/hr (12.9 MWt)
- Estimated capacity factor 20 percent
- Average annual energy use $76.8 \times 10^9$ Btu
- Deep Production (800 ft max)
  - Winter - $195^\circ$ F at 750 gpm
- Shallow Production (325 ft max)
  - Winter - $165^\circ$ F at 720 gpm
  - Summer - $165^\circ$ F at 430 gpm
- Started at 4 acres in 1987 with plans to grow to 40 acres in future
- Resource has potential to add binary-cycle power for on-site use before greenhouse heating
A GEOTHERMAL PROJECT

- PERMITTING
- RESOURCE OWNERSHIP
- WATER RIGHTS
- ENGINEERING FEASIBILITY
- BUSINESS AND MARKETING PLAN
- FINANCING
- RESOURCE ASSESSMENT AND RESERVOIR CONFIRMATION
- PRODUCTION/INJECTION WELLS
- RESOURCE MANAGEMENT PLAN
- ENVIRONMENT AND PUBLIC RELATIONS

Alligator aquaculture, Mosca, Colorado
ADDITIONAL INFORMATION

- **Texas Geothermal Resource Information**
  Southern Methodist University Geothermal Lab
  [http://www.smu.edu/geothermal](http://www.smu.edu/geothermal)

- **Direct-Use Technology and Engineering Design**
  Oregon Institute of Technology GeoHeat Center
  [http://geoheat.oit.edu/](http://geoheat.oit.edu/)

- **Growing, Processing, and Marketing Information**
  Texas A&M Agriculture Extension
  [http://texasextension.tamu.edu/](http://texasextension.tamu.edu/)
  Texas Department of Agriculture
  [http://www.agr.state.tx.us/](http://www.agr.state.tx.us/)

- **Business Plans and Financing**
  Bob Lawrence and Associates

- **USDA Grants and Loans**
  [http://www.rurdev.usda.gov/rd/farmbill/9006resources.html](http://www.rurdev.usda.gov/rd/farmbill/9006resources.html)

- **USDOE Geothermal Program and Geopowering the West**