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Geotermia, experiencia Mundial y proyectos en la región

Siemens Energy Oil & Gas Division

Industrial Power

August 23, 2012

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Content

Why Geo ? A paradigm shift is occurring that will create a sustainable energy system

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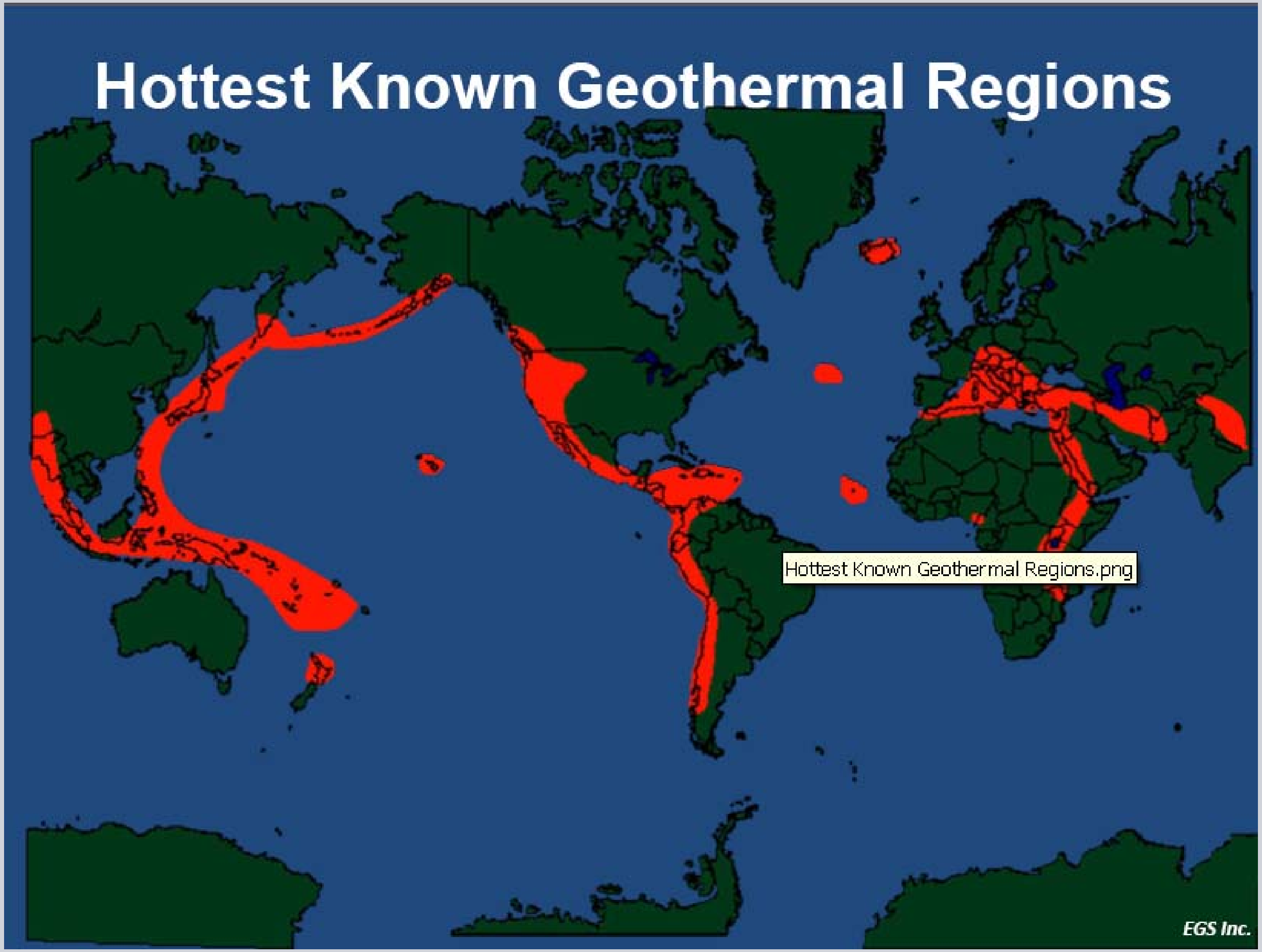
19th century	20th century	Start of 21st century	End of 21st century
Electrification of society "Age of coal"	**Large-scale generation of electrical energy** "Age of fossil fuels"	**Challenges force process of rethinking:** ▪ Demographic shift ▪ Resources becoming scarce ▪ Climate change	**The new power age** Electricity becomes ***the*** form of energy for most applications in daily life
Energy system not sustainable			**Sustainable energy system**
Power supply limited to individual regions or urban areas	Interconnected network grids, centralized power generation by "estimated" consumption	Increasingly decentralized, fluctuating power generation through renewable energies	Intelligent grids enable high percentage of renewable energies, e.g. with eCars and heat pumps
Fossil fuels, water power	**Fossil fuels, water power, nuclear power**	**Fossil fuels, hydro power, nuclear power, biomass, wind, solar and geothermal**	**Renewable energies, "clean" coal, gas**
No environmental concerns			**Environmental awareness**

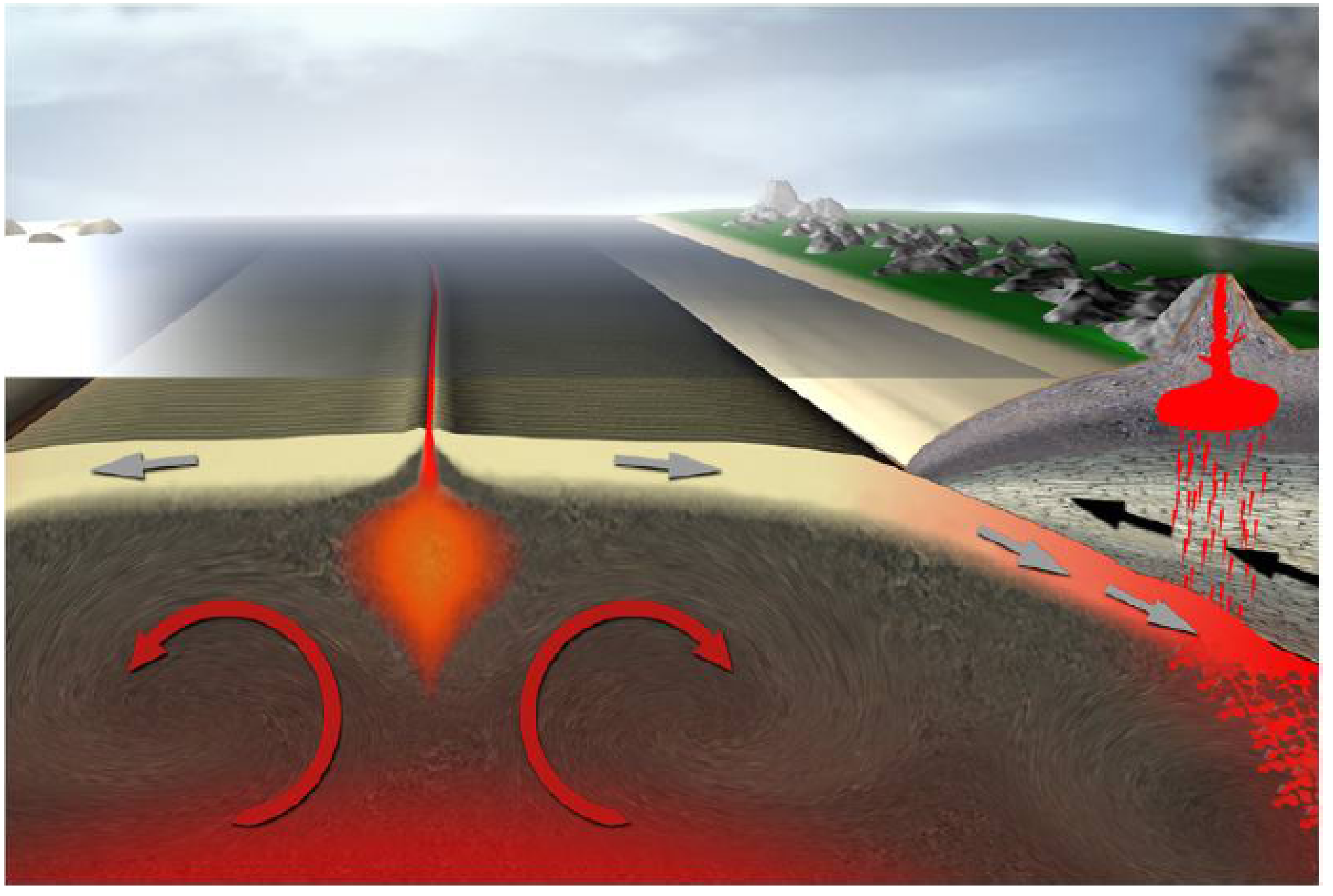
Content

Geothermal Energy – Where is it?



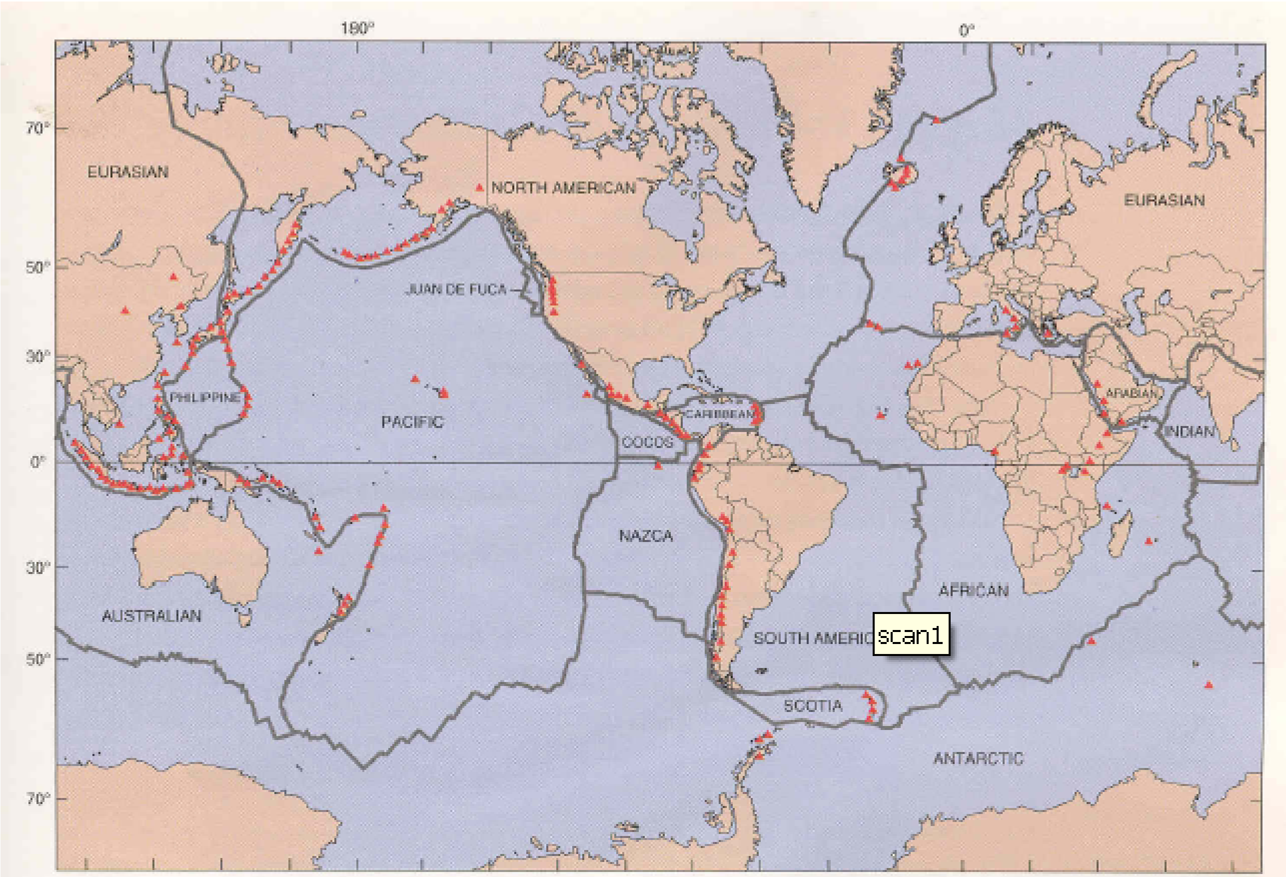
Geothermal Energy – What is it?

