Supercritical Carbon Dioxide Circulated EGS Combined with IGCC in New Mexico

National Geothermal Student Competition

National Renewable Energy Laboratory(NREL)

The Pennsylvania State University
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Overview

- Why $scCO_2$ EGS and IGCC
- Overview of the region
- Technical Considerations
- Environmental Considerations
- Economics
- Conclusions

Problem Statement

Resource assessment and utilization of geothermal energy potential of the Rio Grande Rift Basin: A technical overview and economic analysis of a combined EGS-IGCC system with CO_2 as the working fluid

Why $scCO_2$ EGS and IGCC?

- Semi Arid Region – Intermountain West
- Reduced water usage
  - CO_2 as heat transfer fluid
- High geothermal gradients and shallow
  - reservoir
- IGCC has low net emissions

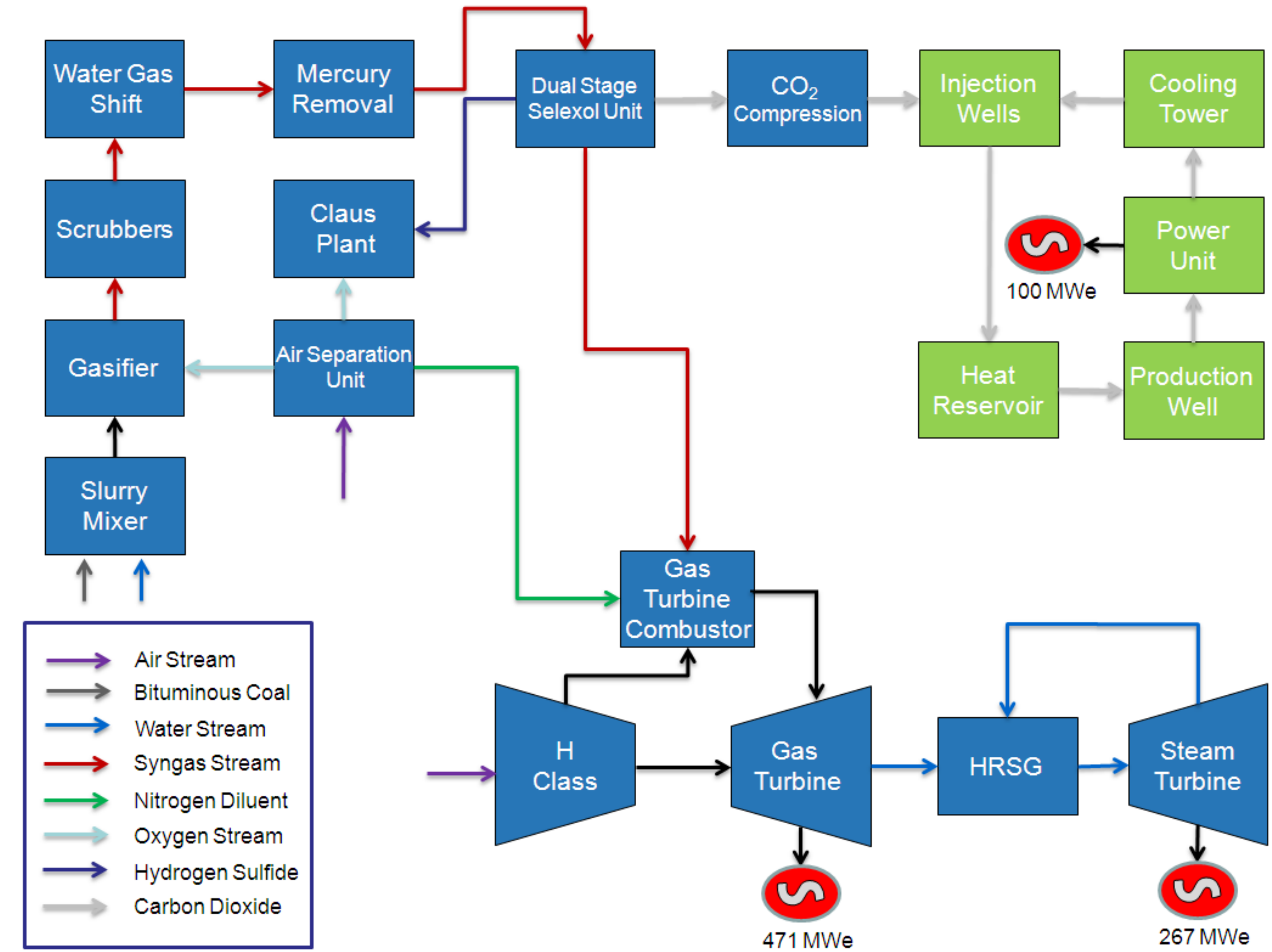
Question:
Is the available water resource being wisely used for power?

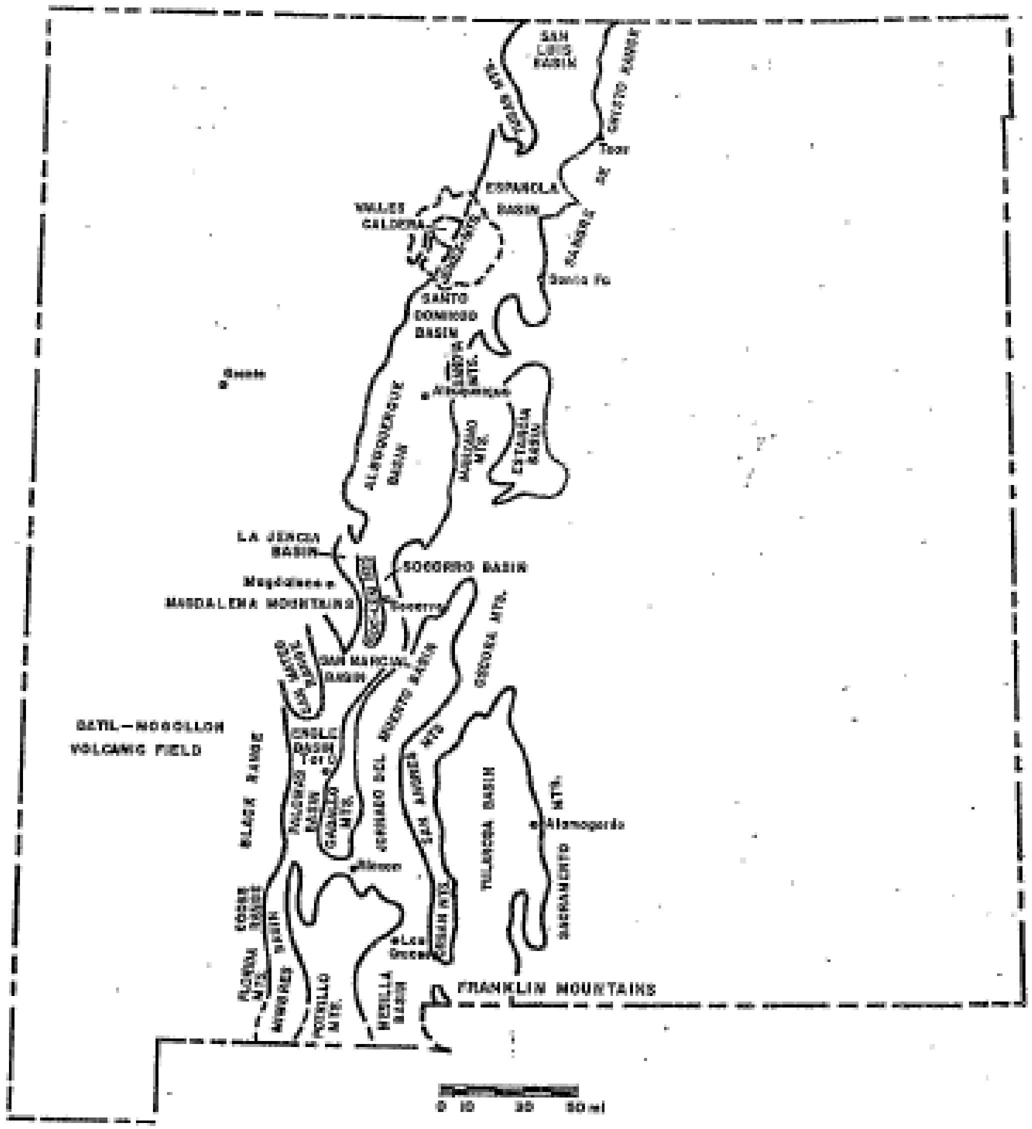
EGS only:
180kg/sec water =~150MWe actual power output

