Division of Energy & Minerals Development

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SUCCESSFUL GEOTHERMAL PROJECTS

Mitigating Risk

How is Geothermal Energy Generated ?

RESOURCE TEMPERATURES FROM 150° TO 350° F

- Organic Rankine cycle (ORC) Technology most appropriate
- Air cooled condensers possible – 100% injection of all fluids/gases
- Most new western US resources are in this category
- Lowest environmental impact

RESOURCE TEMPERATURES OVER 350° F

- Flash technology produces steam for driving turbine
- Condensing steam cycle requires water cooled condensers
- Combined steam & ORC system allows for air cooling

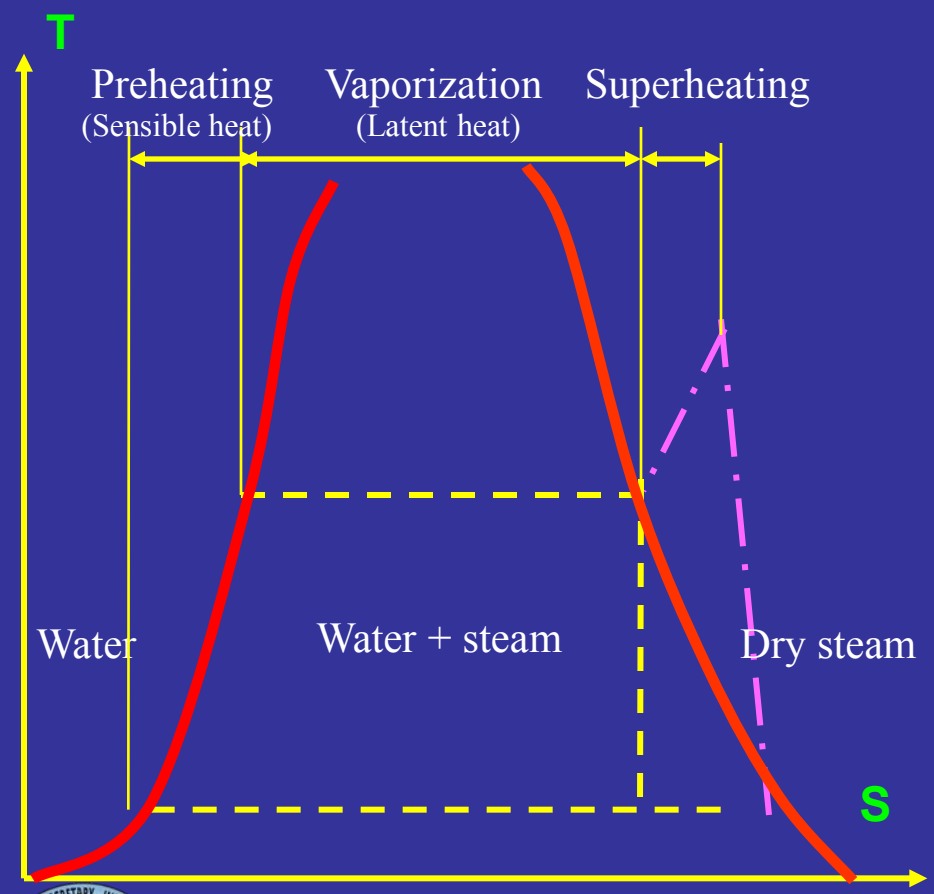
DRY HIGH PRESSURE STEAM PRODUCTION

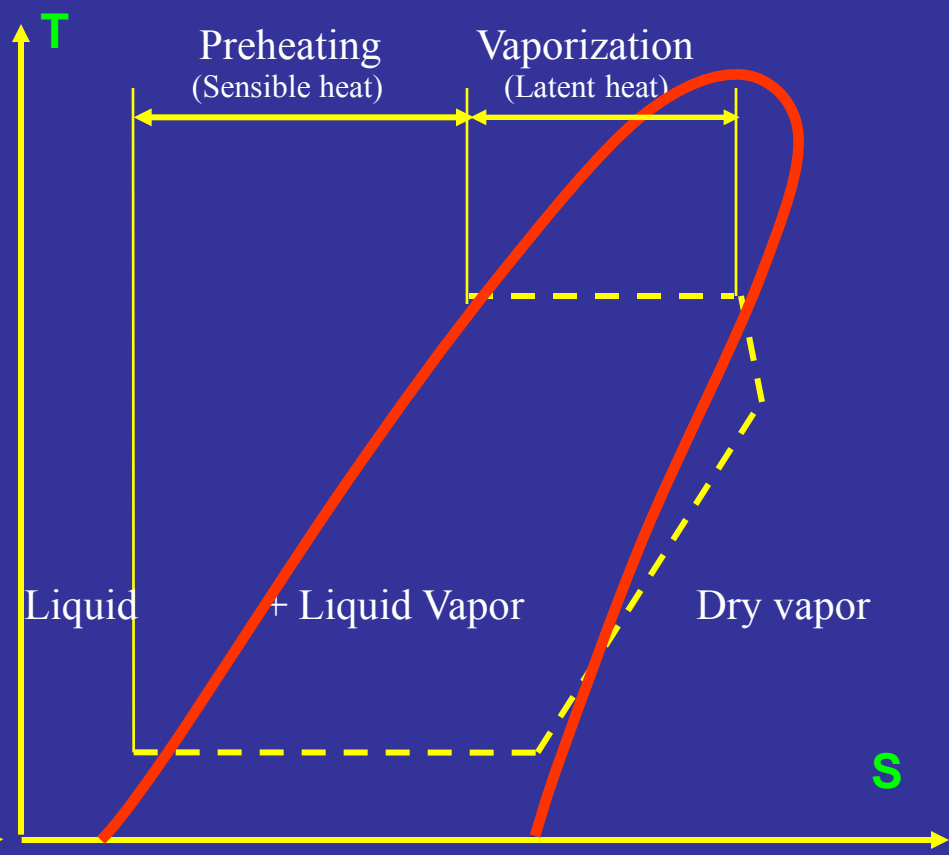
- Conventional steam turbine technology most appropriate
- Geysers (CA), Italy, Iceland, Indonesia & New Zealand
- Water cooled condensers needed
- Higher environmental impact

Temperature - Entropy Diagrams for Rankine Cycles

STEAM: Superheater required to avoid wet steam

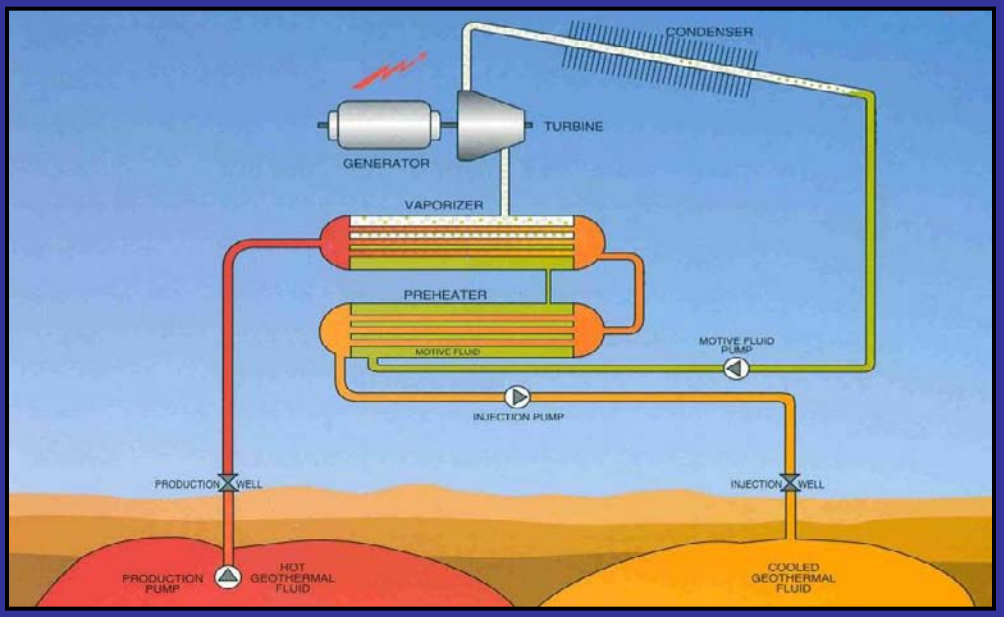
ORGANIC: No superheated required, as vapor dries while expanding





Expansion from saturated state
Expansion from superheated state

How is Geothermal Energy Generated ?