Plate Tectonic Process

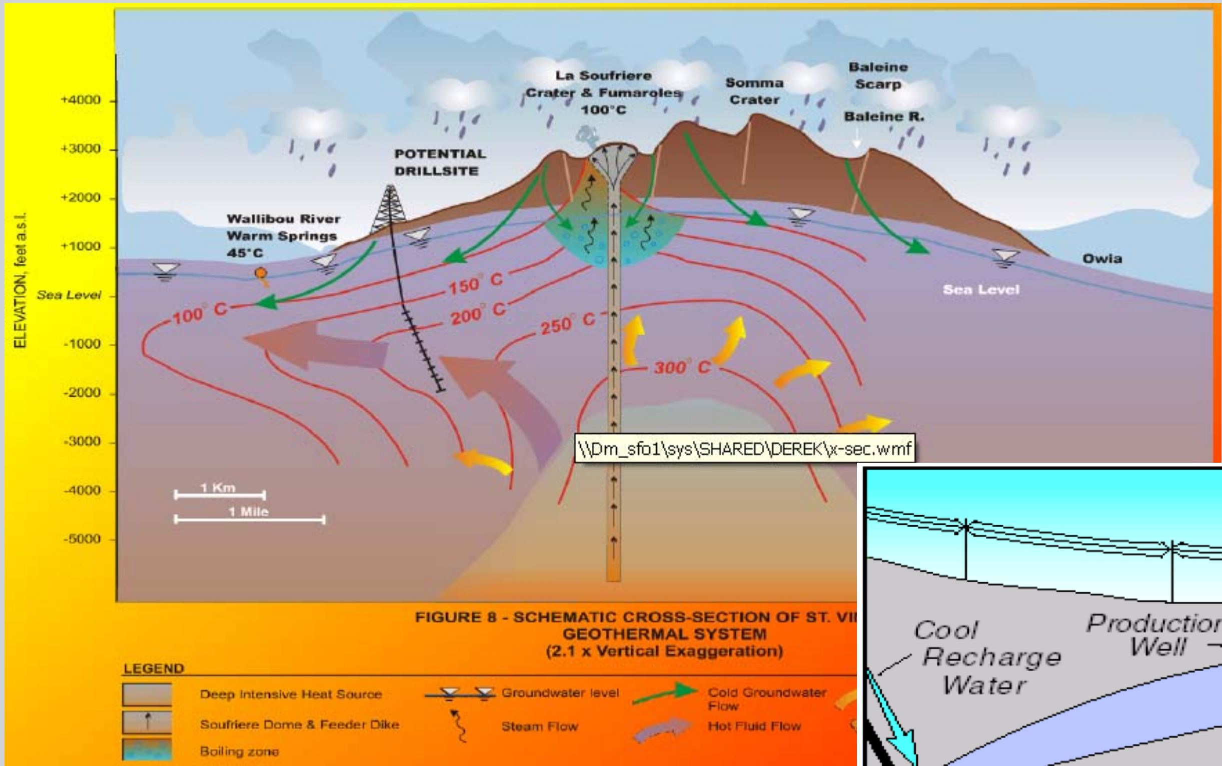


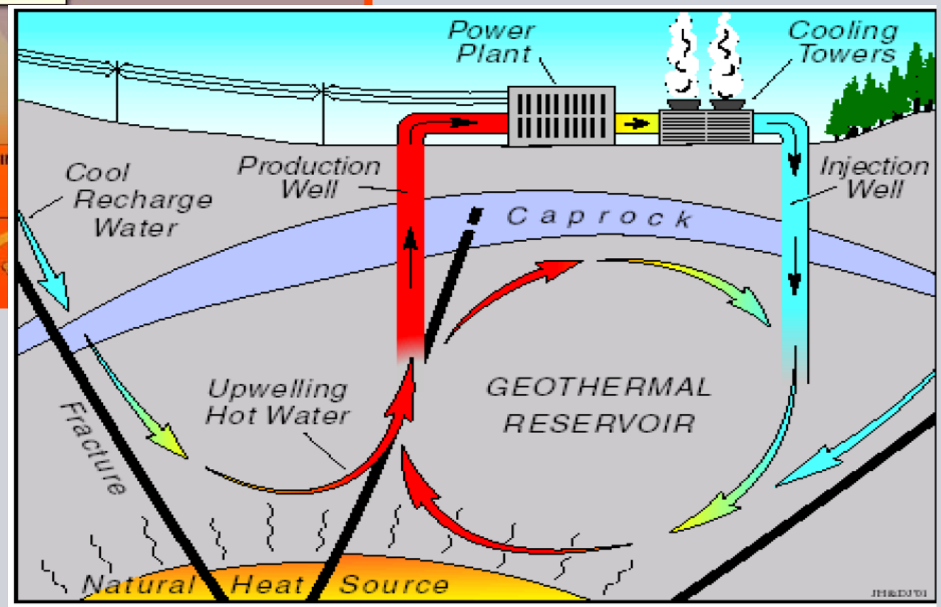
Geothermal Energy – Where is it?

Distribution of Lithospheric Plates and Active Volcanoes



Andesitic Volcano Geothermal Resource





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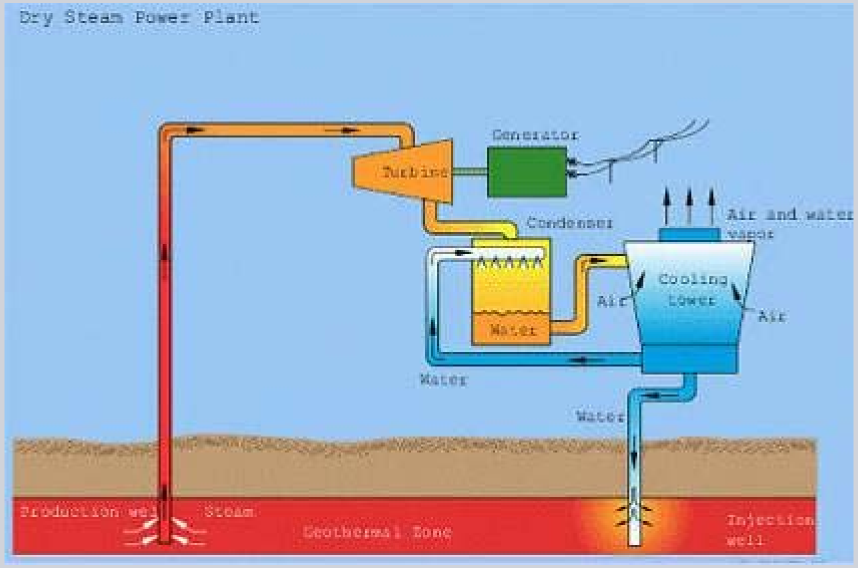
Geothermal plants – how they work

Dry Steam Cycle, Flash, Binary, Combined Cycle

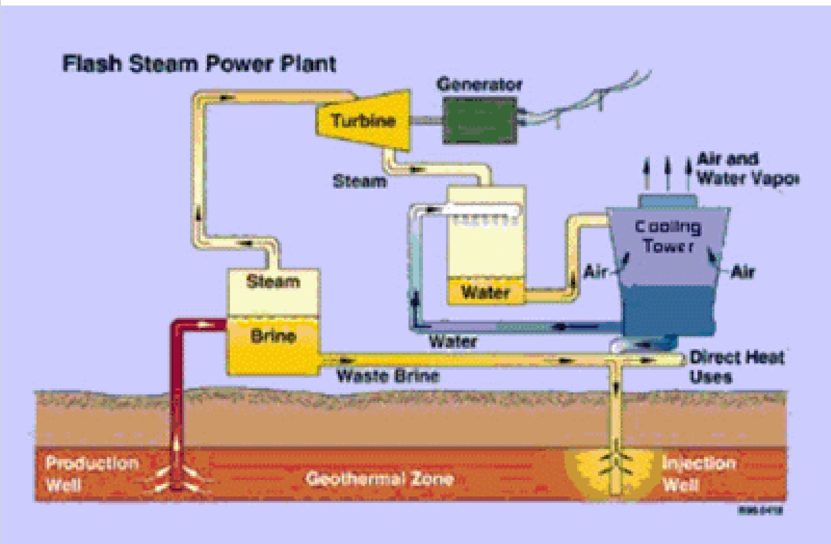
Power plants using dry steam systems were the first type of geothermal power generation plants built. They use the steam from the geothermal reservoir as it comes from wells and route it directly through turbine/generator units to produce electricity. An example of dry steam generation operation is at the Geysers in northern California

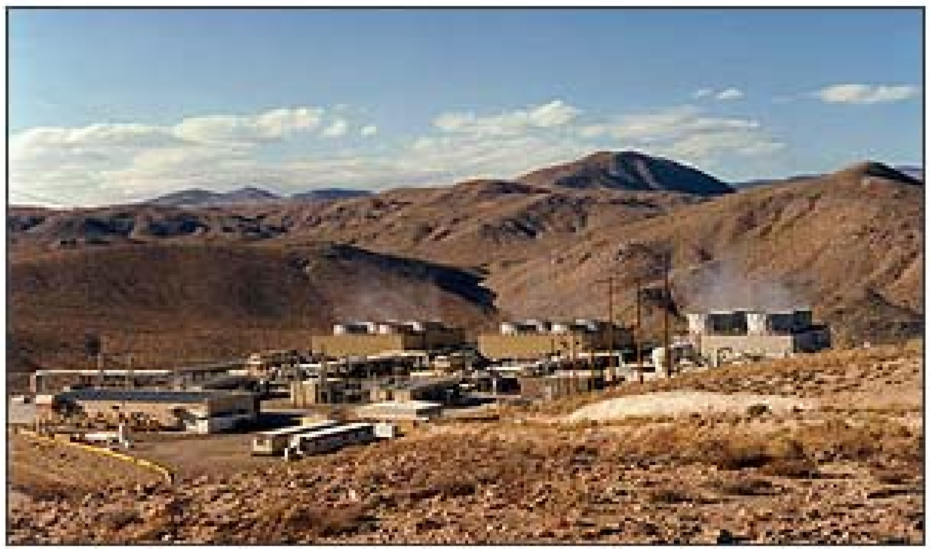


Geothermal plants – how they work

Dry Steam, **Flashed Steam Cycle**, Binary, Combined Cycle

Flash steam plants are the most common type of geothermal power generation plants in operation today. They use water at temperatures greater than 360 °F (182 °C) that is pumped under high pressure to the generation equipment at the surface. Upon reaching the generation equipment, the pressure is suddenly reduced, allowing some of the hot water to convert or "flash" into steam. This steam is then used to power the turbine/generator units to produce electricity. The remaining hot water not flashed into steam, and the water condensed from the steam is generally pumped back into the reservoir. An example of an area using the flash steam operation is the Navy I flash geothermal at the Coso geothermal field





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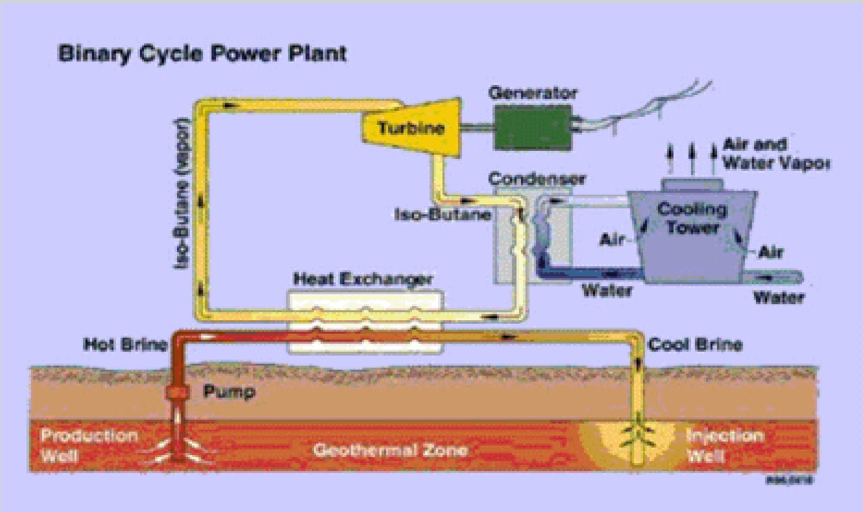
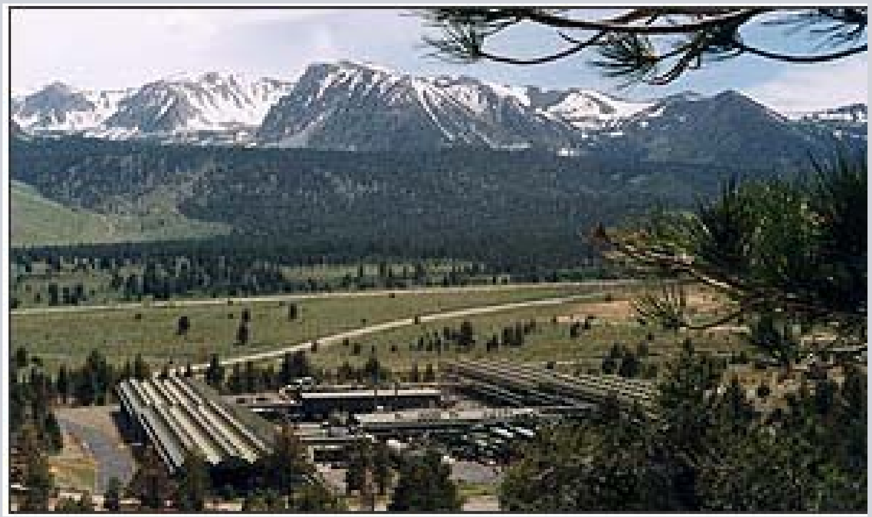
Geothermal plants – how they work

Dry Steam, Flash, Binary Organic Rankin Cycle

Binary cycle geothermal power generation plants differ from Dry Steam and Flash Steam systems in that the water or steam from the geothermal reservoir never comes in contact with the turbine/generator units. In the Binary Systems, the water from the geothermal reservoir is used to heat another "working fluid" which is vaporized and used to turn the turbine/generator units. The geothermal water and the "working fluid" are each confined in separate circulating systems or "closed loops" and never come in contact with each other. The advantage of the Binary Cycle plant is that they can operate with lower temperature waters (225 °F -360 °F) (107 °C -182 °C), by using working fluids that have an even lower boiling point than water. They also produce no air emissions. An example of an area using a Binary Cycle power generation system is the Mammoth Pacific binary geothermal power plants at Casa Diablo Geothermal field