Conventional Coal Power Plant:
180kg/sec water=~400MWe actual power output

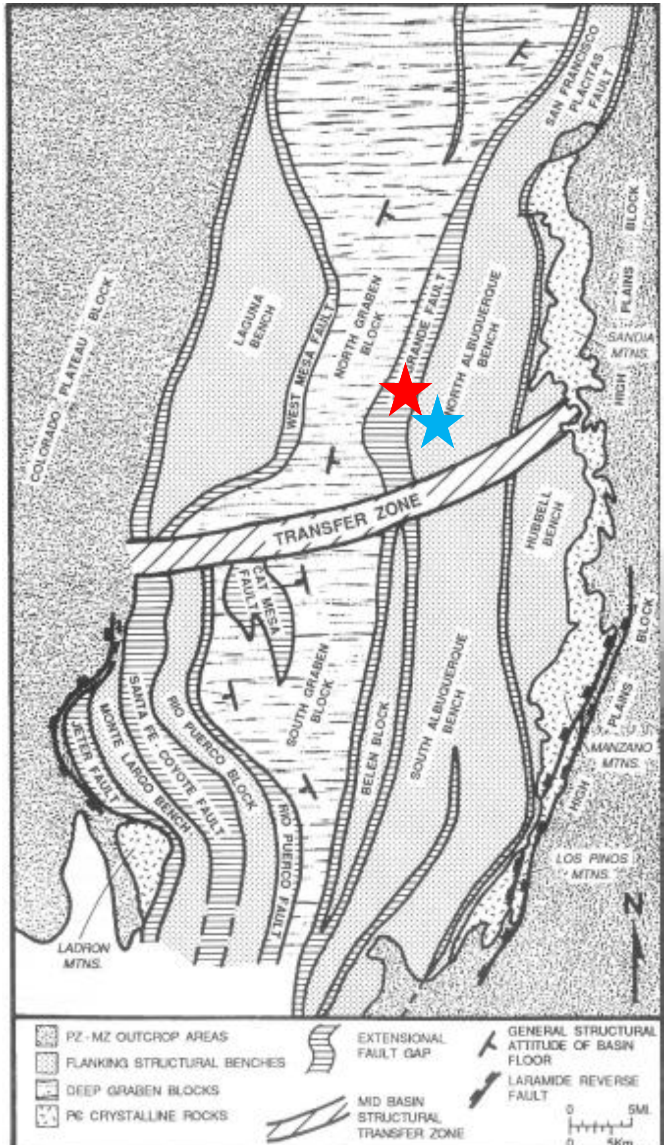
EGS and IGCC:
180 kg/sec water =~ 650MWe actual power output

$scCO_2$ EGS and IGCC system





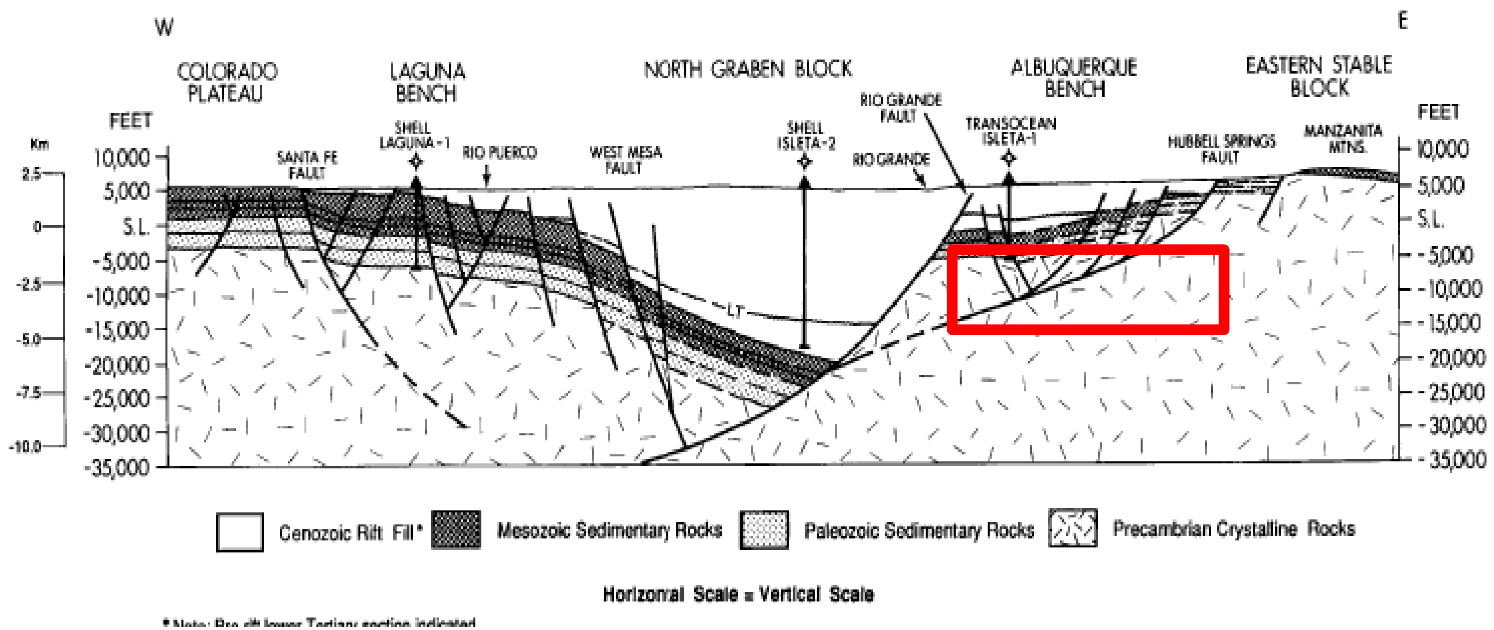
Generalized map of the Rio Grande Rift Basin (Stone 1977)



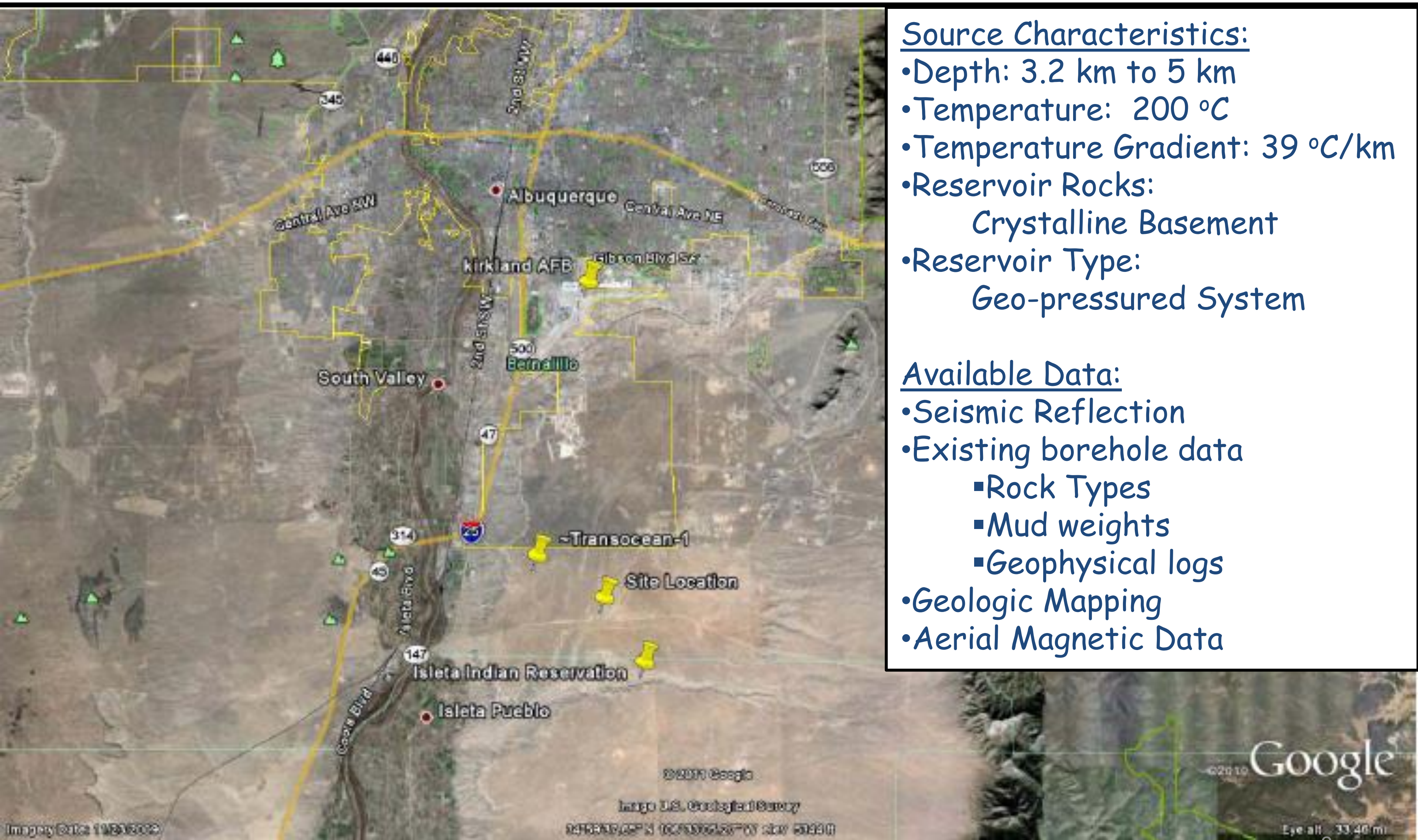
(Russel and Snelson 1994).

