

## Sustainability analysis of the Berlin Geothermal Field. El Salvador

Manuel Monterrosa  
[memonterrosa@lageo.com.sv](mailto:memonterrosa@lageo.com.sv)

5 October de 2012

### Outline

1. Sustainability protocol (in progress)
  1. Level of energy  $E_o$
  2. Performance indicators
2. The Berlin field, main operational and resource aspects
3. Reservoir modelling used in sustainability analysis
4. Estimation of  $E_o$
5. Estimation of some performance indicators
  1. Productive Lifetime
  2. Recovery time
6. Conclusions

### Sustainability protocol for geothermal utilization

- The protocol is based on the definition of the Working group of Iceland (Axelsson) and the Bjarnadottir Msc thesis «Sustainable evaluation of geothermal system in Iceland- Indicators for sustainable production».
- The first task was to assess the level of sustainable energy extraction  $E_o$  (by volumetric stored heat method) for at least 50 years
- To complete  $E_o$ , indicators for sustainable production must be defined

### Performance indicators

1. Utilization efficiency using exergy analysis
2. Productive lifetime using numerical modeling
3. Primary energy efficiency using power plant and field data relationship
4. Recovery time using numerical modeling
5. Change in dissolved chemicals by statistics and modeling
6. Ground subsidence using monitoring of ground level.
7. Power plant performance
  1. Load and capacity factors
  2. Availability factor
  3. Auxiliary load factor
  4. Vacuum pressure at condenser
  5. Non condensable gases rate

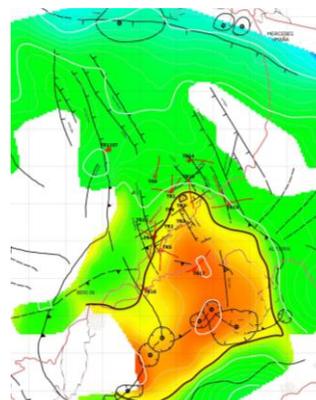


#### Wells location at the Berlin Field

Wells drilled:	38
Wells in operation:	34
Producers wells:	14
Injection wells:	20

Current Installed capacity  
**109.2 MW**

2x28.6 MW condensing type  
 1x44.0 MW condensing type  
 1x9.2 MW binary unit



#### Conceptual model highlight

The hot recharge area is believed to be located at the southern part of the steam field.

The permeability is following the graven SE-NW trend.

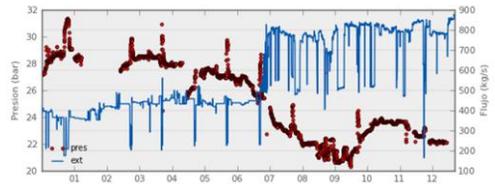
The reservoir temperature was 300 °C and reservoir pressure 110 bar at -1000 masl prior to exploitation.

Discharge enthalpy 1300 kJ/kg and average steam flow rate 8-10 kg/s at 9 barg

The reservoir formation is andesitic rock fractured by tectonics



Production history of the Berlin field

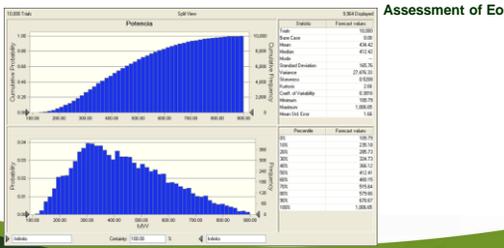
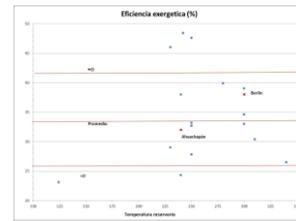


Parámetro de entrada	Símbolo	Unidades	Distribución	Resultado Módulo	Resultado Algoritmo	Posición
Permeabilidad	$\phi$	%	Triangular	20	15	3
Área del reactor	A	m <sup>2</sup>	Triangular	31.9	24.2	45
Espesor	H	m	Triangular	2100	2000	1000
Permeabilidad	$\mu$	kg/m <sup>3</sup>	Constante	2000		
Capacidad calorífica roca	Cr	MJ/kg°C	Constante	0.85		
Temperatura ambiente	Ta	°C	Constante	200	200	800
Temperatura referencia	Tref	°C	Constante	30	30	
Condición agua a condición de saturación	W	kg/m <sup>3</sup>	Constante	800		
Condición agua a condición de saturación	Wref	kg/m <sup>3</sup>	Triangular	1200	1200	1200
Condición a temperatura referencia a saturación	Ws	kg/m <sup>3</sup>	Constante	187.7		
Factor de recuperación	Rf	%	Constante	20		
Factor de conversión	W	%	Constante	15		
Factor de conversión	T	%	Constante	30		
Factor de conversión	MT	%	Constante	30		

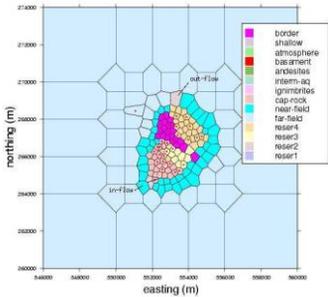
LaGeo

Exergy efficiency in selected geothermal power plants around the world

LaGeo

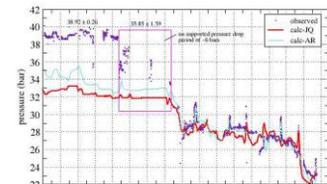


Numerical modeling grid for TOUGH2

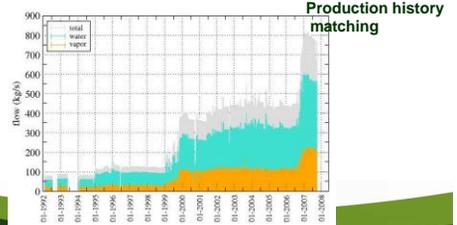


- Model description
- 14x14x3.5 km
  - 12 layers
  - 190 elements/layer
  - 14 types of rocks
  - Natural state matching
  - Production history matching

LaGeo

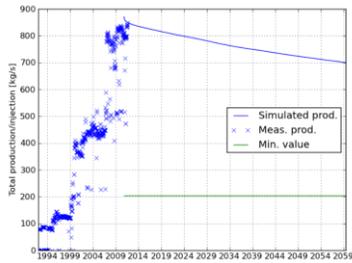


LaGeo



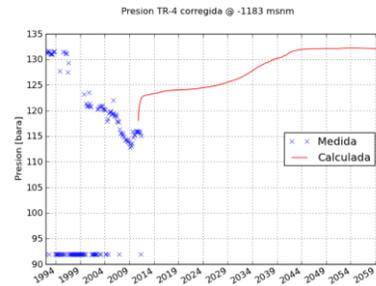
## Productive lifetime

LaGeo



## Recovery time

LaGeo



## Conclusions

LaGeo

1. The Berlin geothermal field is being in commercial operation for at least 20 years, during this period no evidence of irreversible conditions has been observed to the whole productive field. Spite of LaGeo is focused to develop a more complete sustainable utilization to guarantee a stable condition for at least 50 years of operation.
2. The preliminary results indicate it is possible to do an analysis on the sustainability for the Berlin Geothermal field which suggests the utilization of the resource is doing in a sustainable way.
3. The numerical modeling is being utilized as powerful tools to estimate the sustainable operation indicators