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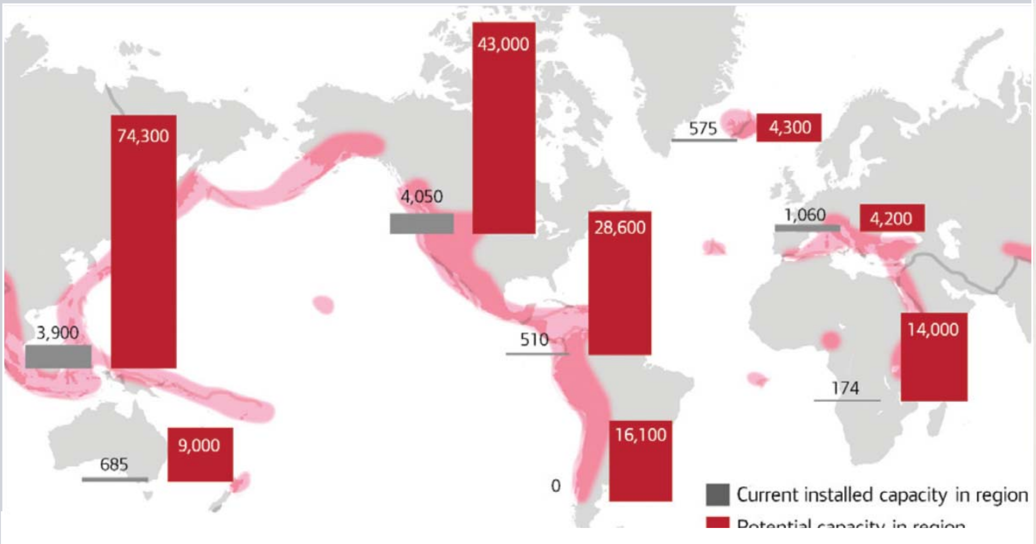
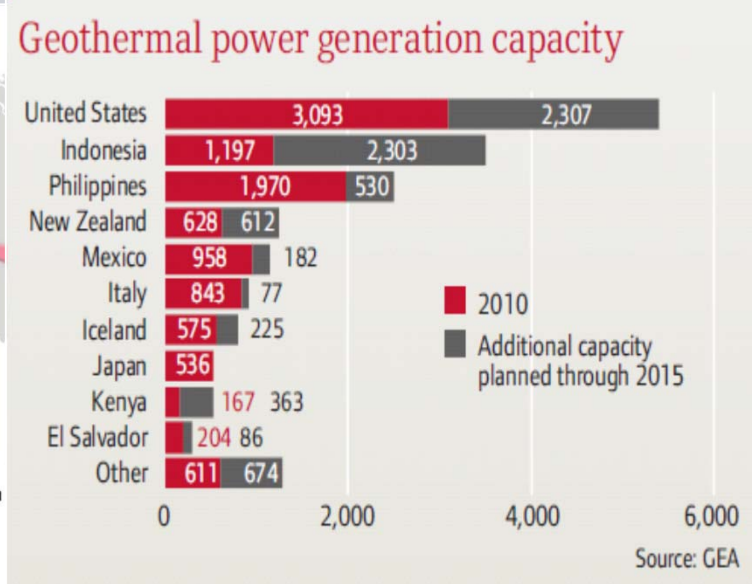
Global Geothermal Market

Installed geothermal capacity & potential in MW



Source: Islandsbanki

Existing & planned Capacity



- Ring of fire = hottest known geothermal regions
- Current installed capacity in region
- Potential capacity in region

Current Global Capacity ~ 10 GW
Potential Capacity approaches 200 GW

The countries with the largest installed geothermal power generation capacity are the United States, Indonesia, and the Philippines

Geothermal Energy
Comparison with other Renewables

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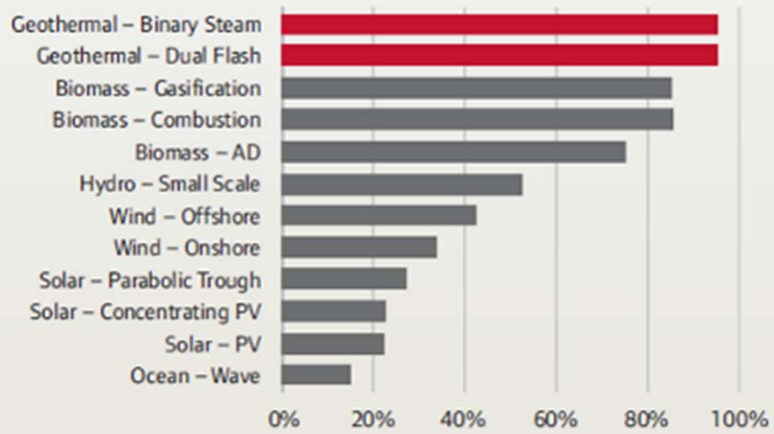
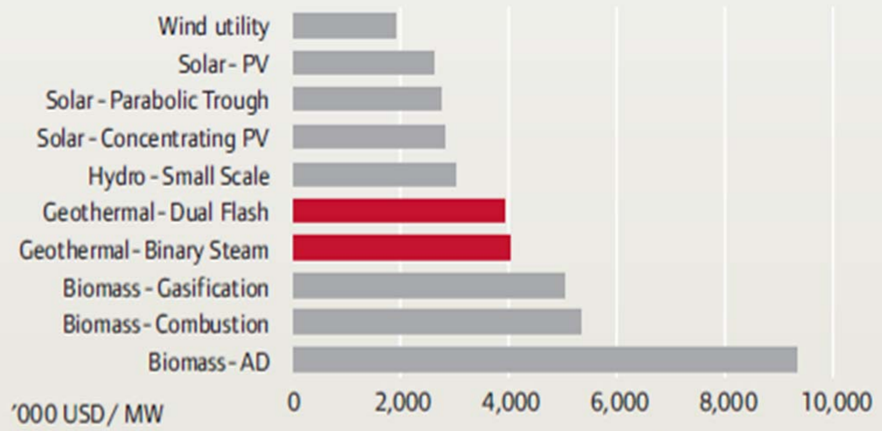
Capacity factors of selected renewables



Net capacity as a percentage of up time

Source: Íslandsbanki estimates

Installed cost of electricity generation



Sources: Íslandsbanki research

Geothermal energy can be used around the clock, with average capacity factors of around 90-95%

Capital cost for geothermal systems is about $4 million per MW installed capacity

High availability of base load power

Cost-effective compared to other renewable energy sources

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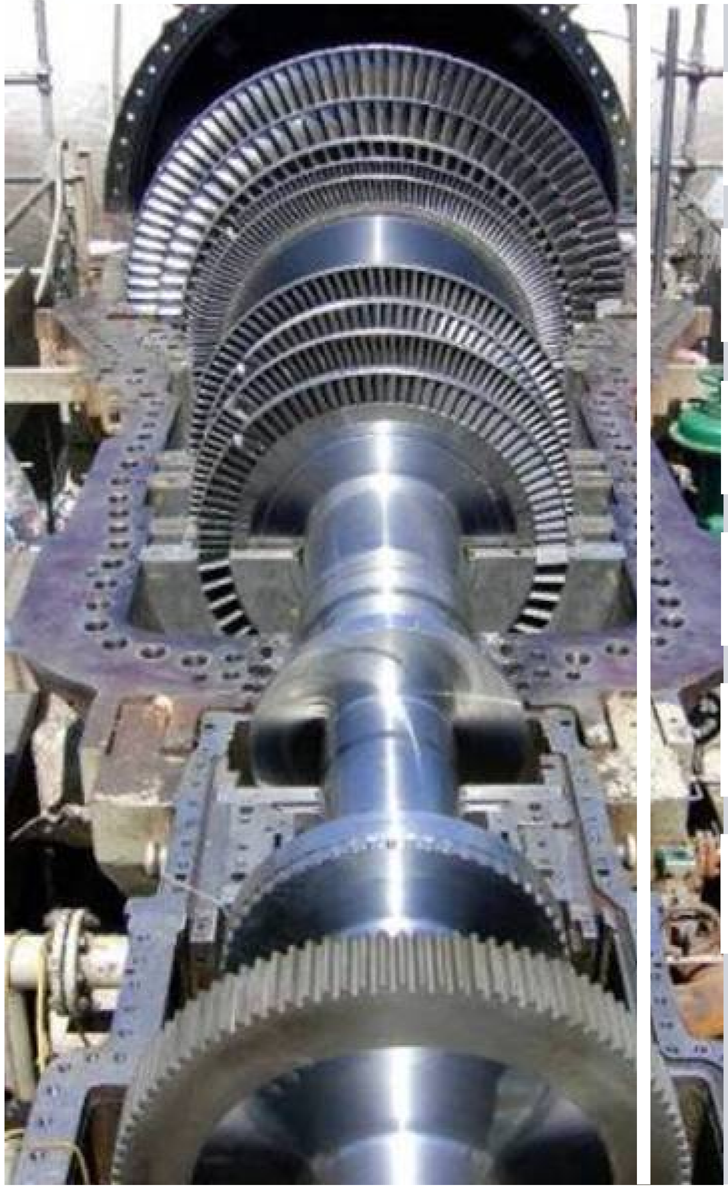

Siemens Vision for Renewables

Geothermal Energy – what is it?

Austral-Andina Regional Experience

Central & Mezo American Regional Experience

Geothermal Energy in Bolivia – Unique Challenges

Geothermal Energy in Bolivia – Unique Solutions

Argentina – Earth Heat Resources - Copahue

The Copahue project area is located in the western part of Neuquén Province.

Time Line:

- **1970s Geothermal exploration activities begin**
- **1986-1987 670kW binary demonstration plant – converted to road heating in 1997-1998**
- **March 2011 – Earth Heat Resources engaged Sinclair Knight Merz (SKM)**
- **April 2012 - SKM announces Phase I field studies complete**
- **Est. COD: 2015**

Copahue Village Circa 1937

Copahue project site today

Geothermal Development in Chile

- Early exploration began at Antofagasta in 1908.
- Formal exploration under UNDP & CORFO began in 1968 and ended in 1976 under Pinochet.
- In 2000, due to volatility in oil prices and gas deliveries, coupled with increasing electrical demand, resulted in the Chilean government passing "The Law of Geothermal Concessions" which continues to create interest.

Tatio Geysers

Punto 3

Liolaemus barbarae

Announced Project Austral-Andina Region

Argentina
Copahue
Los Desoblados
Tuzgle-Tocamar-Jujuy
Anetta

Chile
Cerro Pabello
Puchildiza
Curacautin/Tolhuaca
Mariposa
Apacheta
Colpitas
Juncalito
Pampa Lirima
Paniri
Polloquere
Tinguirrica
Tuyajto

Bolivia
Laguna Colorada

Columbia
Isagen

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El Salvador – Ahuachapan

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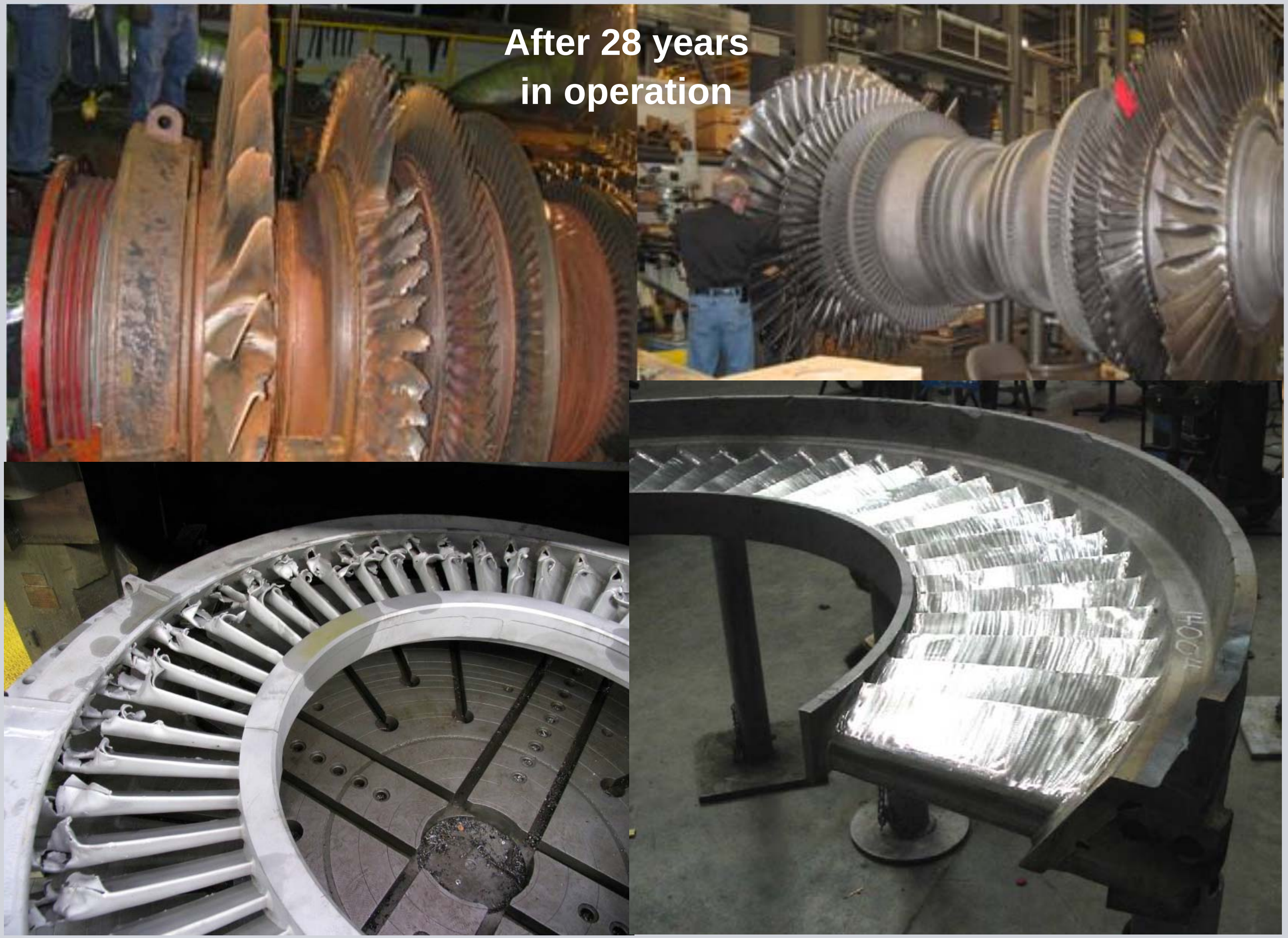
Courtesy:

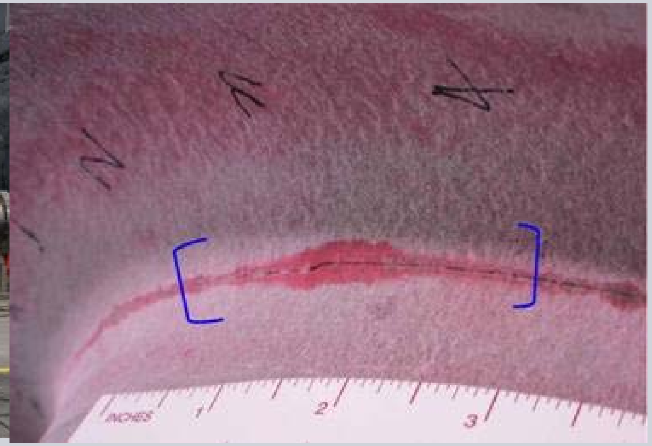
LaGeo S.A. de C.V.

El Salvador – Ahuachapan
Pay attention to initial design to avoid unnecessary repairs in future years



Ormat – Momotombo – Sophisticated Repair Required

- Frequent tectonic activity caused on-going T-G train misalignment.
- Resulting increased alternating stress cracked rotor – almost in half.
- Crack in shaft-wheel radius – propagated to within 1.5 cm of bore.
- Failure analysis consisted of Metallurgical Analysis, FEA and Site Alignment Survey.
- Conclusion: Failure occurred due to miss-alignment causing alternating stress & reduction in material endurance strength due to corrosion attack.
- Solution: Weld repair rotor, 12 Cr cladding of radius & realignment of turbine-generator.
- Repair could not be executed in Nicaragua.



Design plant so as to avoid engineered repairs

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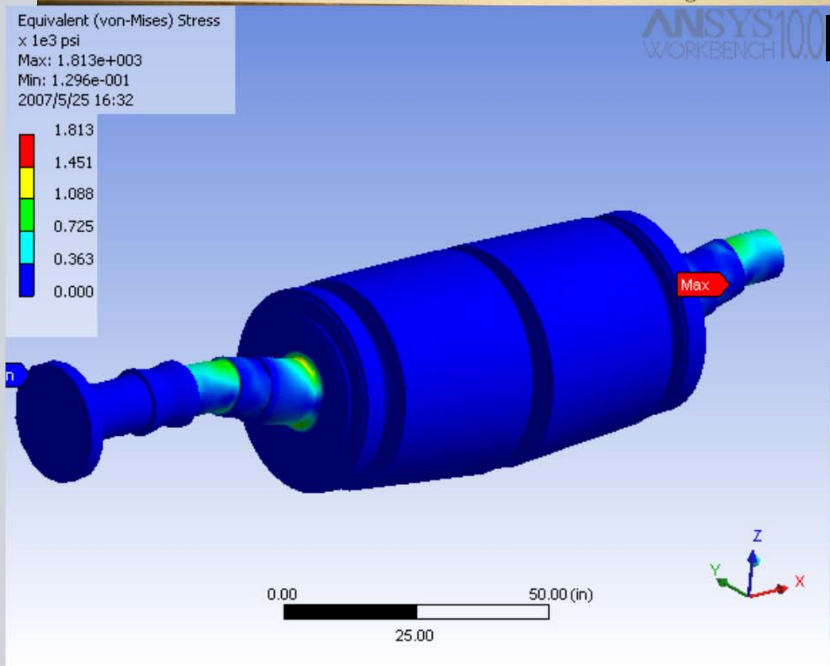

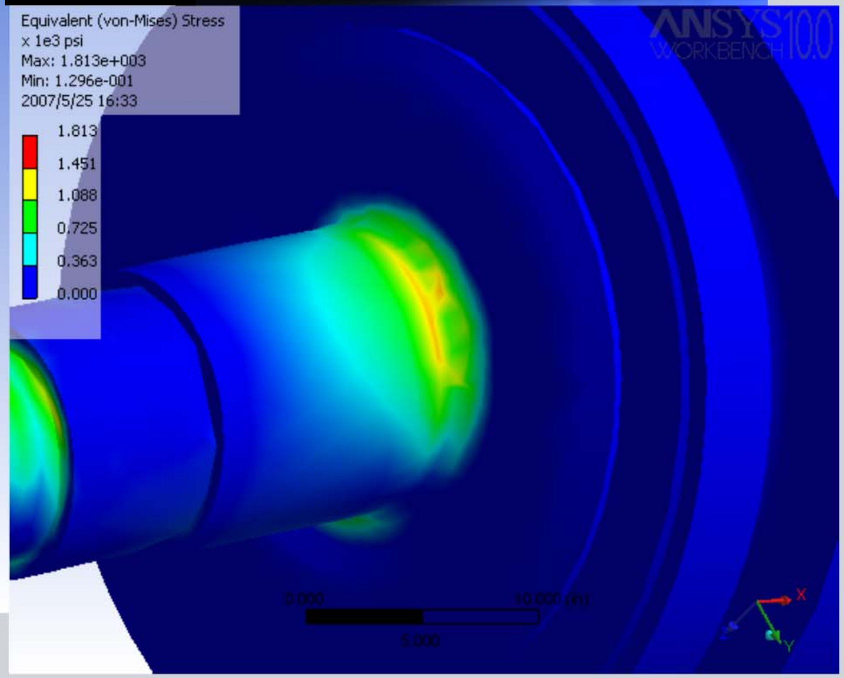

Such repairs require rotor transport to the US or Europe

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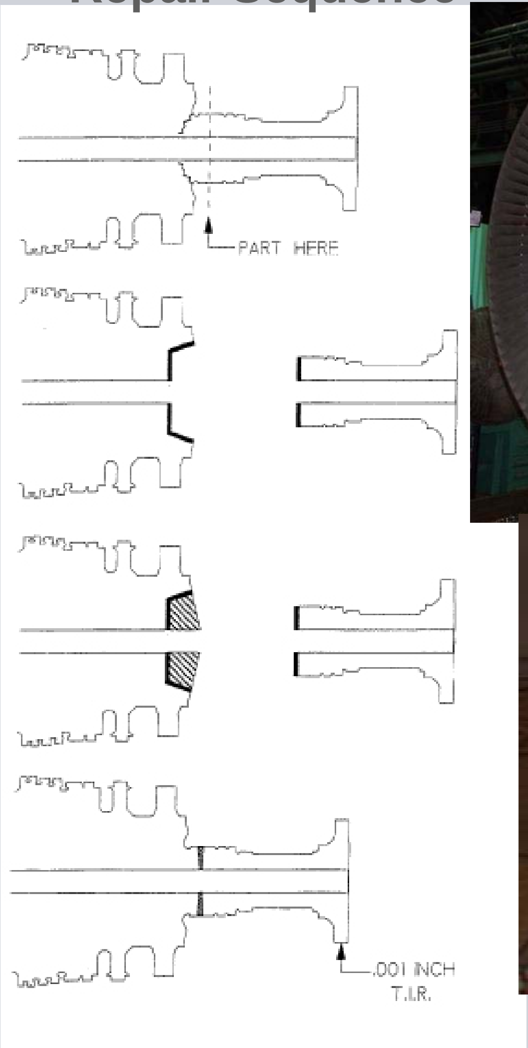
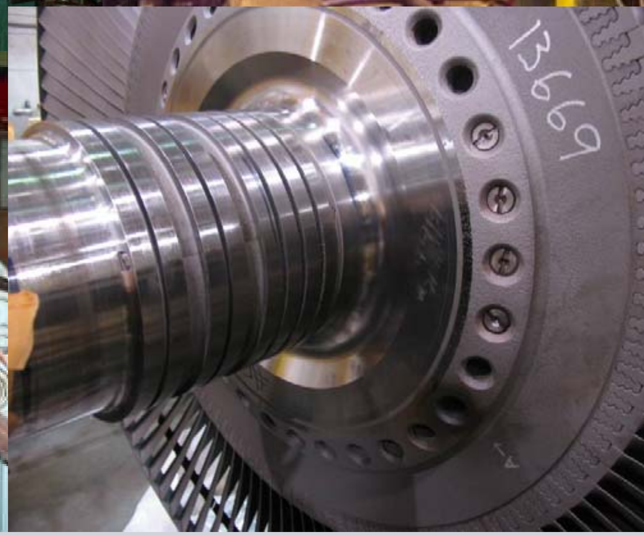
Repair Sequence





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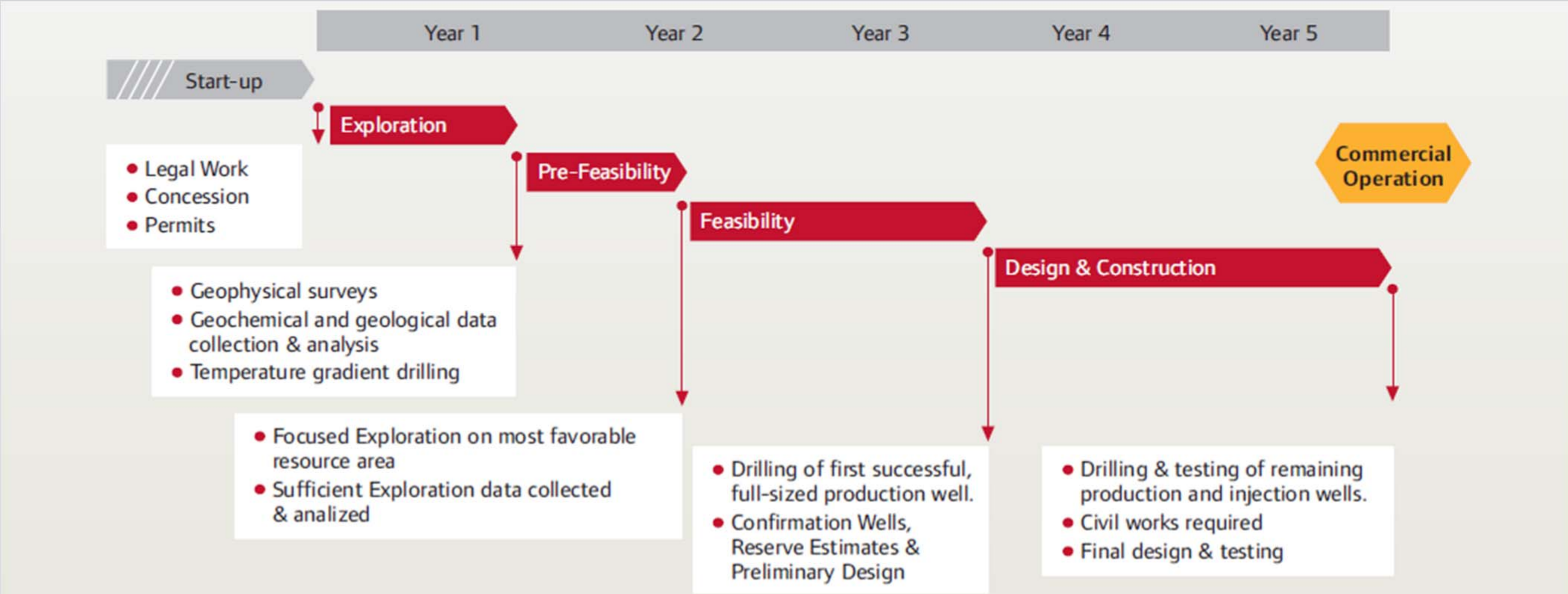
Geothermal Project Timeline

Phase 1
- Identifying site, secured rights to resource
- initial exploration drilling