- Structural Geology of the Albuquerque Basin
  - Albuquerque, NM (Red Star)
  - Proposed Site (Blue Star)
  - Located on the East Bank of the Rio Grande River
  - Exists within the North Albuquerque Bench geologic structure

Geologic and seismic sections illustrating the structural configuration of the southern portion of the North Albuquerque basin



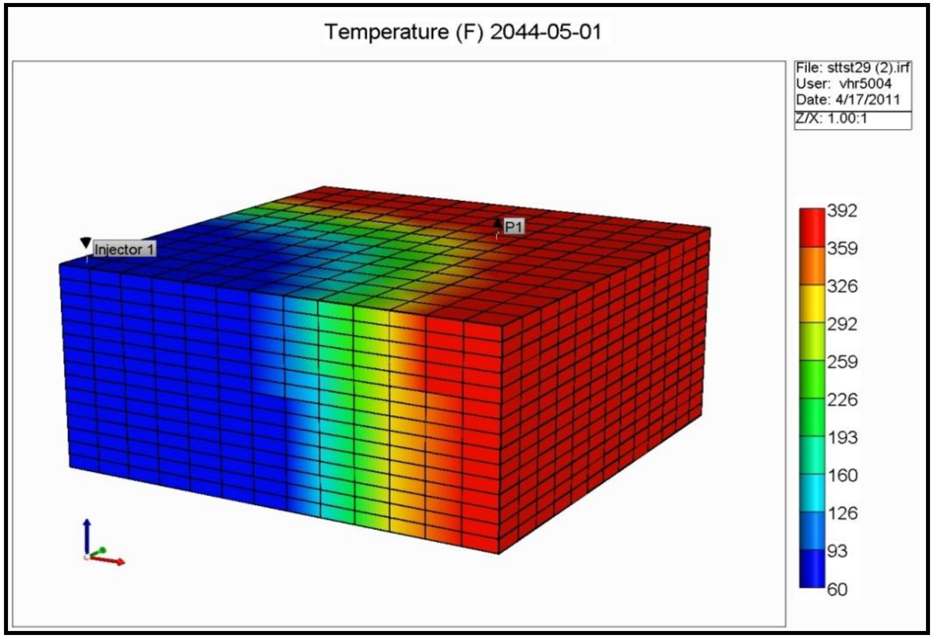
(Russel and Snelson, 1994)



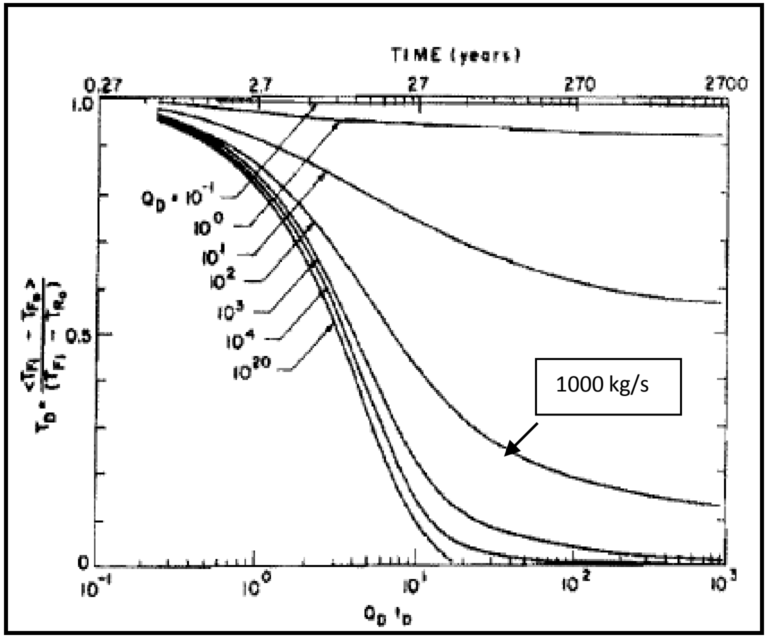
Source Characteristics:
- Depth: 3.2 km to 5 km
- Temperature: 200 °C
- Temperature Gradient: 39 °C/km
- Reservoir Rocks:
  Crystalline Basement
- Reservoir Type:
  Geo-pressured System

Available Data:
- Seismic Reflection
- Existing borehole data
  - Rock Types
  - Mud weights
  - Geophysical logs
- Geologic Mapping
- Aerial Magnetic Data

CMG Results



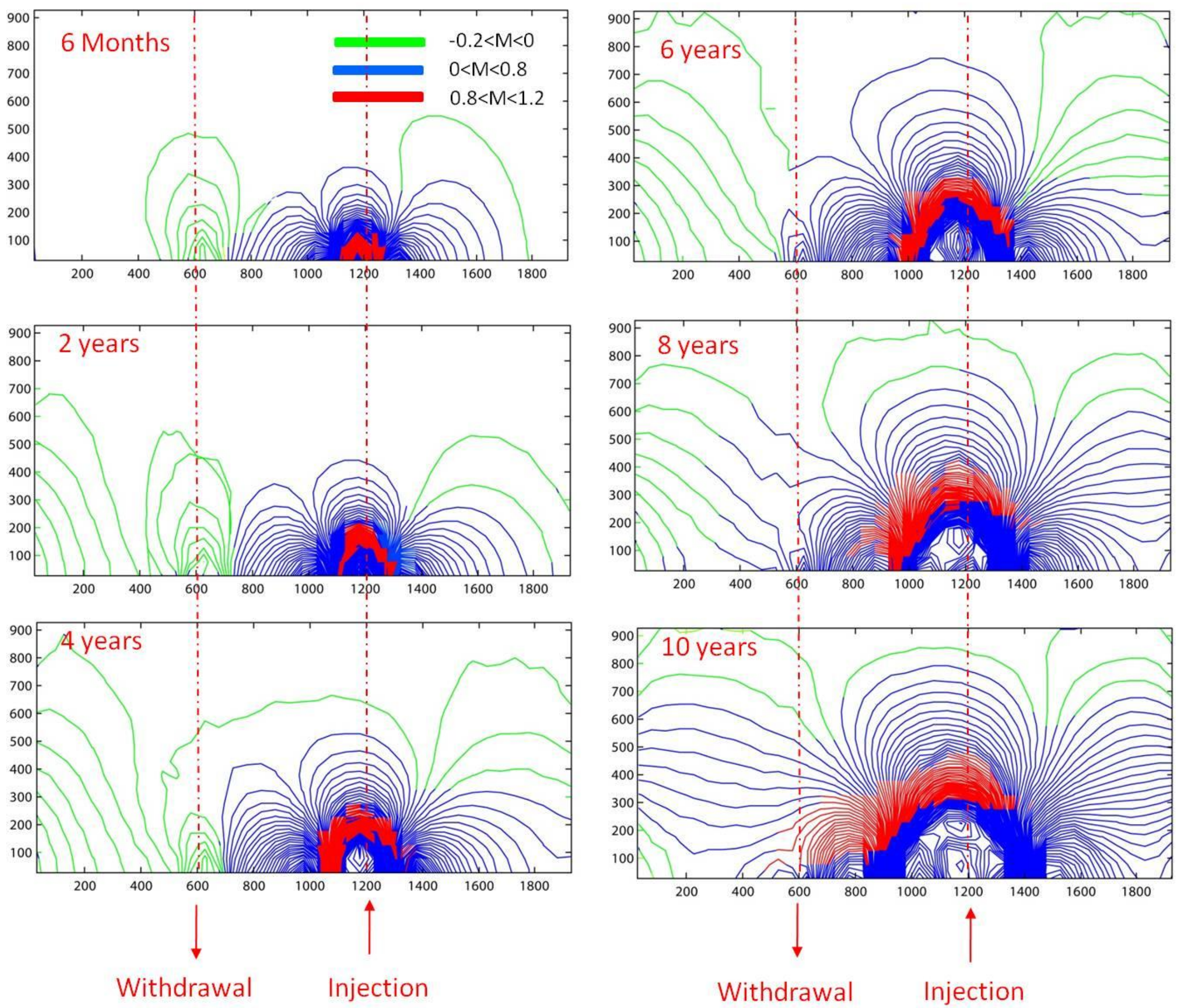
Spherical Reservoir Model Results



Major results from reservoir simulation for a five spot pattern:

- Water production continues until 30% water saturation in the reservoir is achieved
- For initial 50% water saturation and 10 meter fracture spacing, thermal break through occurs after approximately 33 years
- For this case water production occurs for the first three years
- As fracture spacing increases thermal break through time increases
- Similar thermal break through results from prototypical reservoir modeled with either CMG and SRM

The evolution of moment magnitude in an EGS reservoir with 200m fracture size



Plots of the potential for triggered seismicity relative to injector

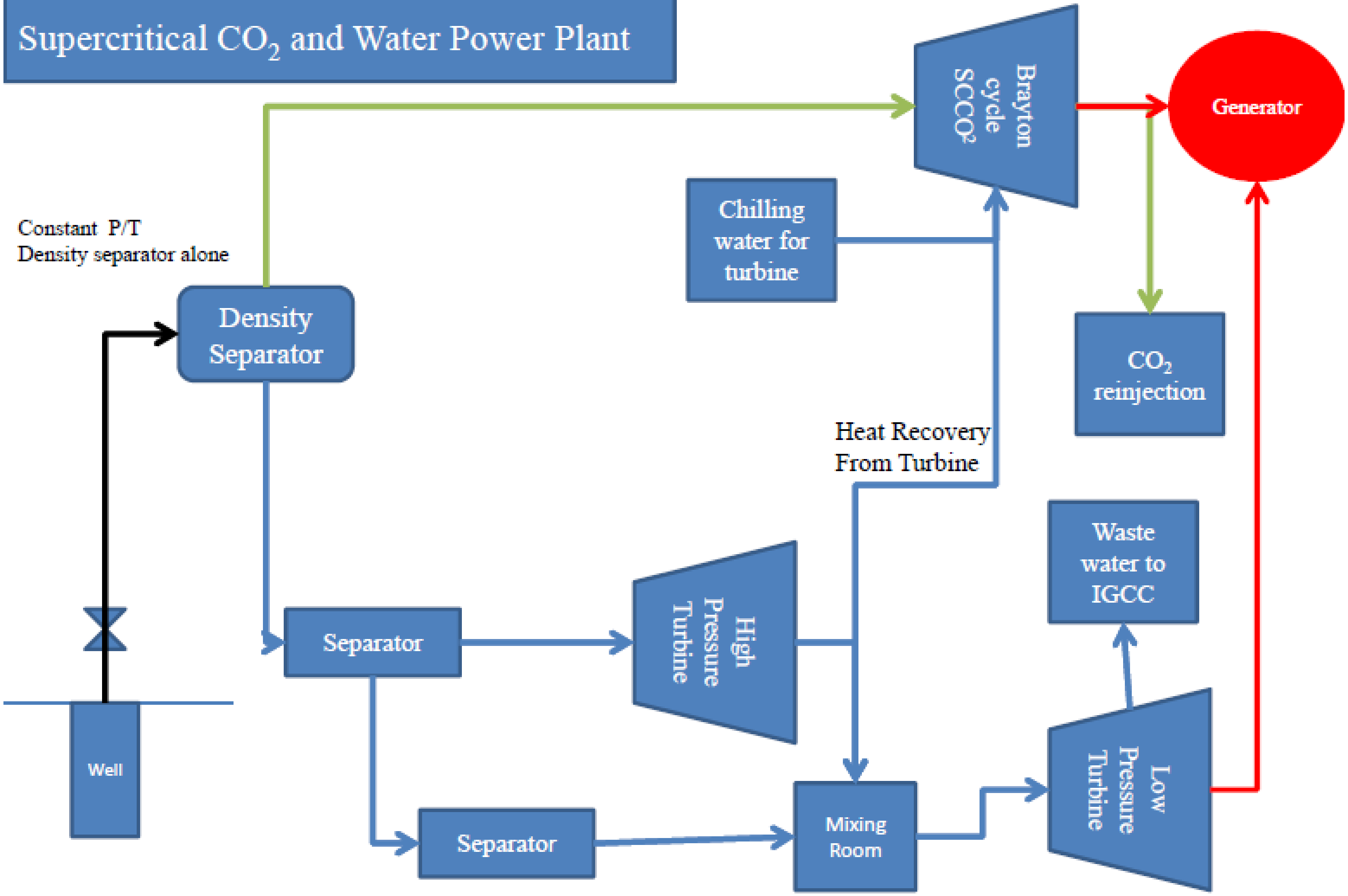
Potential energy release is defined as $E = \Delta\sigma^2 a^3 / G$

This translates to a Moment magnitude for each event as: $\log M_0 = 1.5 M_s + 9.1$

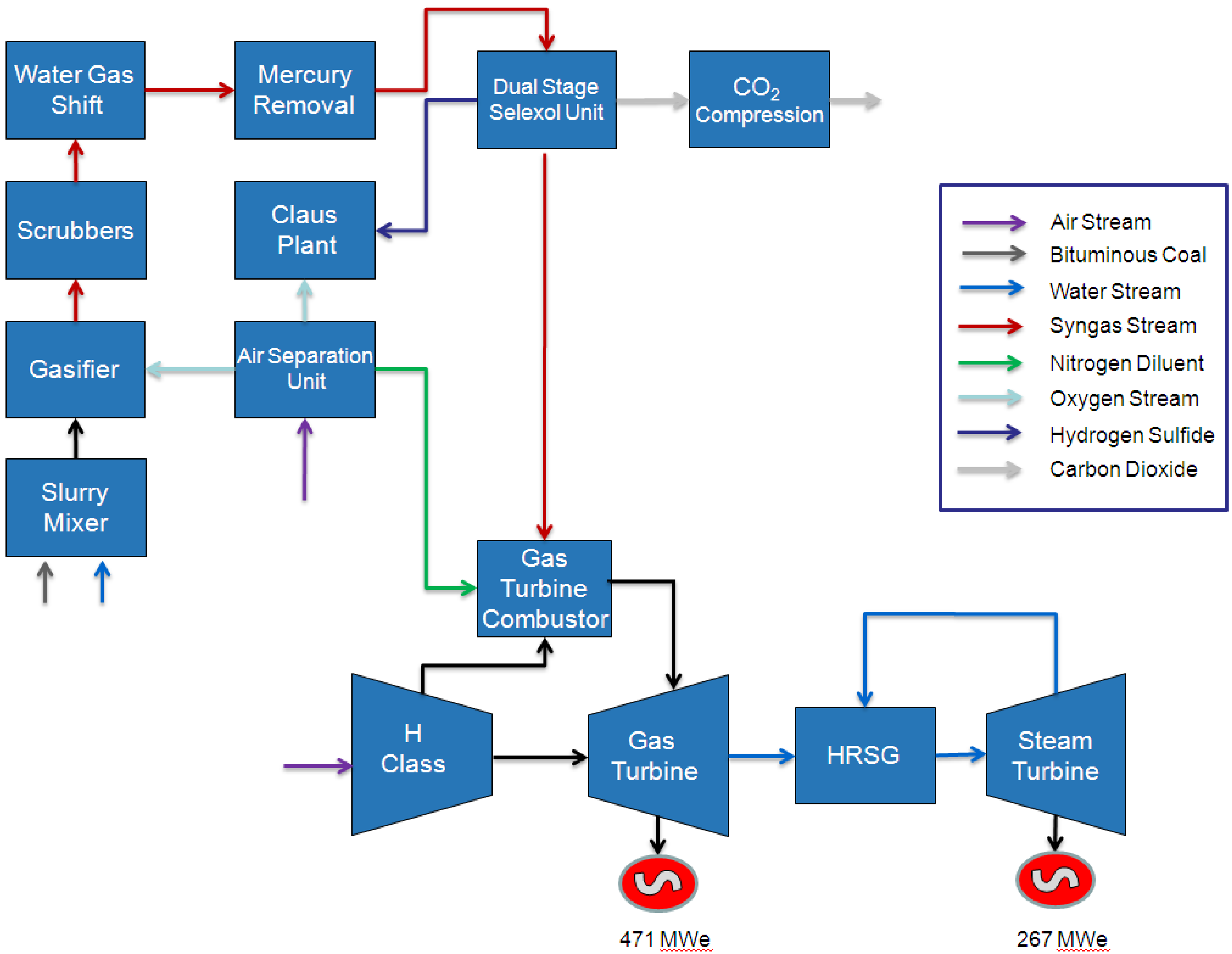
Note that seismicity migrates outwards from injector with development of the reservoir.