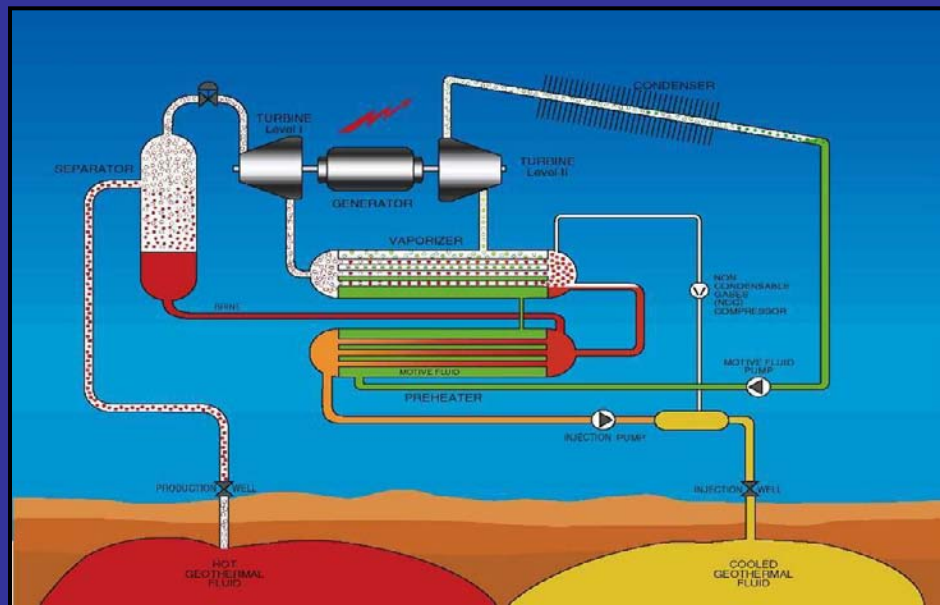


Binary Geothermal Power Plants

24 MW Zunil Geothermal Power Plant, Guatemala

Combined Cycle Geothermal Power Plants

30 MW Puna Geothermal Power Plant, Hawaii



What Are The Attributes of Geothermal Projects

Geothermal Projects Positive Attributes

- Lifetime supply of fuel capitalized – no fuel price risk.
- Only operating costs escalate – tied to inflation index.
- Best economics if power plants run full output.
- Base load operation – effective use of transmission lines.
- Purchasing utility gets energy + environmental attributes.

Geothermal Projects Have Their Risk Issues

- Some variation in hourly production due to weather etc.
- Commercial capacity may be more/less than predicted.
- PPAs should allow for long term changes in geothermal resource.
- Development permitting stringent – project delays common.
- Air cooled systems require no water consumption –
  but power output may vary by +/- 15% winter/summer.

What are the market drivers and their risks?

Market Drivers

- **PRODUCTION TAX CREDIT (PTC)**

  10 year tax credit to owner if project in service by 12/31/2008
  $0.019/kwh tax credit for energy sold
  Risks: - Impact depends on tax liability of developer/owner
  - Projects must meet placed in service date

- **INVESTMENT TAX CREDIT (ITC)**

  Available now at 10% of equipment capital costs
  Permanent credit, but may not be taken with PTC
  Risk: - Not applicable if PTC option is selected

- **RENEWABLE PORTFOLIO STANDARD (RPS)**

  Nevada RPS : 20% renewable by 2015
  California RPS: 20% renewable by 2010
  Arizona, Colorado, Montana, New Mexico, and Washington State have an RPS
  Risk: - May be modified if states unable to meet RPS requirements

How do you mitigate Geothermal project risks? (1)