Phase 2
- Drilling & confirming

Phase 3
- Securing PPA & final permits

Phase 4
- Under Construction



Source: Íslandsbanki

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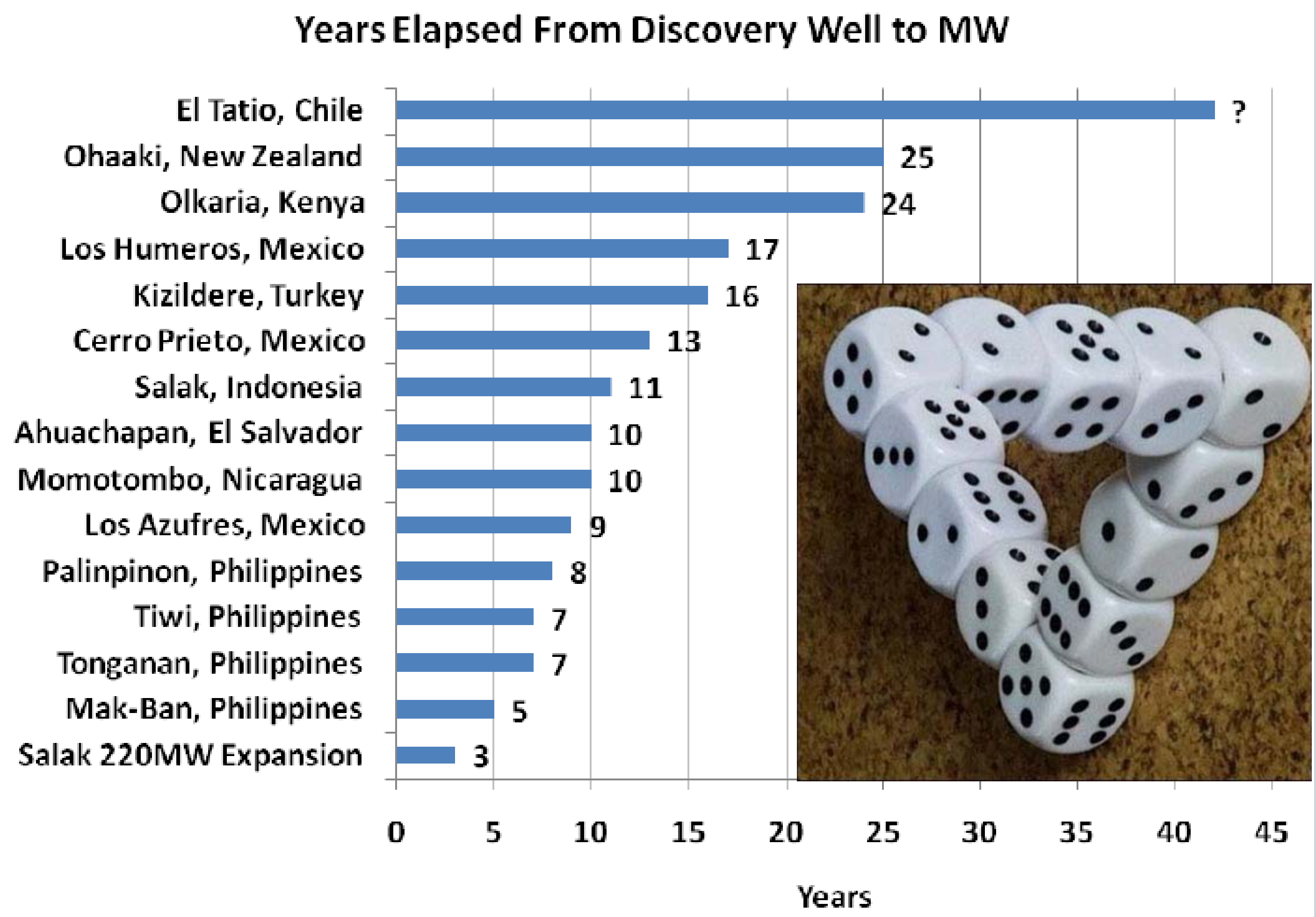
Geothermal Energy in Bolivia – Unique Challenges



Geothermal Energy in Bolivia – Unique Challenges

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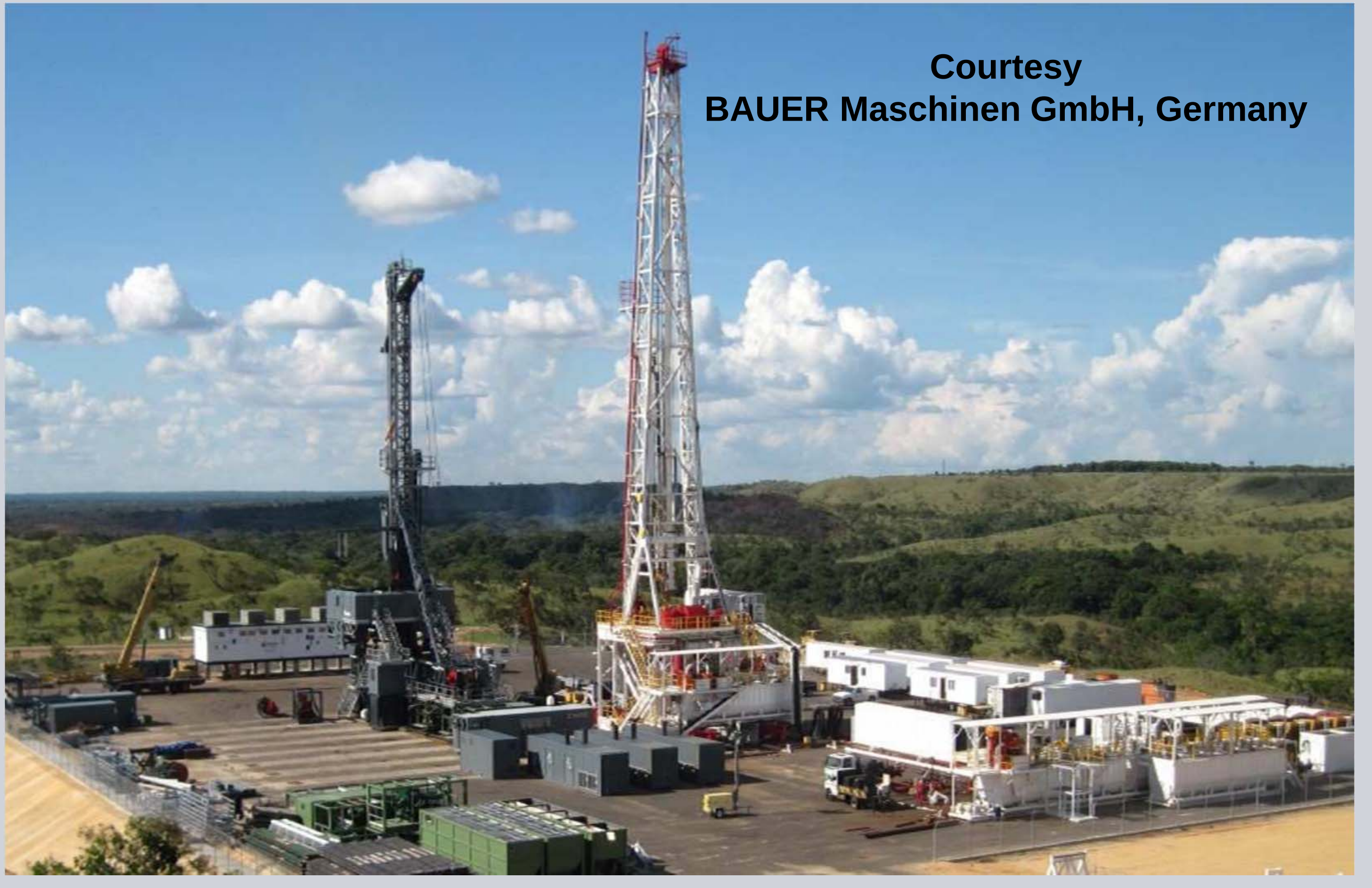
Challenges – Size & Location



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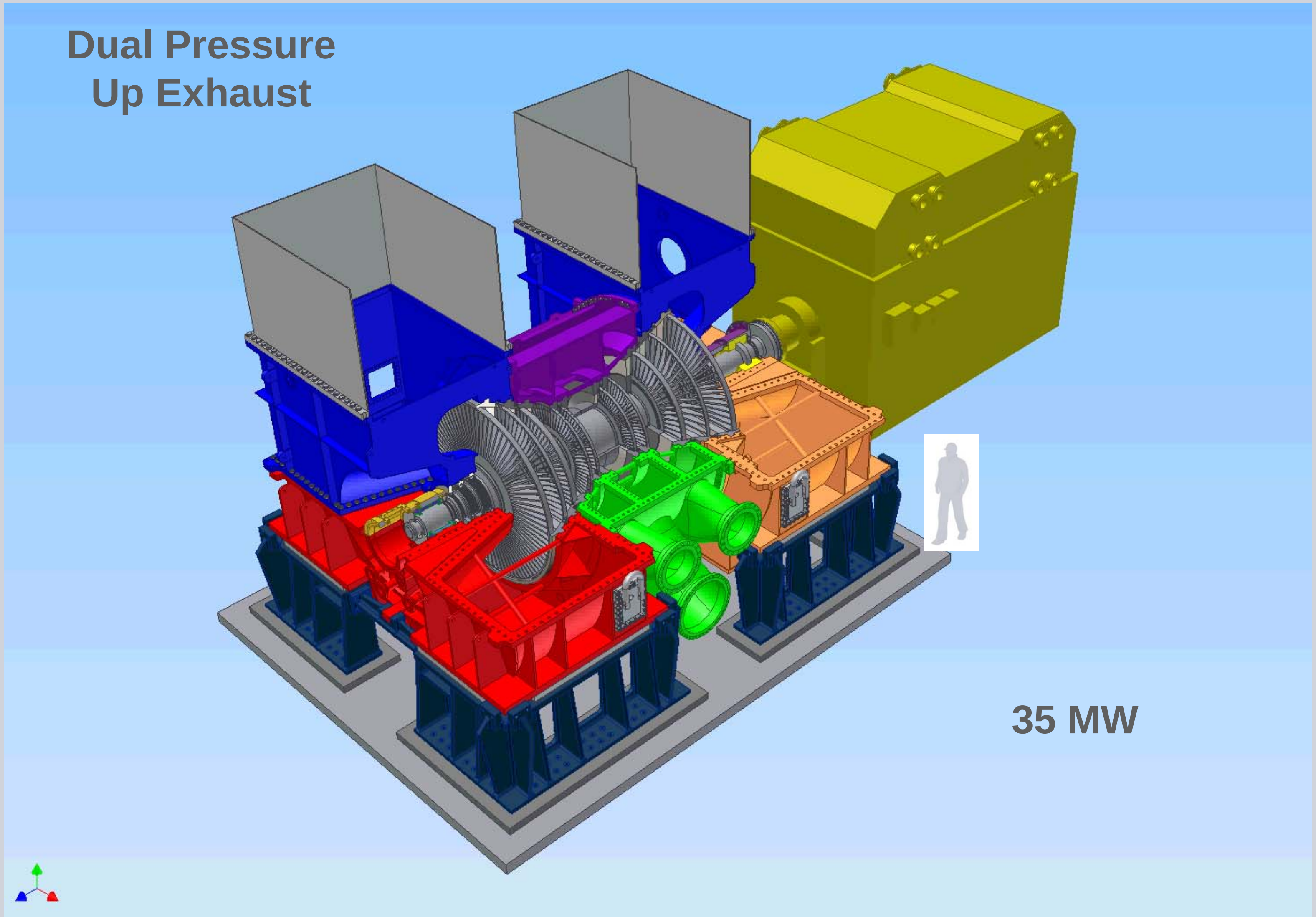
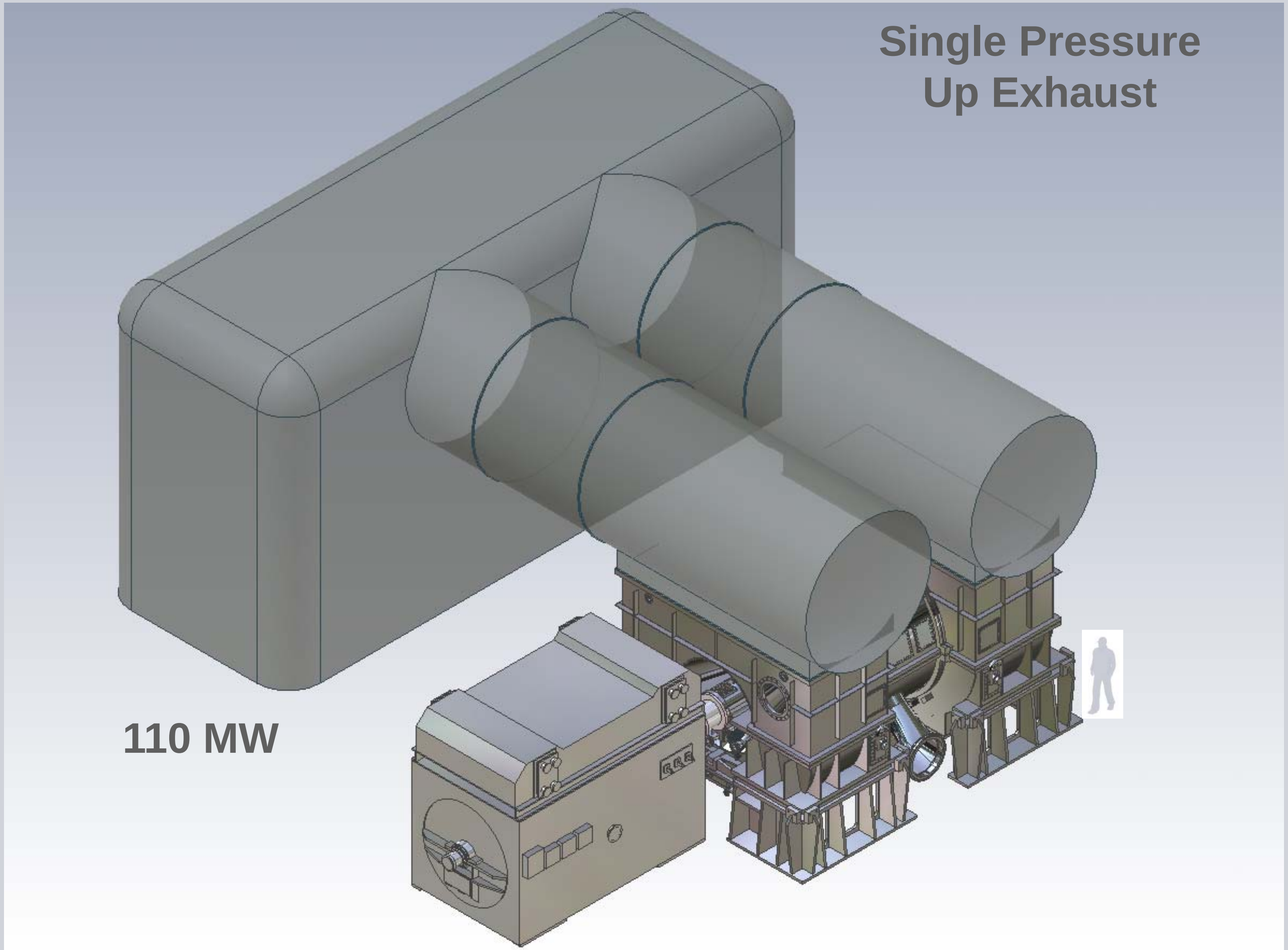
SST-500 GEO Dual Flash Steam Turbine