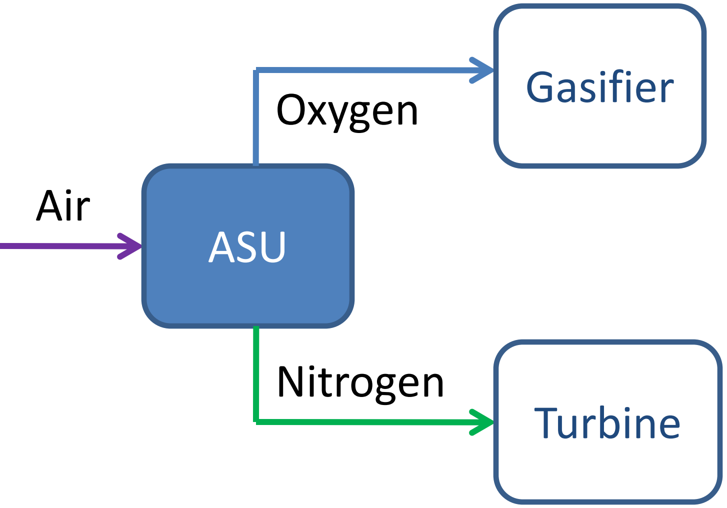
Maximum magnitude is defined by fracture size.

Supercritical CO_2 and Water Power Plant

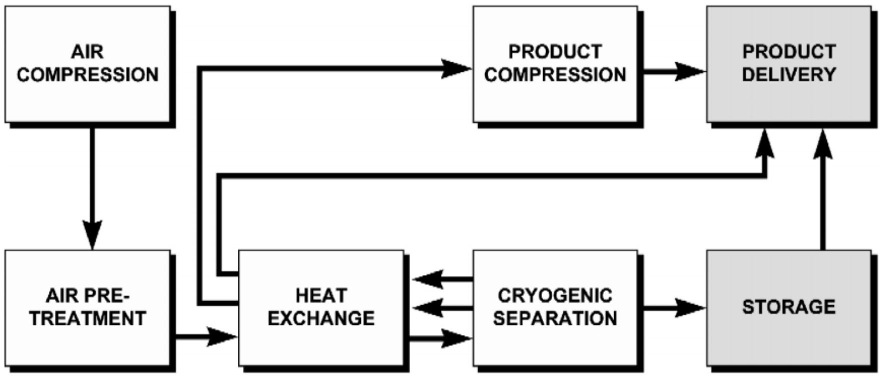


IGCC - ASU Gasifier Gas Cleaning Units Power Generation





- Nitrogen is used as diluent for gas turbines to reduce NOx emissions.
- Oxygen is used for gasification of coal.
- Cryogenic technology is preferred as it can be integrated with other process



Cryogenic Processing(A.R Smith 2001)

- Uses cryogenic distillation to separate oxygen and nitrogen
- Removes water, CO_2 and hydro-carbons
- Most efficient and cost effective
- Liquid products