PROJECT RISK	MITIGATION
Site Control	Geothermal leasehold must contain entire resource Lease terms allow for development & operation Leases allow for financing requirements
Exploration	Prior exploration data available Max use of surface technologies Exploration financing sufficient for planned action Go-No Go exploration steps
Resource Capacity Risk	Development financing sufficient for planned action Use experienced consultants Develop resource models Drill & Test deep production & injection wells
Regulatory Risk	Use experienced permitting consultant Apply early & take no short cuts

How do you mitigate Geothermal project risks? (2)

Drilling Risks	Prepare geological model to site wells Drill with blow out protectors & insurance Use reputable drilling contractors Use experienced drilling consultants Have experienced staff on site during drilling Allow sufficient funds for contingencies
Plant Construction Risk	Use experienced supplier/contractor Use experienced engineering staff Get turn-key fixed price/date certain contract Use Field Proven technology supplier Get start-up performance guarantee
Financing Risk	Execute financeable take or pay PPA with utility Execute binding commitment with lender Use experienced financial staff or consultants

How do you mitigate Geothermal project risks? (3)

PROJECT RISK	MITIGATION
PPA Risks	Ensure that project can deliver required: - Supply amounts - Capacity requirement - Energy supply profile Consider milestone schedules carefully - Full Site Control - Resource delineation - Permits - Drilling & construction milestones - Commercial Operation Date Security deposits should limit liabilities - Delayed Commercial Operation - Under production after COD Other terms which mitigate potential risks - Capacity reset ability - Uncontrollable forces - Insurance requirements Financibility - Assignments allowed for financing - Allow Investors/lenders security interest

How do you mitigate Geothermal project risks? (4)

PROJECT RISK	MITIGATION
Operating Risks	Well field operation - Use experienced field managers - Maintain well field reserve funds - Use on condition monitoring of wells Power Plant operation - Hire experienced team - Maintain Capex fund account - Upgrade when ever possible - Use on condition monitoring Regulatory and Permitting - Maintain compliance records - Perform community outreach - Apply for new permits promptly

What are the financing challenges

TYPICAL BUDGET FOR 20 NET MW 2007 PROJECT DEVELOPMENT

1. Exploration & resource assessment — $ 5.0 M
   12 Months time frame

2. Well field drilling and development (10 wells) — 20.0
   12 Months time frame after completion of item 1

3. Power plant, surface facilities, & transmission — 40.0
   20 Months time frame with overlap of item 2

4. Financing, and "soft costs": — 5.0
   - Financing Commitment fees
   - Legal, Accounting & consulting fees
   - Interest during construction,
   - Debt service and operating reserve, and
   - Project contingencies and Development Fee

   12 Month process, begins after completion of item 1

5. TOTAL *FINANCED* COST FOR 20 MW PROJECT — $70 M
   To be provided as construction phase financing

6. TOTAL AVERAGE DEVELOPMENT PERIOD — 36 MONTHS
   Plus approximately 12 months to acquire federal or private site lease control.

CONCLUSIONS

THERE ARE MANY OPPORTUNITIES FOR GEOTHERMAL PROJECT DEVELOPMENT IN WESTERN UNITED STATES.

RENEWABLE ENERGY PROJECT DEVELOPMENT NEEDS TRANSPARENT MARKETS SUPPORTED BY PUBLIC POLICY.

GEOTHERMAL ENERGY HAS SPECIAL ATTRIBUTES WHICH MUST BE CONSIDERED WHEN ENTERING INTO AGREEMENTS.

CONCLUSIONS, CONT

DEVELOPERS NEED SIGNIFICANT FINANCIAL RESOURCES TO COVER INITIAL DEVELOPMENT EXPENSES AND GUARANTEES.

PROJECT RISKS REQUIRE CAREFUL ASSESSMENT AND CONSIDERATION OF MITIGATION MEASURES.

UTILITIES WHO PURCHASE GEOTHERMAL POWER ARE CUSTOMERS, AND PPAs ARE THE CREDIT SUPPORT FOR THE OPERATING PROJECT.