SST-500 GEO Single Flash Steam Turbine



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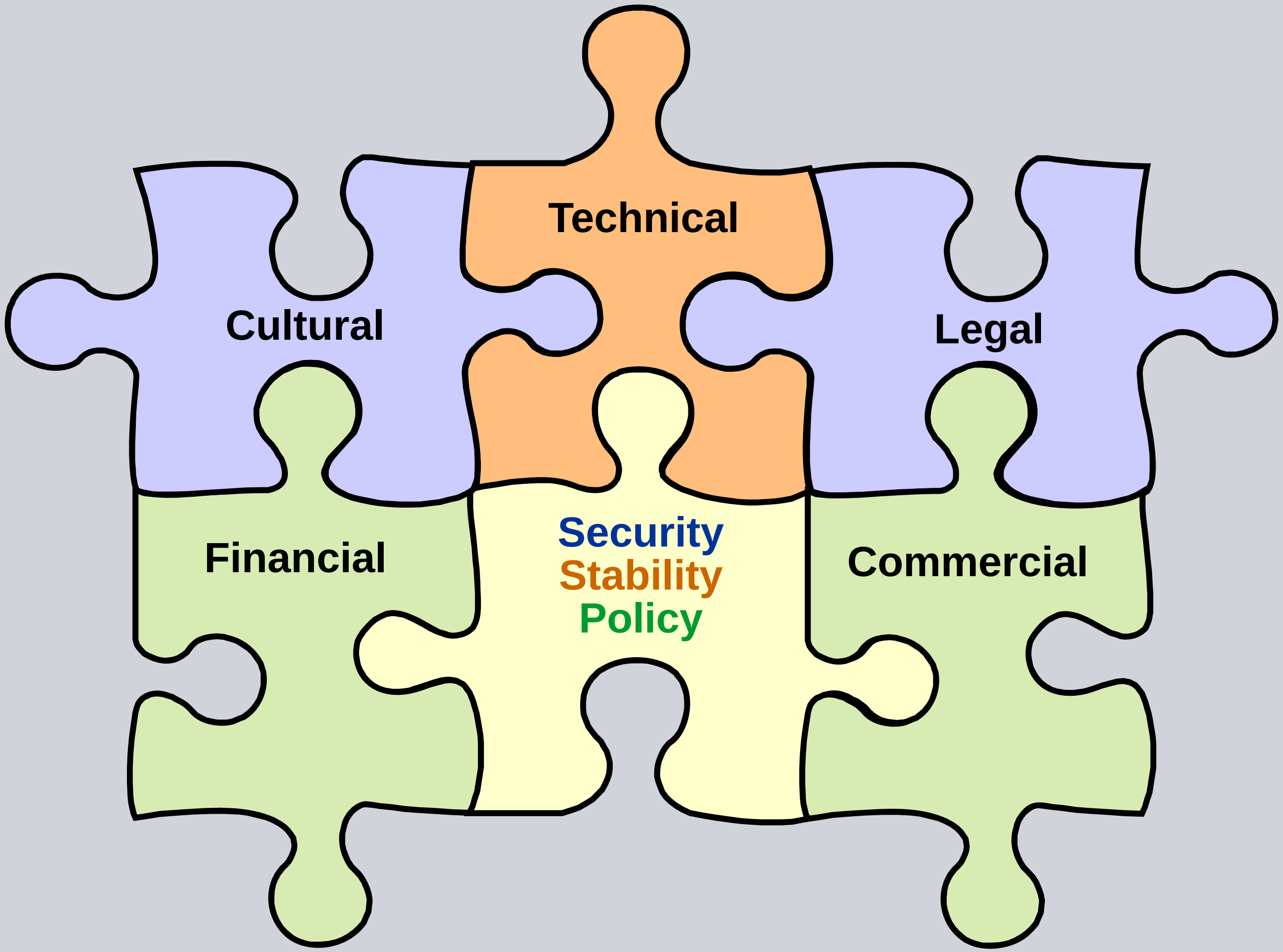
Key metrics for geothermal success



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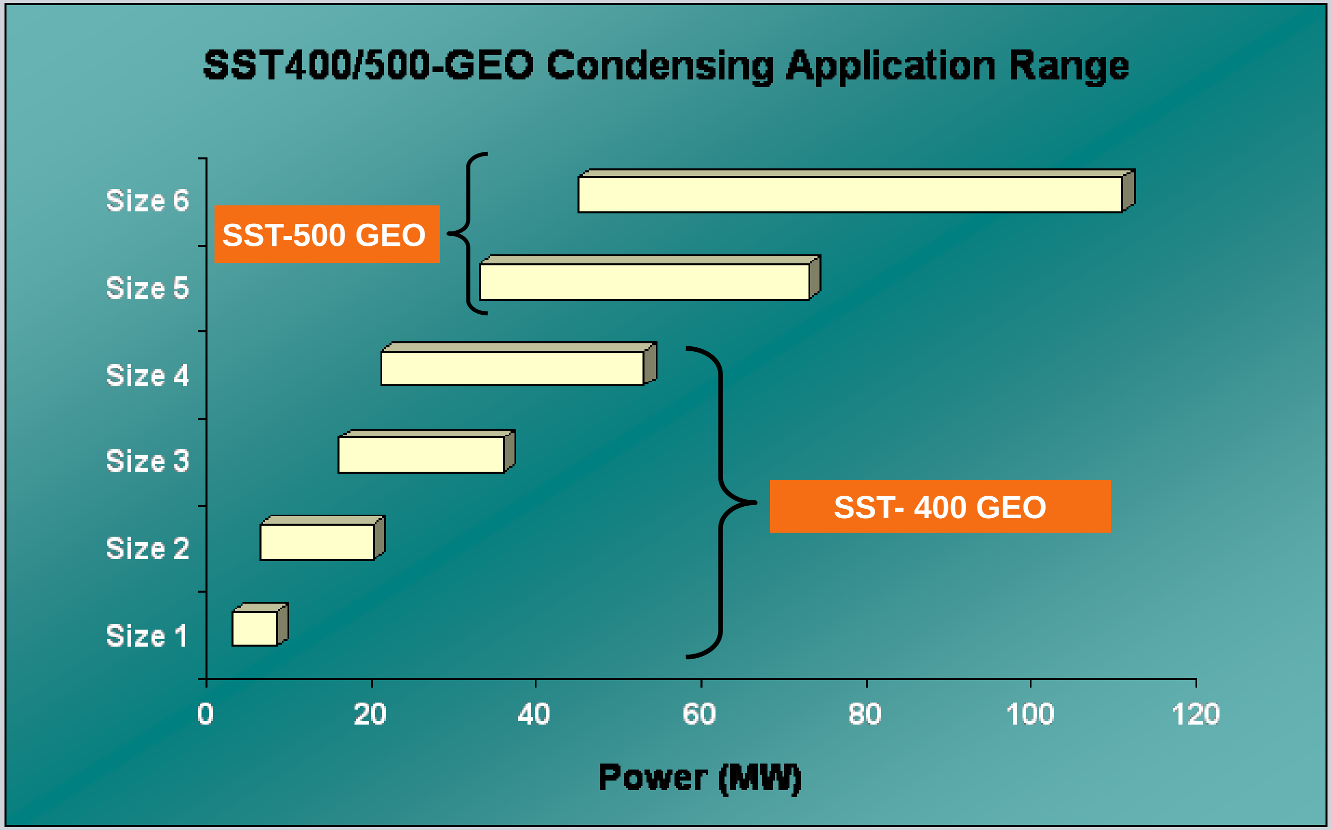
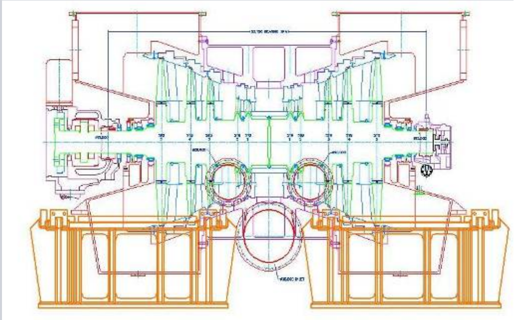
Geothermal Energy in Bolivia – Unique Solutions Leading to PPP

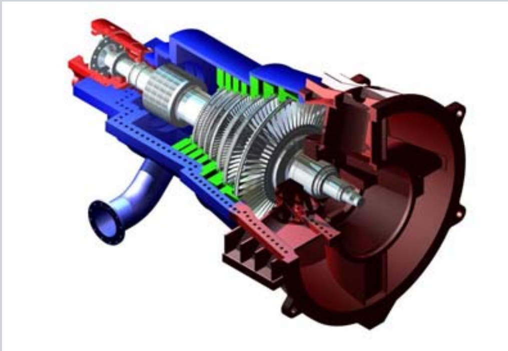
Structure	Financing	Construction	Operation	Ownership	Off-taker Payment
BOT/BOO	Private (20-30 yrs)	Private	Private	Private f/term of contract	Tariffs over contract term (20-30 yrs)
BT/BTO	Private (2-5 yrs)	Private	Off-taker (BT) Private (BTO)	Off-taker/ Government	Upfront or shortly after construction
BLT/BOLT	Private (10-12 yrs)	Private	Off-taker (BLT) Private (BOLT)	Private for term of lease; transfer to off-taker	Lease payments
JV/JS	Joint	Joint	Joint	Joint	Tariff over term of contract
EPC/Construction Contracts	Off-taker/ Government	Private	Off-taker/ Government	Off-taker/ Government	Not applicable

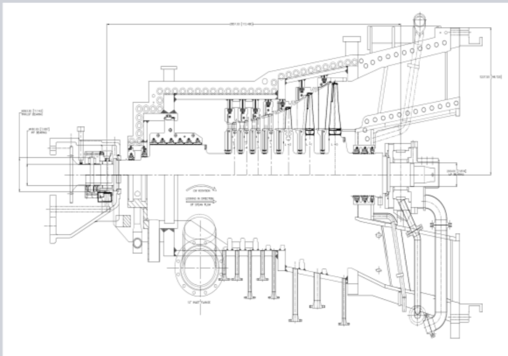
- **Best method to fully implement PPP? BOOT? Or other?**
- **How do we attract private finance?**
- **What incentives are fair, proper and sufficient ?**