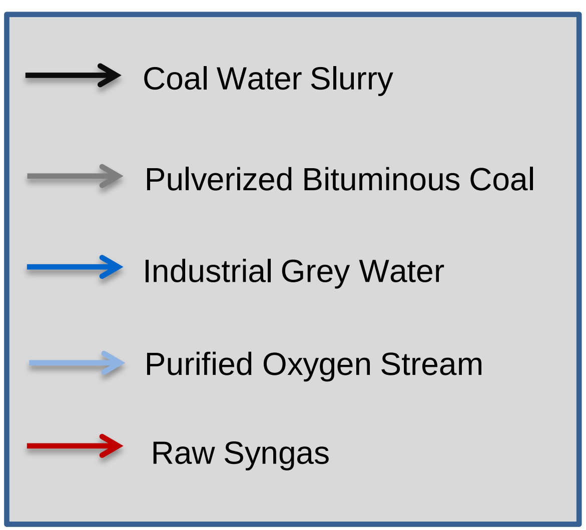
Gasification
How it Works

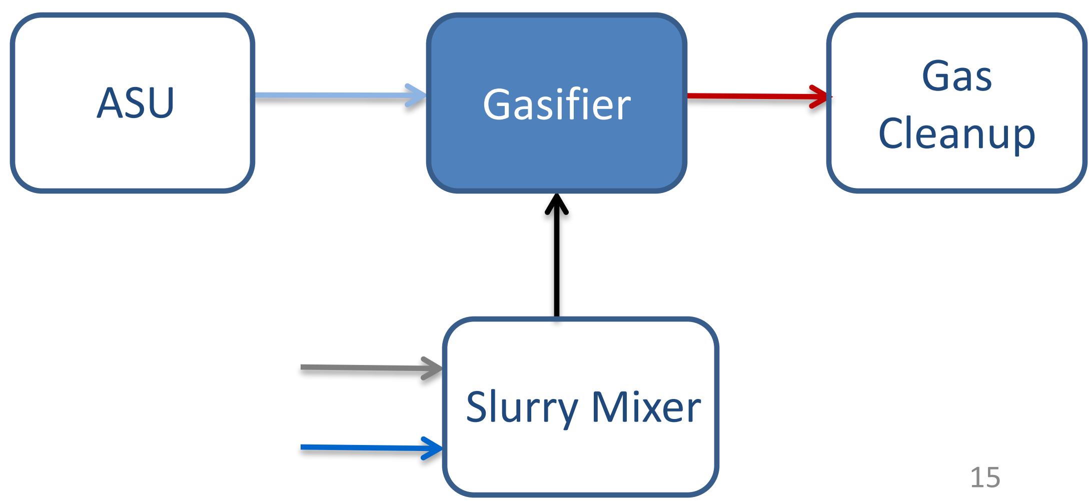
Steam Reformation

$$H_2O + C(s) \rightarrow H_2 + CO$$
$$2H_2O + C(s) \rightarrow 2H_2 + CO_2$$

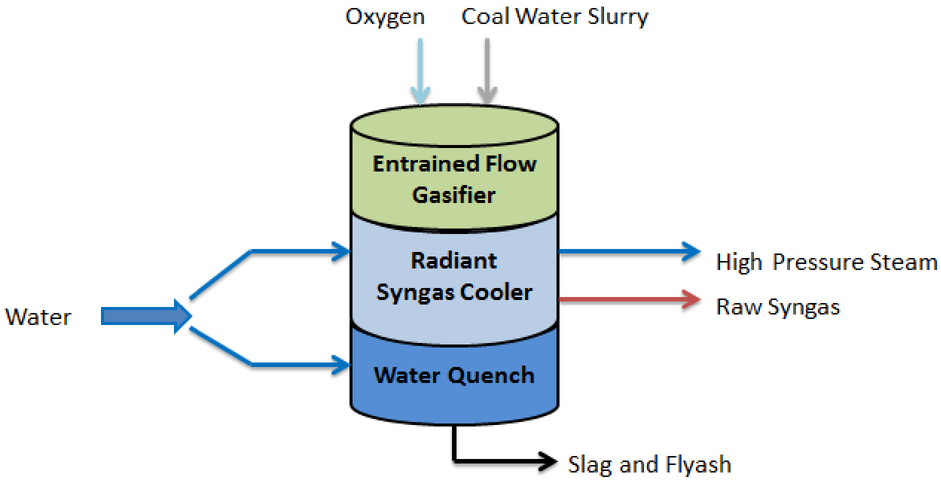
Partial Oxidation

$$C(s) + O_2 \rightarrow CO_2$$
$$2C(s) + O_2 \rightarrow 2CO$$

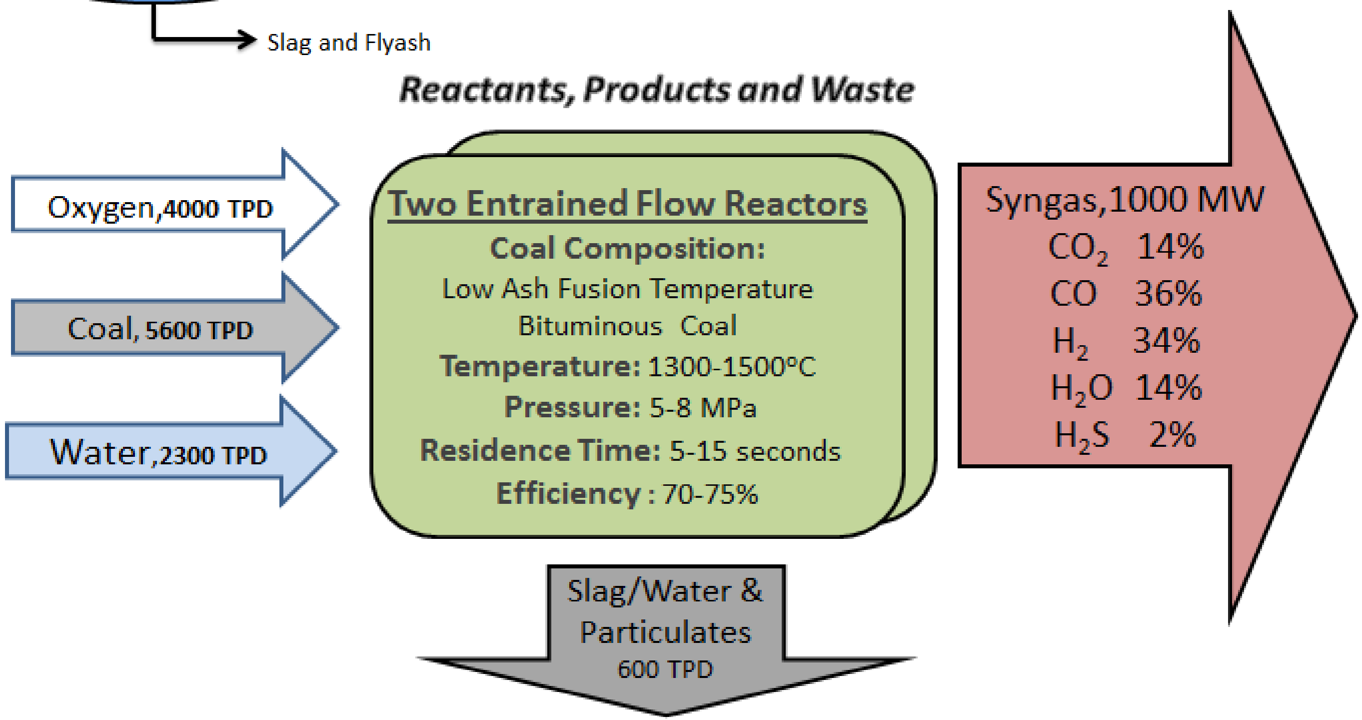


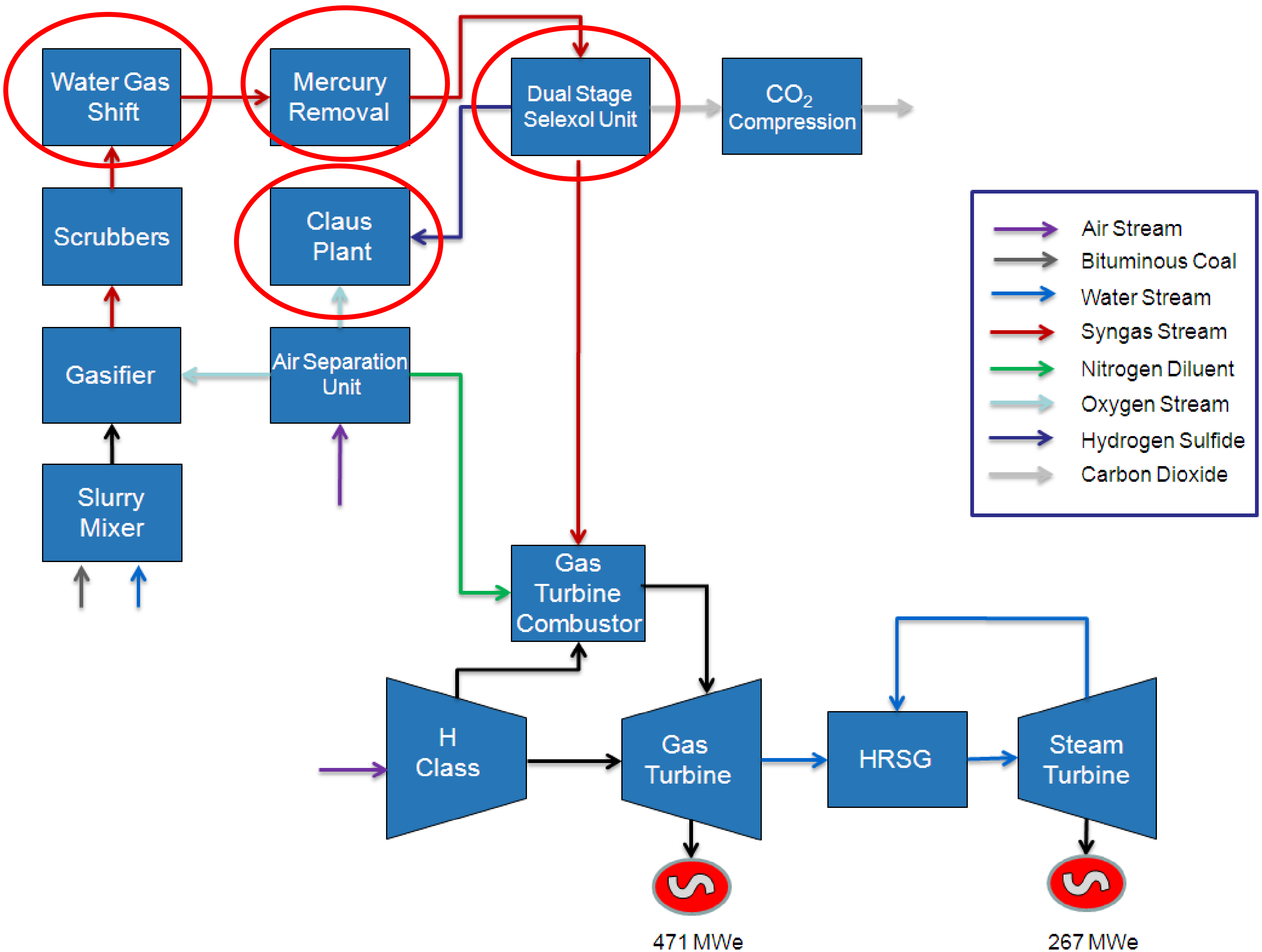


Gasification Reactor
Entrained Flow



Entrained Flow Advantages
- Short Residence Time
- High Temperature
- Few Coal Constraints
- Coal Water Slurry Feed