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Case Studies

Great Lakes Region

Rosebud Health Center

Purpose: Provide geothermal water to heat health center

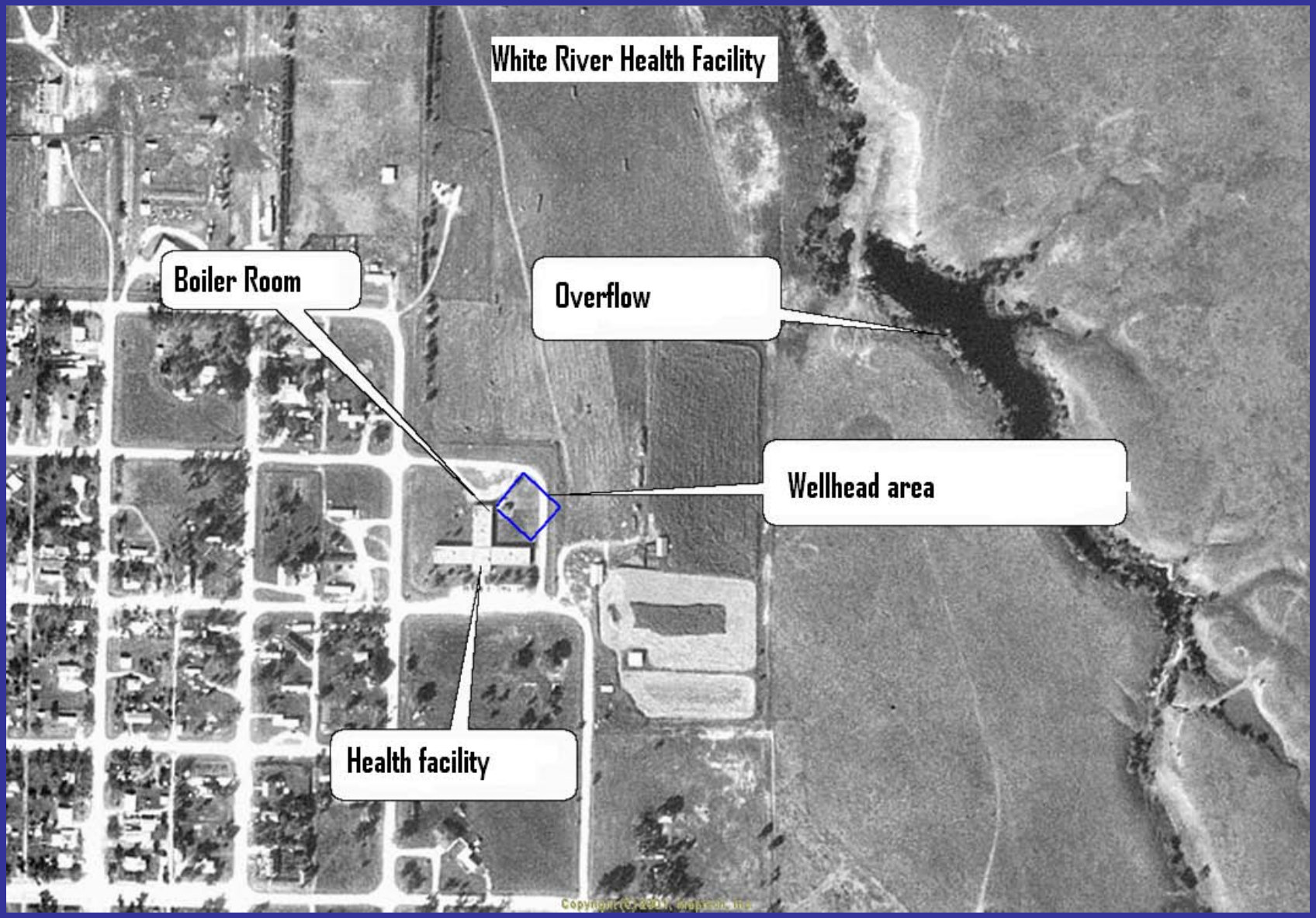
Savings: ± $50,000 per year – offset propane cost

DEMD contracted University of Colorado for engineering support

PROJECT:

Drill 3300' Madison Formation well for ±160º F water
Use hot water to replace boiler requirements in facility
Use hot water for laundry facility
Build greenhouse on facility property for patient therapy and food – heat with Madison water

Rosebud Health Center



Rosebud Health Center

Total DEMD funding to date: $195,000

Drilling Well Estimate:	**$ 230,000**
Facility Modification Estimate:	**$ 38,000**
TOTAL FUNDS REQUIRED:	**$ 268,000**
ADDITIONAL FUNDS REQUIRED:	**$ 73,000**
DEMD 2008 FUNDS:	**$ 45,000**

Estimated completion date – Fall 2008

Cheyenne River Geothermal

Use existing hot water well to build a sustainable industry for the Tribe

Project: Geothermal well providing water to heat greenhouse and aquaculture

Jobs: 40 jobs with fish processing included

Income: +$ 500,000 per year

Cheyenne River Geothermal

Total DEMD funding to date: $300,000

Work performed: Reworked well & built office

DEMD funds remaining(2007): $130,000

Drilling funds from private contribution: $60,000

DEMD 2008 funds: $45,000

Cheyenne River Geothermal

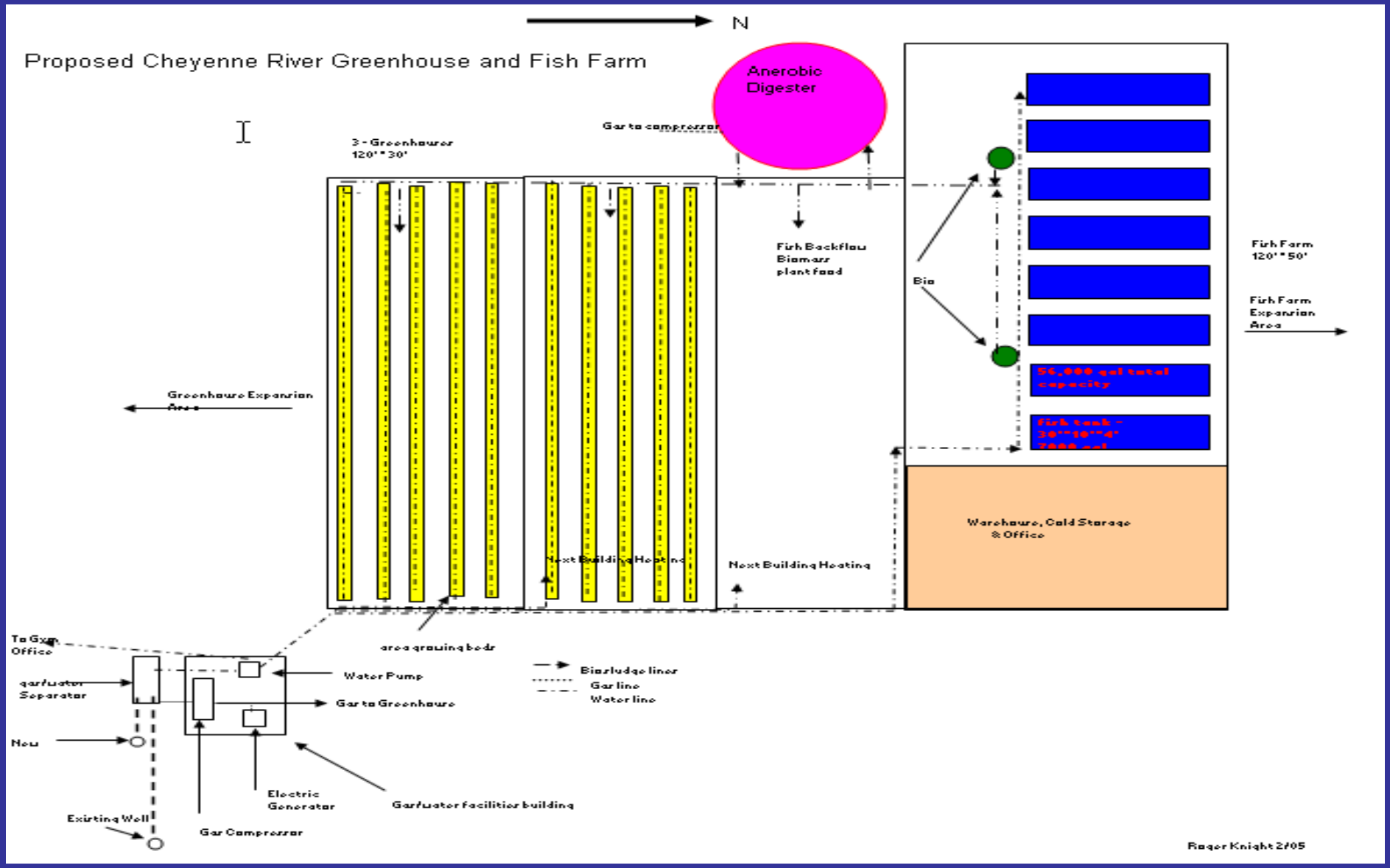
Additional project funding estimate:

Drill 2nd well:	$ 210,000
Well completion:	$ 30,000
Surface equipment:	$ 60,000
Greenhouse:	$ 100,000
Aquaculture facility:	$ 200,000
TOTAL FUNDS REQUIRED	**$ 600,000**

ADDITIONAL FUNDS REQUIRED $ 360,000

Cheyenne River Geothermal

Cheyenne River Geothermal



Cheyenne River Geothermal

Specialty Jobs required:

Agronomist

Aquaculturalist

JC program in Alamosa Colo.

Tribe needs to plan ahead for positions

Economic model

Expenses	unit	$/unit
Facility Mgr	$/yr	50000
Fish, purchase	$/fish	0.1025
Plants	$/plt	2.00
Electricity	$/ft2/yr	0.75
Gas	$/ft2/yr	2.25
Employees	$/yr	20000
Electricity	$/kwh	0.054
Emulsion processing	$/fish	0.20
Fish food	$/lb	0.21
Fish facility	sq ft	6000
greenhouse base	sq ft	13800
GH head house	sq ft	3000
GH # of employees		6
FF # of employees		6
Fish emulsion empl		3
Processing # employees		0
Processing cost	$/lb	0.20
Processing, yes=1, no=0		0
Total Employees		16
CO2 cost	$/ton	90
Use CO2, yes=1, no = 0		0

Assumptions	
Live fish purchased/ yr	55556
Fish Mortality%	10%
FF Employees, #/lb fish	0.00006
lb of fish sold/ yr	100,000
Wholesales price $/lb/fish	2.00
Proc sales price of fish, $/lb	3.00
Lbs food req./ lb fish	1.50
# Tomato Plants/ yr	2,700
lb. Tomato/ Plant	38
Sales price of Tomato, $/lb	1.95
GH Employees, #/plant	0.0022
Gas purchased, % of time	0.00%
Electricity purchased, %	0.00%
Fish Emulsion sales, $/fish	2.00
# tomatoes/sq ft	0.25
GH building cost, $/sq ft	20.00
FF building cost, $/sq ft	14.00
GH building, sq ft/unit	3600
FF building, sq ft/unit	6000
GH Diff from base 3 bldg	0
GH base size, # bldg	3
Lb fish processed/day	303
lb fish/ # emply process	150
Process value added $/lb	1.00
CO2 usage, ton/sq ft/yr	0.0034
Inc tomato prod.w/ CO2, %	30.00%

Variable Values Yellow highlights

Cheyenne River Geothermal

Economic model for Cheyenne River Project

Cap Exp	100%	M$
Well	100	100
Rework well	37	37
General Facilities	108	108
Greenhouse	345	345
Fishfarm	610	610
Emul Process, fish	4	4
TOTAL CAPEX	1203	1204

Income	M$/yr
Tomatoes	200
Tilapai	300
Fish Emulsion	111
Processing, value added	0
CO2 Tomatoes inc	0

Output values

Tomato Plants/yr		2,700	NPV	M$
	Lb Fish/yr	100,000	10%	746
Case 1			8%	1005

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