Condensing Application Range



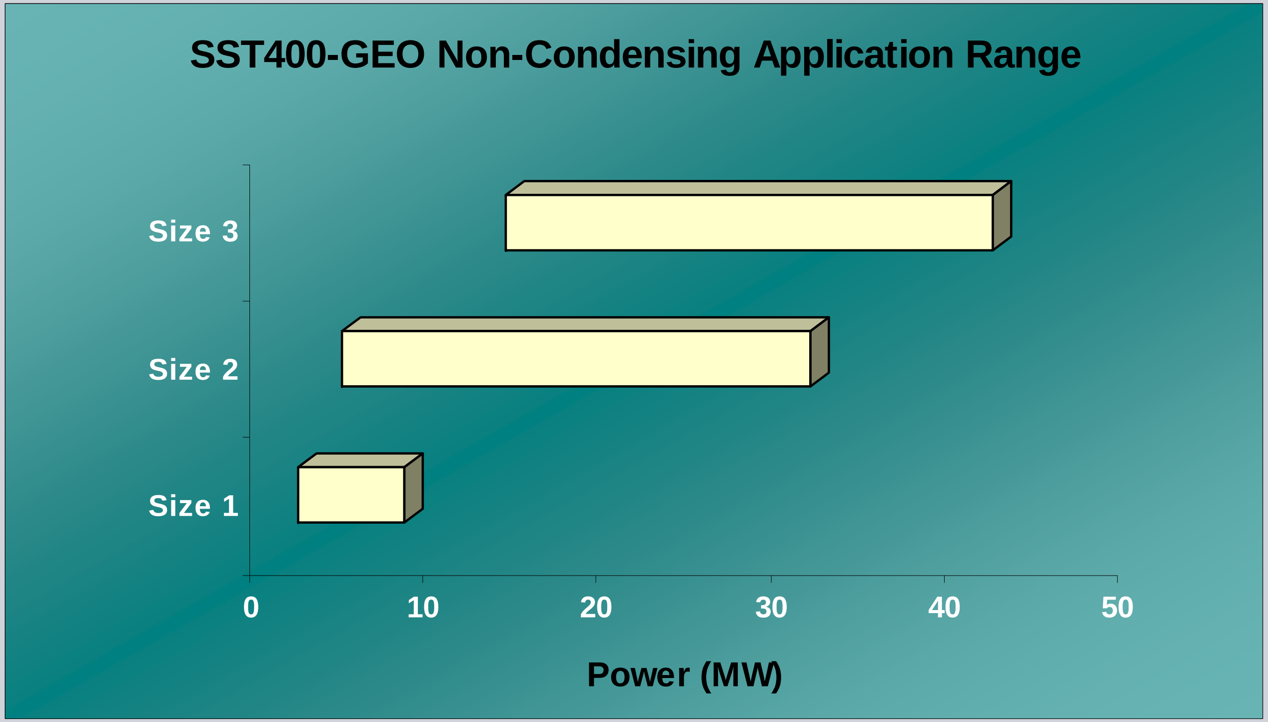


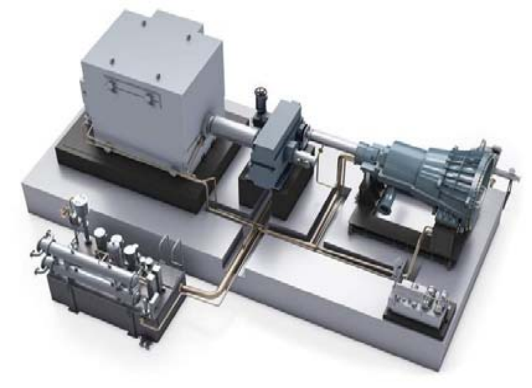


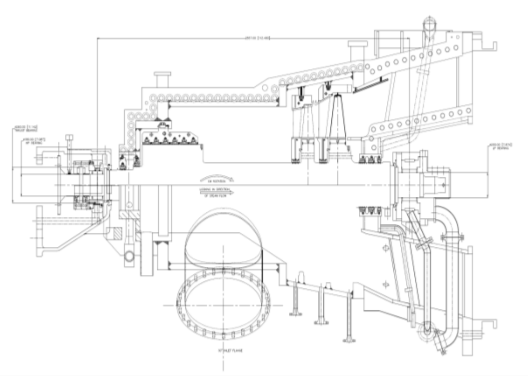


Proven geothermal impulse type steam path

Non-Condensing Application Range







Non-condensing turbines designed for geothermal combined cycle applications

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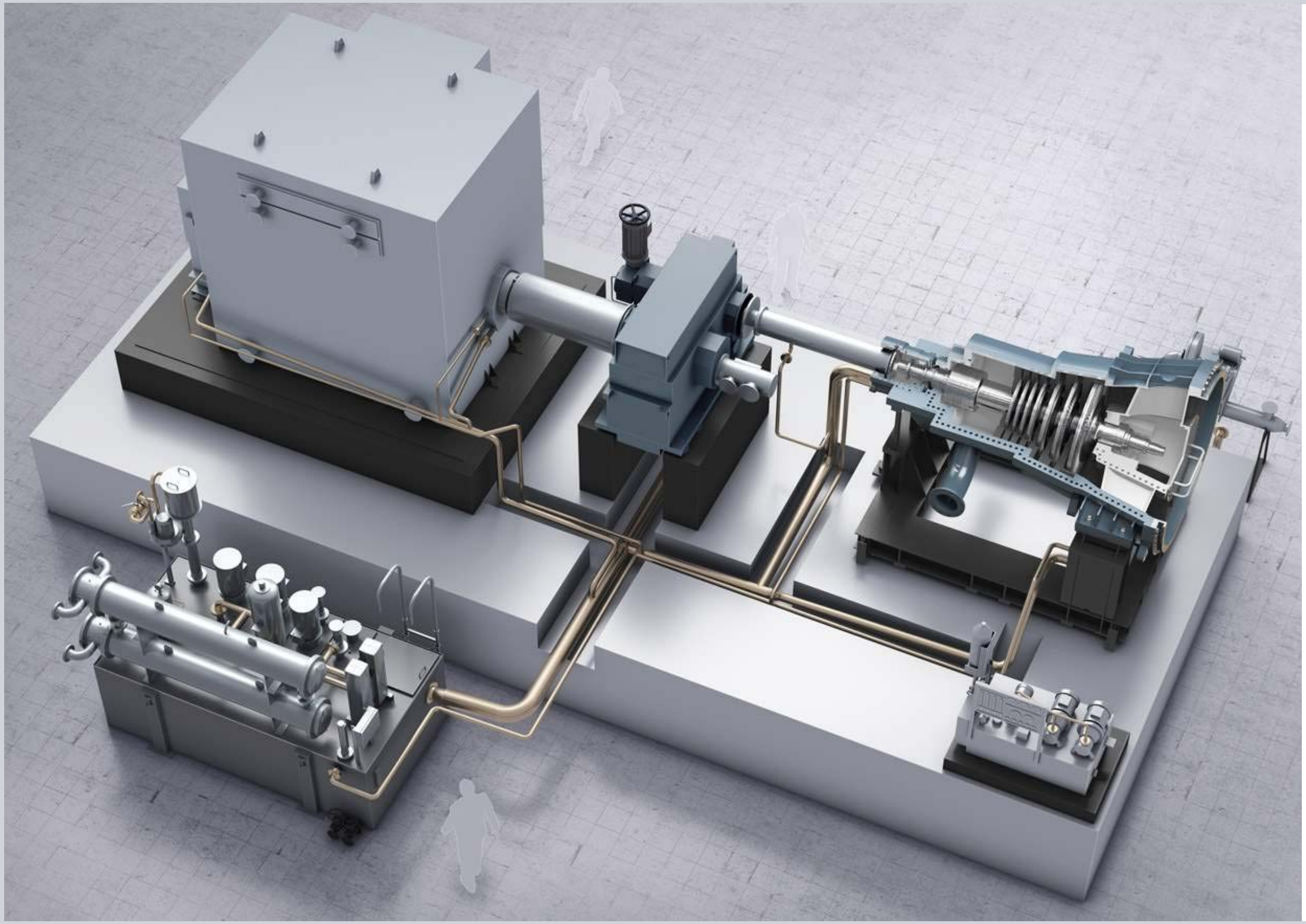
SST-400 GEO Turbogenerator



SST-400 GEO

Power output:
5 – 55 MW
(condensing)
5 – 60 MW
(non-condensing)

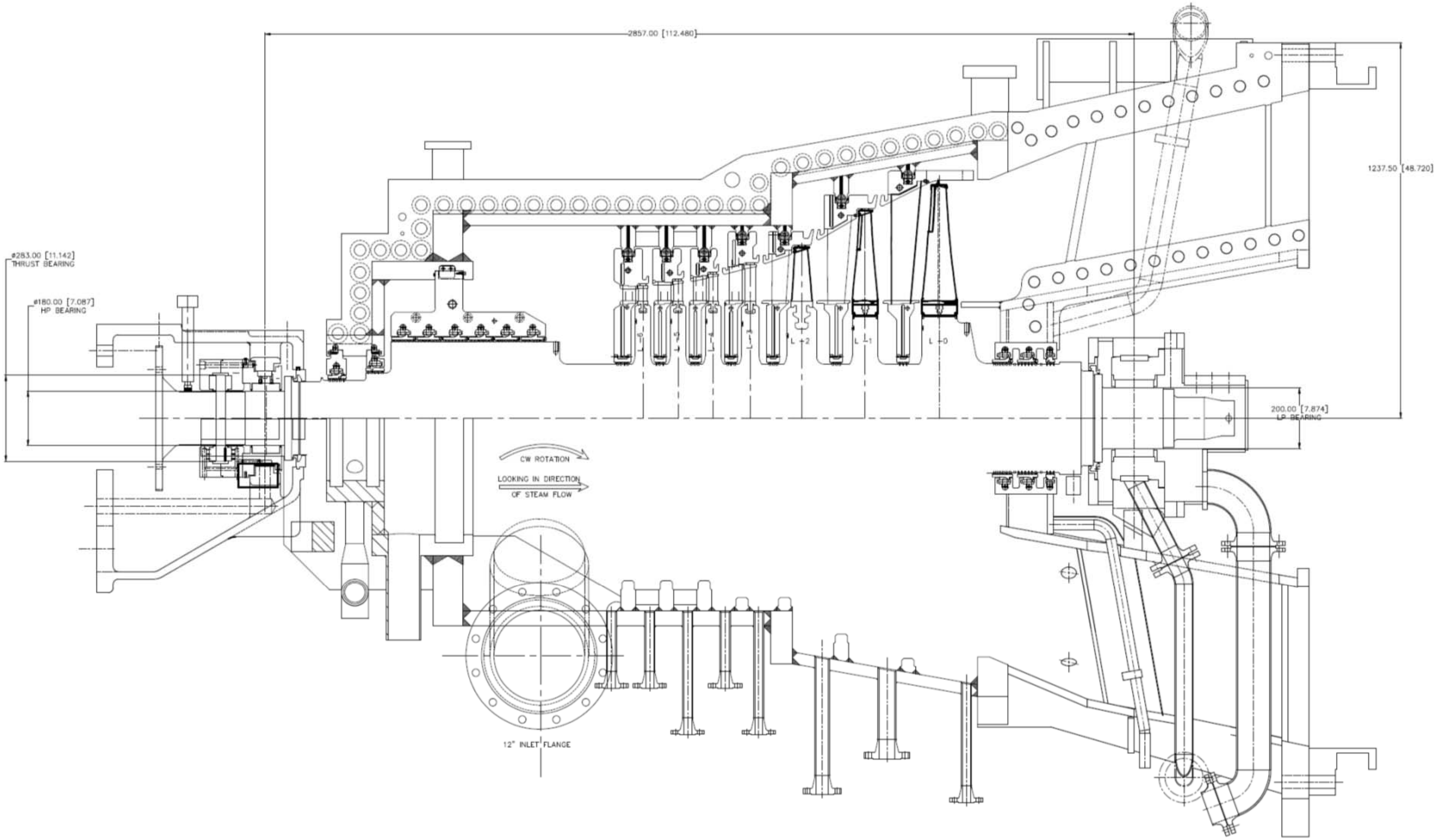
Frequency:
50 or 60 Hz

Speed:
max. 6000 rpm

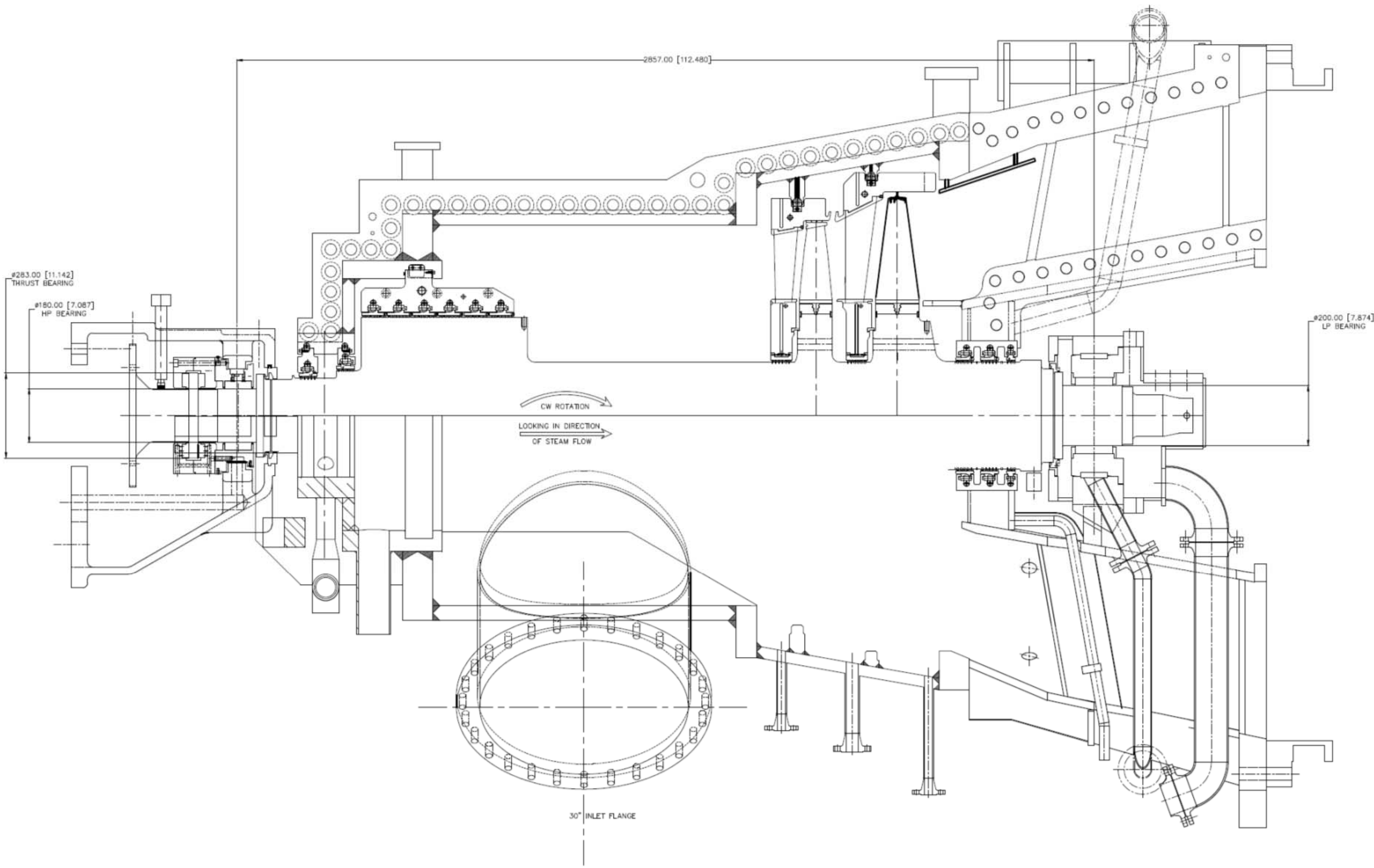
Live steam:
Up to 250°C (482°F)/ 12 bara