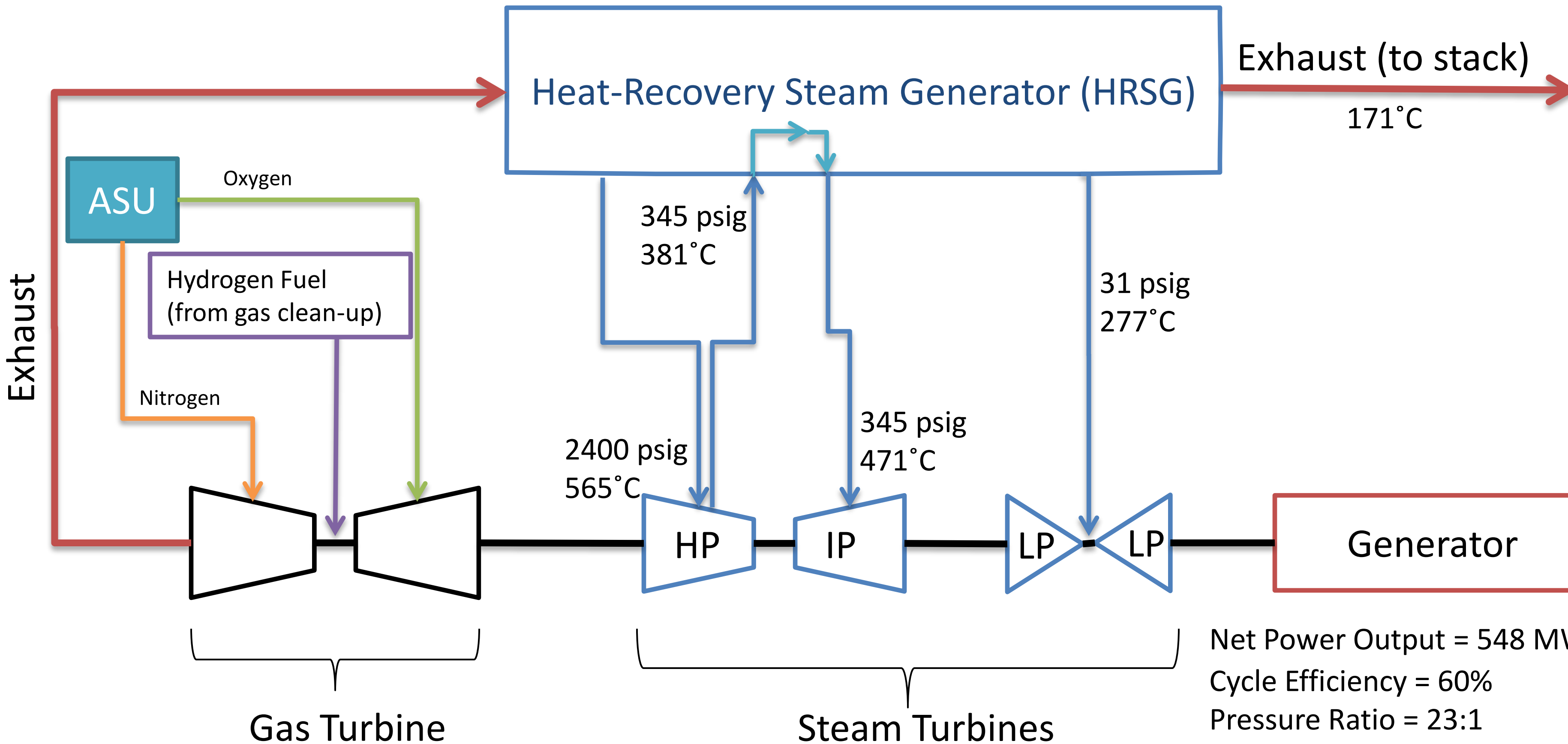



Water Gas Shift
Mercury Removal
Dual Stage Selexol Unit
CO_2 Compression
Scrubbers
Claus Plant
Gasifier
Air Separation Unit
Slurry Mixer
Air Stream
Bituminous Coal
Water Stream
Syngas Stream
Nitrogen Diluent
Oxygen Stream
Hydrogen Sulfide
Carbon Dioxide
Gas Turbine Combustor
H Class
Gas Turbine
HRSG
Steam Turbine
471 MWe
267 MWe

Main Components of Gas Cleanup

Water Gas Shift	• Two-stage sour gas shift reaction • Hydrolyzes COS to H_2S • 97% conversion of CO to CO_2
Mercury Removal	• Sulfur impregnated activated carbon • 90-95% removal efficiency
Acid Gas Removal	• Two-stage Selexol process • 99.7% H_2S removal capacity • 90.3% CO_2 removal at 99.5% purity
Claus Process Plant	• 95% sulfur removal from H_2S stream • Tailgas (H_2, CO_2) sent back to AGR

GE H-Class Turbines



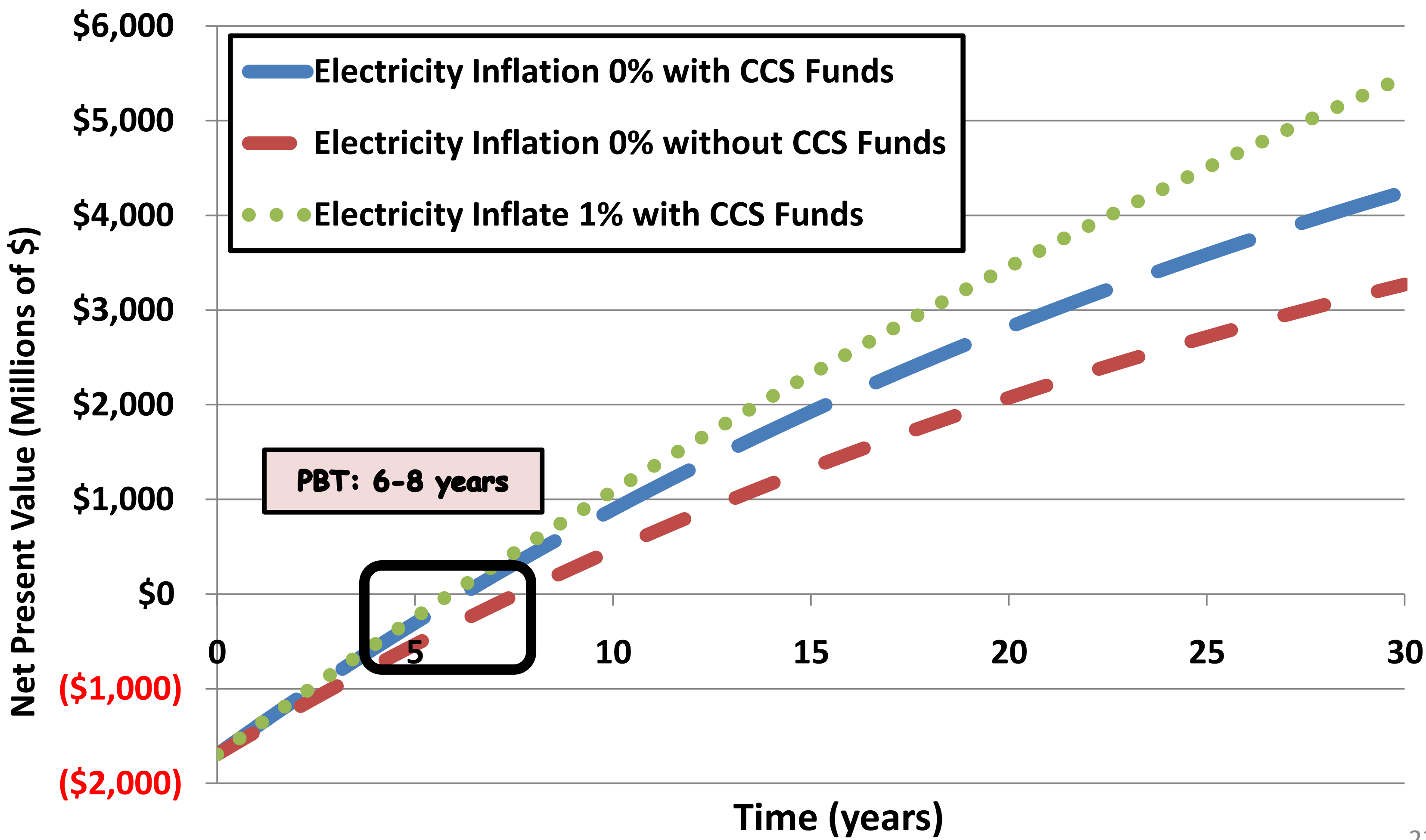
Net Power Output = 548 MWe
Cycle Efficiency = 60%
Pressure Ratio = 23:1

- Emission savings
  - By coupling EGS and IGCC substantial emission savings will be generated
  - $50 million of government incentives for CCS(carbon capture and sequestration) will be received per year
- Sustainable Water Usage
  - Water Sources
    - Grey Water/Industrial Water
    - Coproduced water from geothermal field
  - Water Management Strategy
    - Scheduled downtimes for maintenance will occur during known low water periods
    - Total days of electric generation – 292 days

Elements of Economic Analysis

Main Assumptions	• Electricity selling price = $0.09/kWh • Interest rate = 3% • Capacity factor = 80%
System Costs	• Capital cost = $1.7 billion • Annual O&M = $190 million
Revenue Streams	• Selling 4.7 million MWh / yr • $1.25 million / yr sulfur value • Possible $50 million / yr for CCS
Net Present Value Analysis	• Present day dollar values for cash flows • 3 possible scenarios • Payback Time (PBT) for each scenario

Results of NPV Economic Analysis



Conclusions

- Synergy between $scCO_2$-EGS and IGCC
  - Near-zero emissions system
  - Reduced water usage on per MW-basis
  - Partial sequestration of CO_2
- Economic Viability
  - Thermal break through after ~30 years on par with design life spans of other power plant designs
  - Short transmission distances to market
  - Short PBT: 6-8 years
- Other Benefits
  - A low visual and carbon foot print
  - Coal to Liquid fuel potential from IGCC for various applications