Exhaust steam:
Up to 0.4 bara
(condensing)
Up to 1.4 bara
(non-condensing)

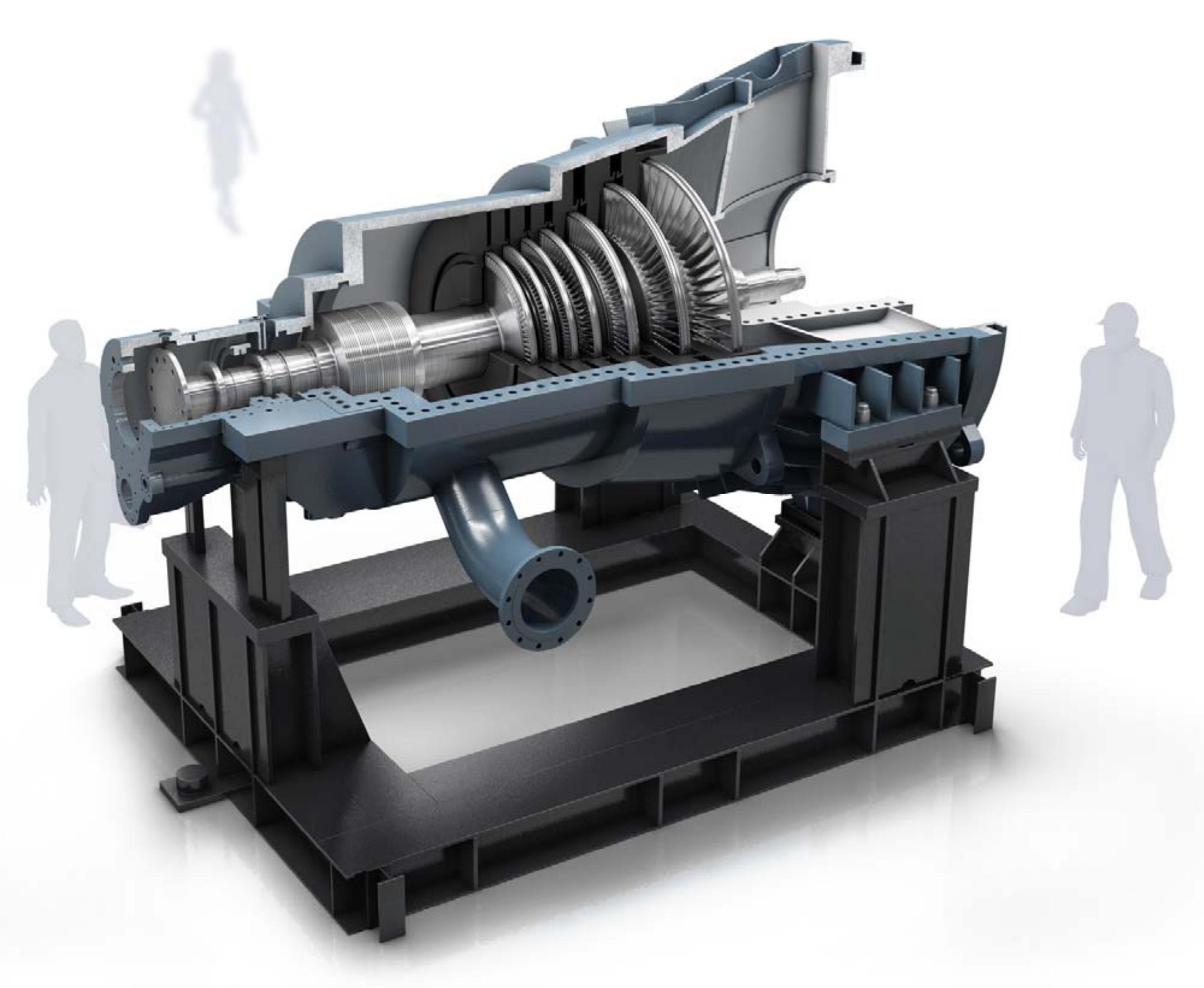
SST-400 GEO Condensing Application



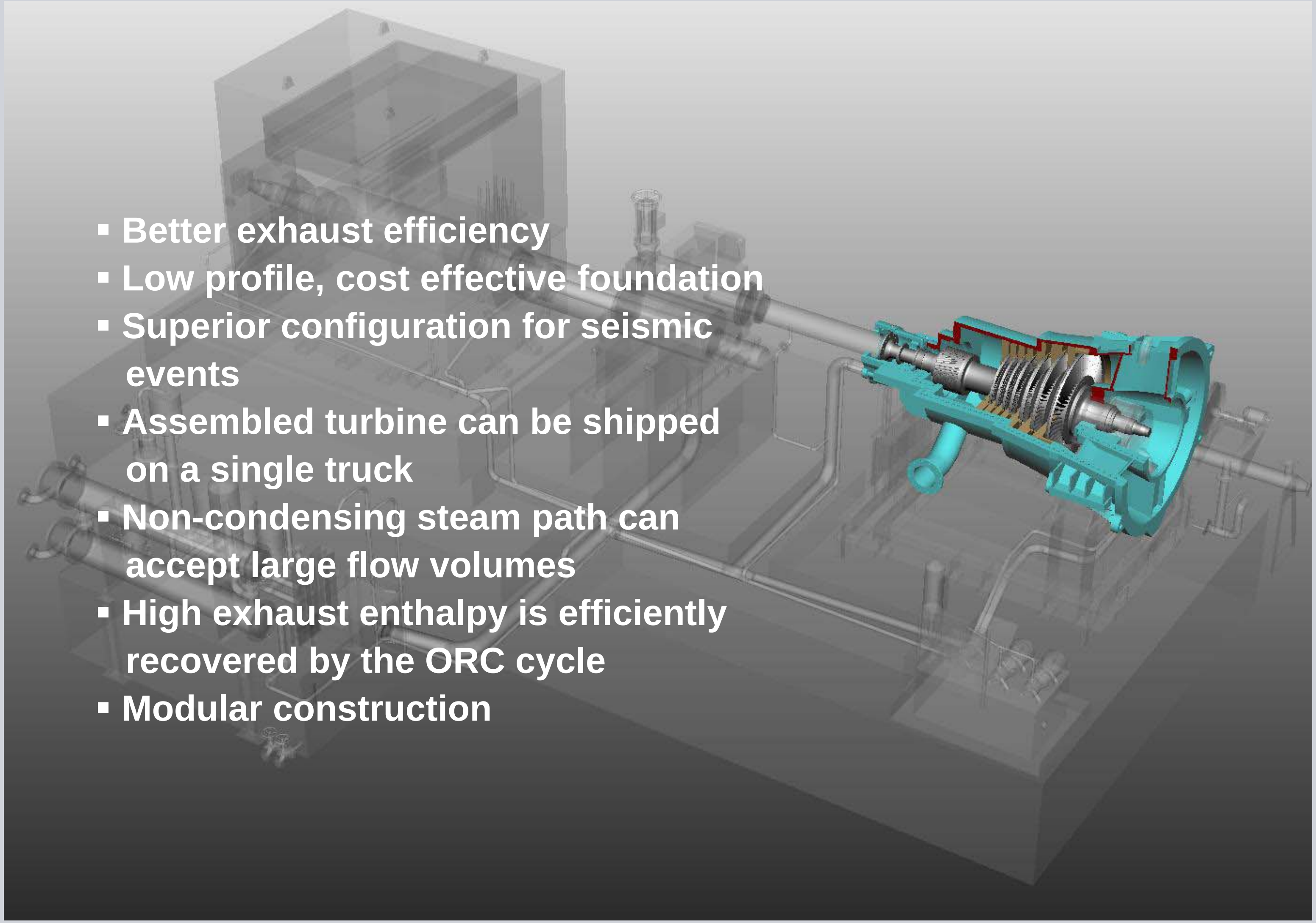
SST-400 GEO Non Condensing Application



Siemens Geothermal Combined Cycle Power Park

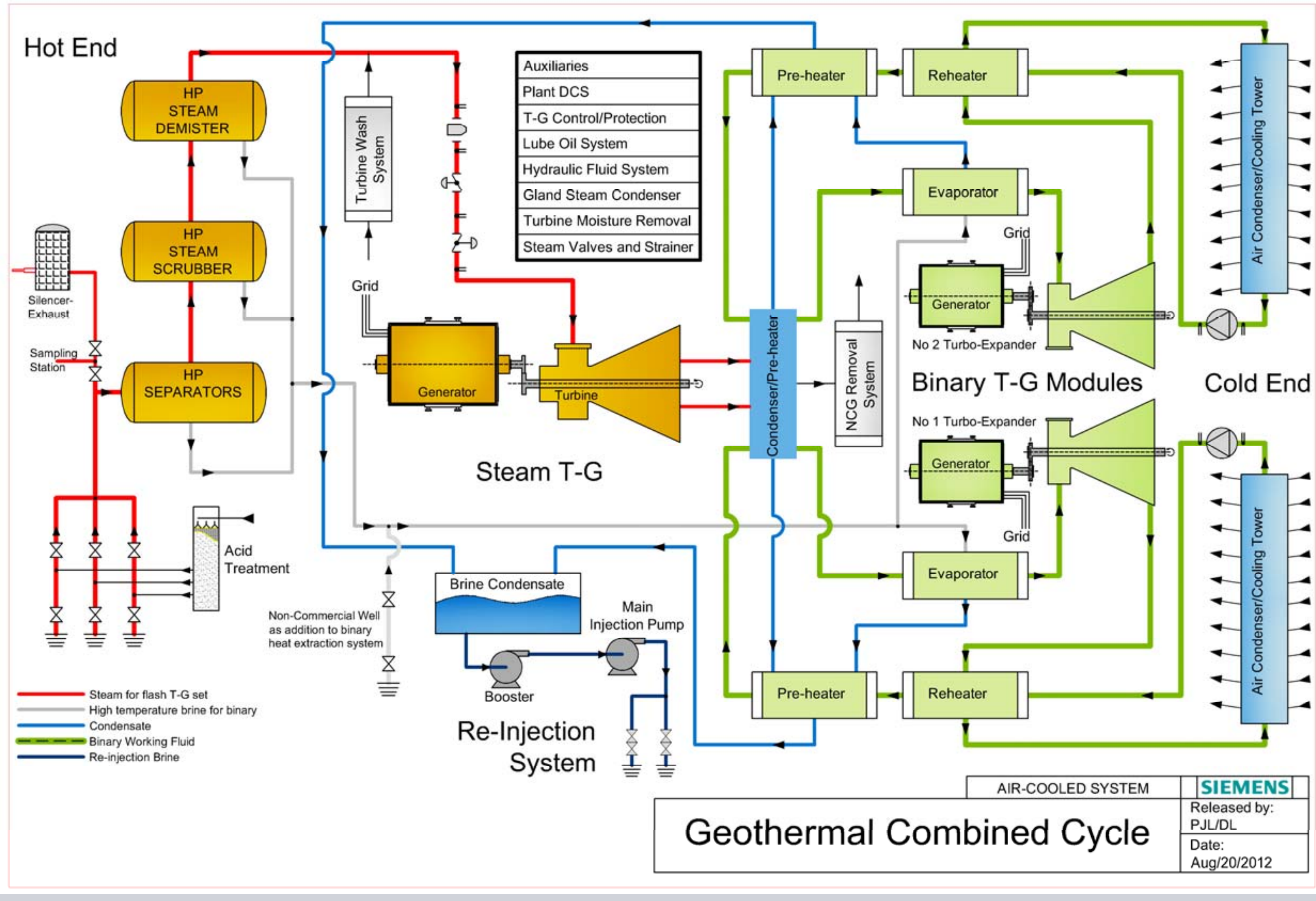


SST- 400 GEO Axial Exhaust - Configuration



- Better exhaust efficiency
- Low profile, cost effective foundation
- Superior configuration for seismic events
- Assembled turbine can be shipped on a single truck
- Non-condensing steam path can accept large flow volumes
- High exhaust enthalpy is efficiently recovered by the ORC cycle
- Modular construction

Geothermal Combined Cycle Process



Ormat's Mokai Geothermal Combined Cycle Plant

Siemens Geothermal Combined Cycle Power Park - Advantages

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- **Improved, sustainable resource utilization – at least 15% more efficient than a simple cycle flash plant**
- **100% brine & NCG re-injection**
- **Low profile, cost effective foundations for the entire plant – both cycles**
- **Superior configuration for seismic events**
- **All components can be shipped to site fully assembled**
- **Modular construction for the entire plant**
- **Zero atmospheric emissions**
- **Sub-optimal wells can be used and zero liquid effluents**

Siemens' "Net Zero" Geothermal Combined Cycle Energy Park

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Do you have any questions?

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