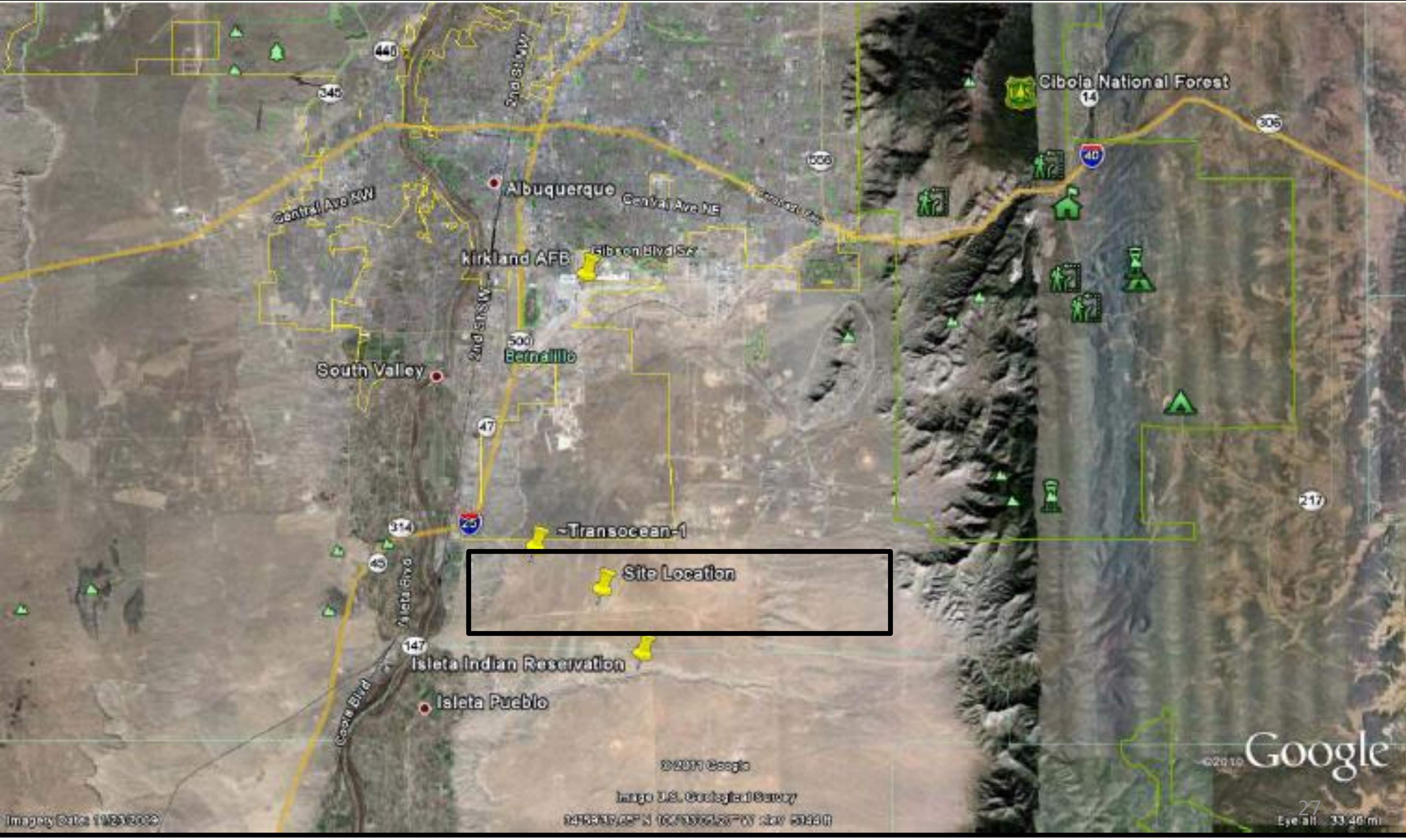
Questions


shop
stage
induced
close
principal
fugitive
case
plants
reduced
combustion
sent
occupy
kilometers
ROI
seismicity
design
carbon
may
high
CO
anticipated
located
billion
thermal
equipment
two
make-up
energy
rates
production
contamination
methods
basement
Considerations
processes
Jobs
transfer
combined
injection
rocks
coal
distributed
CCS
pairing
gas
Geothermal
plant
components
impacts
developed
rate
assessment
estimated
hydrogen
facilities
IGCC
CO2
use
environmental
followed
transmission
comprise
reactors
capture
costs
MW-electricity
worth
overall
pure
area
system
governmental
water
iii
also
impact
electricity
operation
Albuquerque
possible
air
reservoir
Mexico
environment
flow
gasifier
using
H2S
separation
NM
long
turbine
resources
km
fluid
site
generation
oxygen
ii
gasification
synthesis
emissions
power
kg/s
results
term
fuel
resulting
metric
year
stream
order
cycle
becomes
infrastructure
maintenance
heat
years
tons/day
produce
well
total
scenario
Technical
WGS
burning
geothermal
region
H2
Specifically
proposed
nitrogen
depths
EGS
km2
conversion
MWe
conditions
sCO2-EGS
explore
project
output
road
tons
city
minimal
available
efficiency
closed
temperature

Acknowledgments

- National Renewable Energy Laboratory(NREL)
- Dr Derek Elsworth
- Dr Sarma Pisupati
- Dr Uday Turaga

- Water Management:
  - Grey water and produced water use
  - Scheduled maintenance during known drought periods.
- Aesthetic Landscape Preservation:
  - Tactical industrial architecture design
  - Paint schemes
- Education Activities:
  - Water use
  - Induced seismicity
  - Affects on the local community



Cibola National Forest
Albuquerque
Central Ave NW
Central Ave NE
Kirkland AFB
Gibson Blvd SE
2nd St NW
2nd St SW
Bernalillo
South Valley
~Transocean-1
Site Location
Isleta Indian Reservation
Isleta Pueblo
Coors Blvd
Isleta Blvd
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The evolution of moment magnitude in an EGS reservoir with 200m fracture size

The elastic strain energy released by failure and the drop in shear stress can be recovered from:

$$\mathrm{E} = \frac{1}{2}\int_{2A} \tau u dA = \int_0^a \int_0^{2\pi} u\tau r dr d\theta =$$

$$= \frac{8(\lambda + 2G)}{3G(3\lambda + 4G)} = \frac{8(1-\nu)\tau^2 a^3}{3G(2-\nu)}$$

$$\mathrm{E}_p = \frac{2\Delta\tau^2 a^3}{3G}$$

Total Energy:

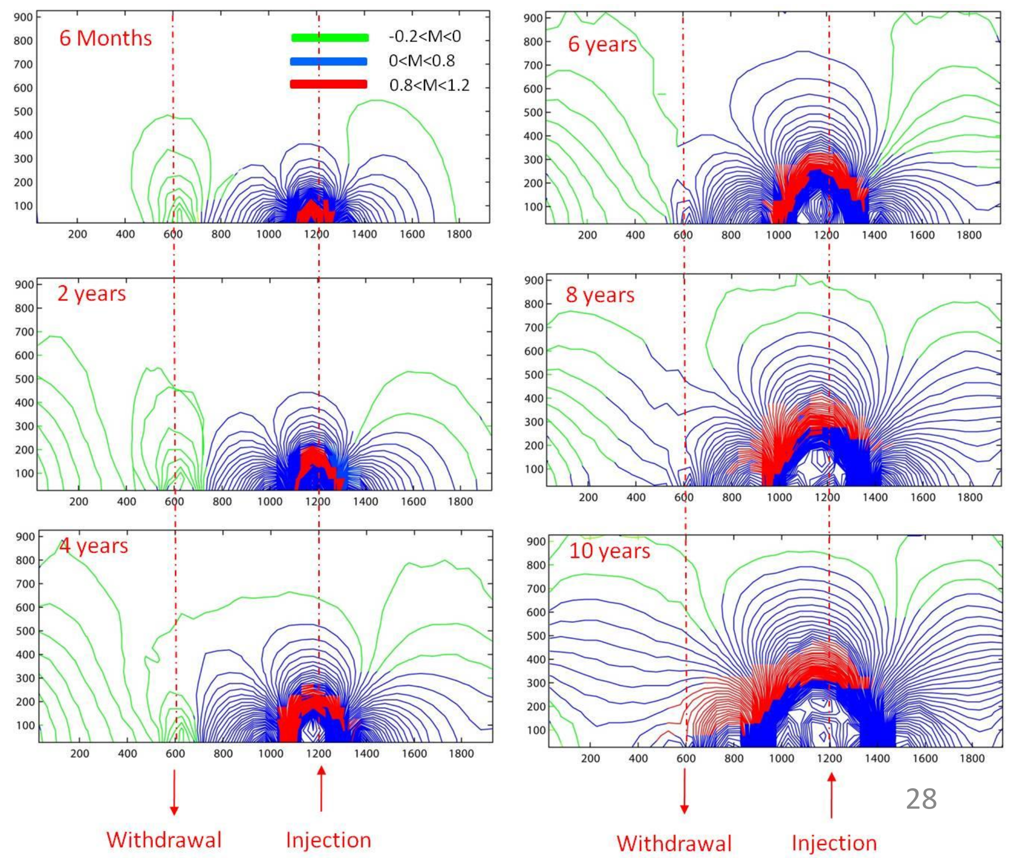
$$E_T = \int \tau_f - \tau_i{}^T \ \varepsilon_f - \varepsilon_i \ dV$$

Moment magnitude for large fracture:

$$\log M_0 = 1.5 M_s + 9.1$$

Number of events which occur during the failure process:

$$N_{event} = \frac{E_T}{E_p}$$



- Short Term
  - Maintenance Shop
  - Labor Camp
  - Water and waste water facilities
  - Storm water management units
  - Erosion and sedimentary control structures
  - Material sources and staging areas
  - Initial road access
- Long Term
  - Plant Facilities
    - Power generation
    - Geothermal well fields
    - Plant equipment and machinery
    - Piping and waste fluid disposal
  - Support Facilities
    - Transmission lines
    - Access roads
    - Rail line
    - Water pipe line
    - Water supply and storage
    - Storm water management
    - Waste water treatment
    - Emergency shelters