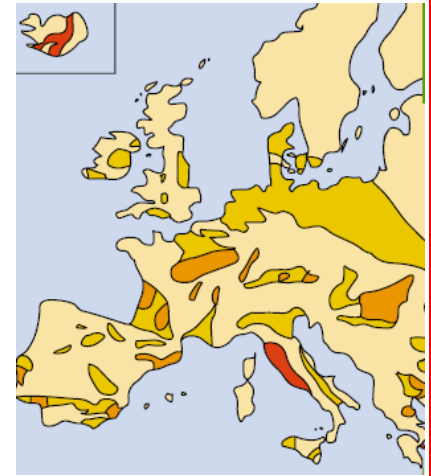


**ETP Geothermal  
Pisa, 10.06.2010**

# **Level of typical efficiencies for electricity generation of geothermal plants**

## **EUROSTAT DEMAND**

**Ruggero BERTANI**

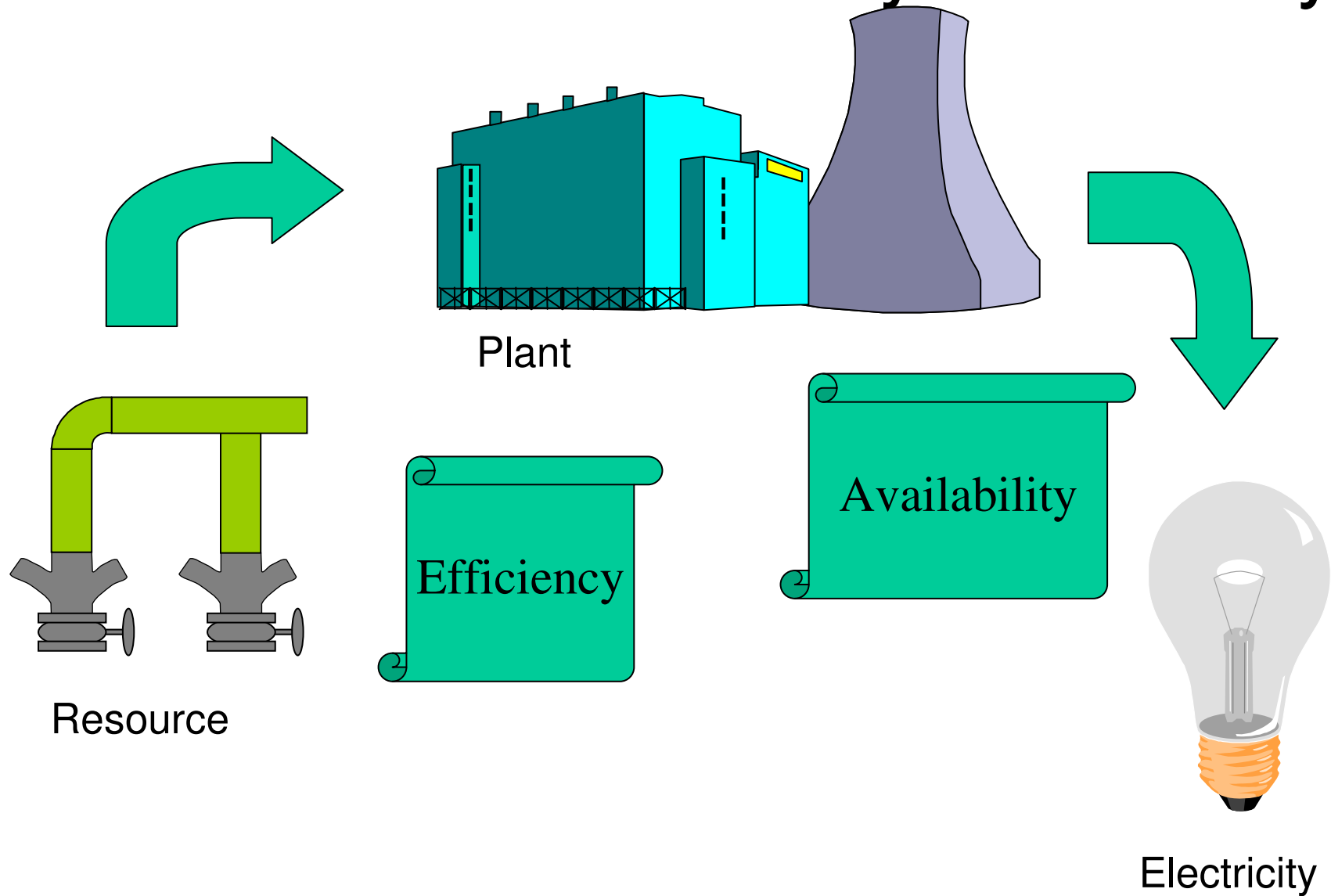


# Proposal

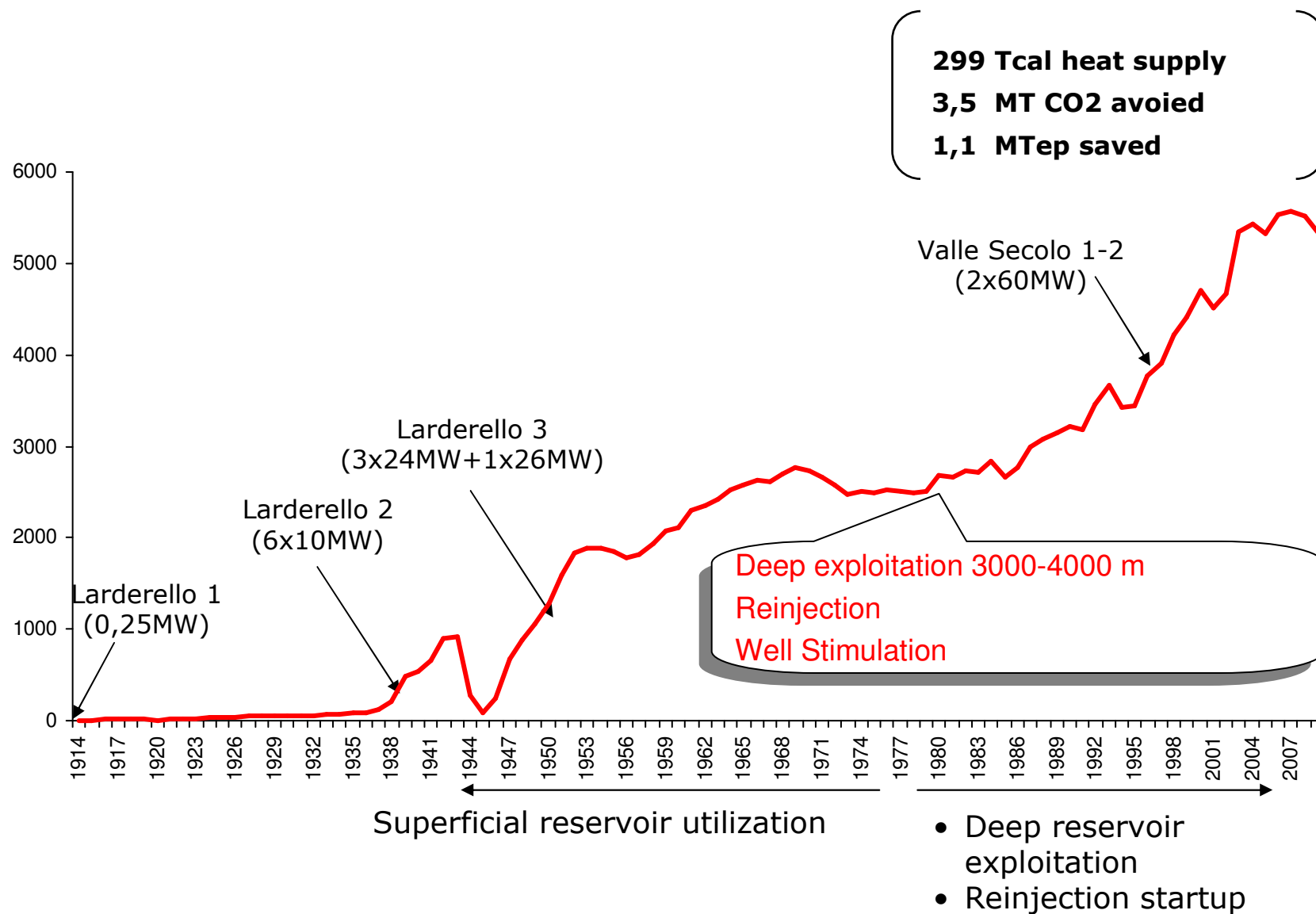
## Introduction:

- all RES must be treated in the same way concerning conversion efficiency. ( Solar PV, i.e. the ratio of electricity generated to the total irradiation. / Biomass taking into account the energy content of the biomass and the generated power / for wind, a ratio of power and kinetic energy content of the wind...)
- Is the power delivered considered a primary energy, or just as final energy, i.e. a portion of the primary energy within solar irradiation, etc.?
- The same is for geothermal energy:
  - > the energy content of the hot fluids from the underground can be considered as primary energy, and
  - > the electricity as final, using the conversion factor of the powerplant - or the electric energy from renewable source could be considered as primary

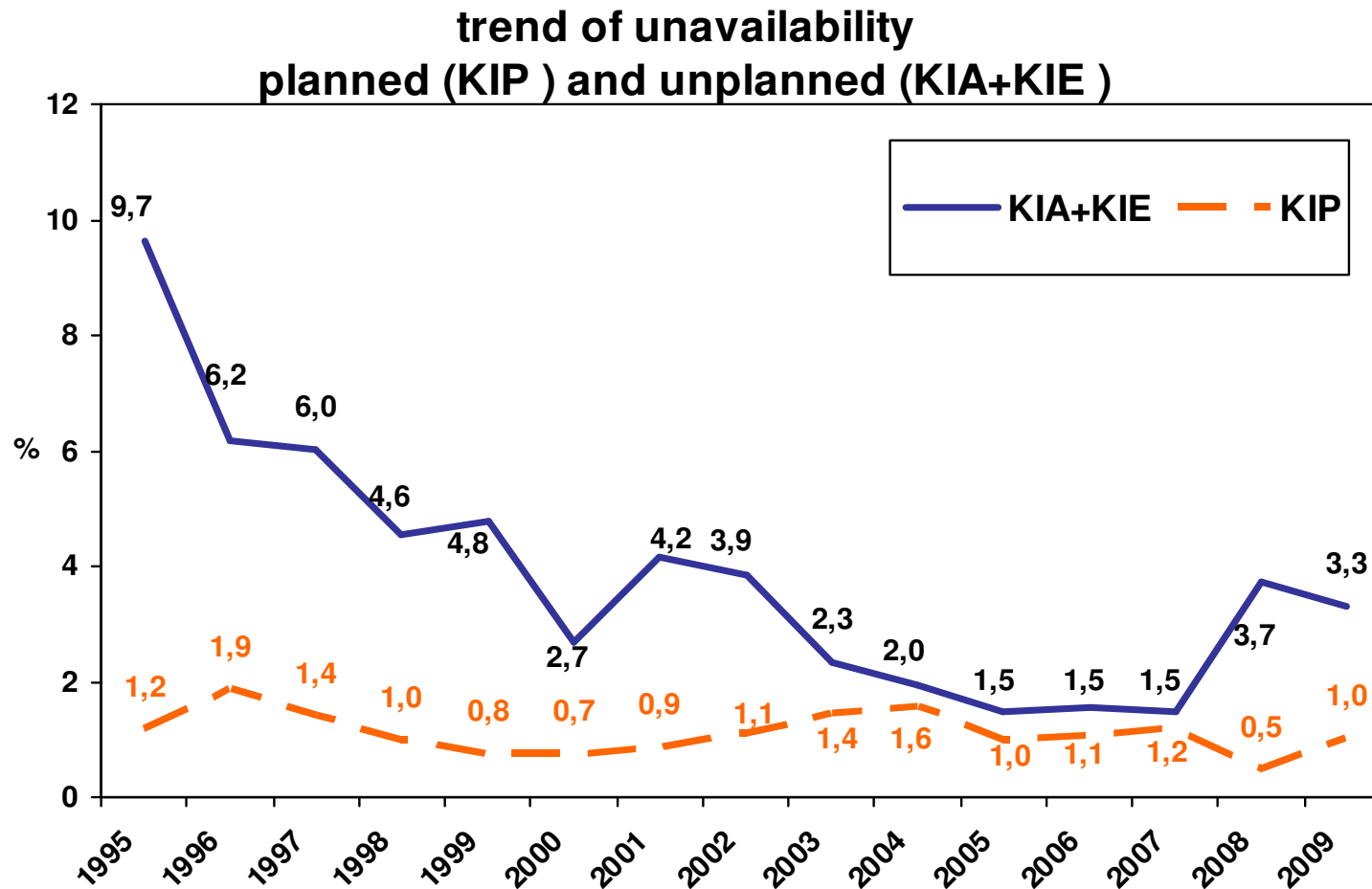
# Geothermal Efficiency/Availability



# History of Italian Production



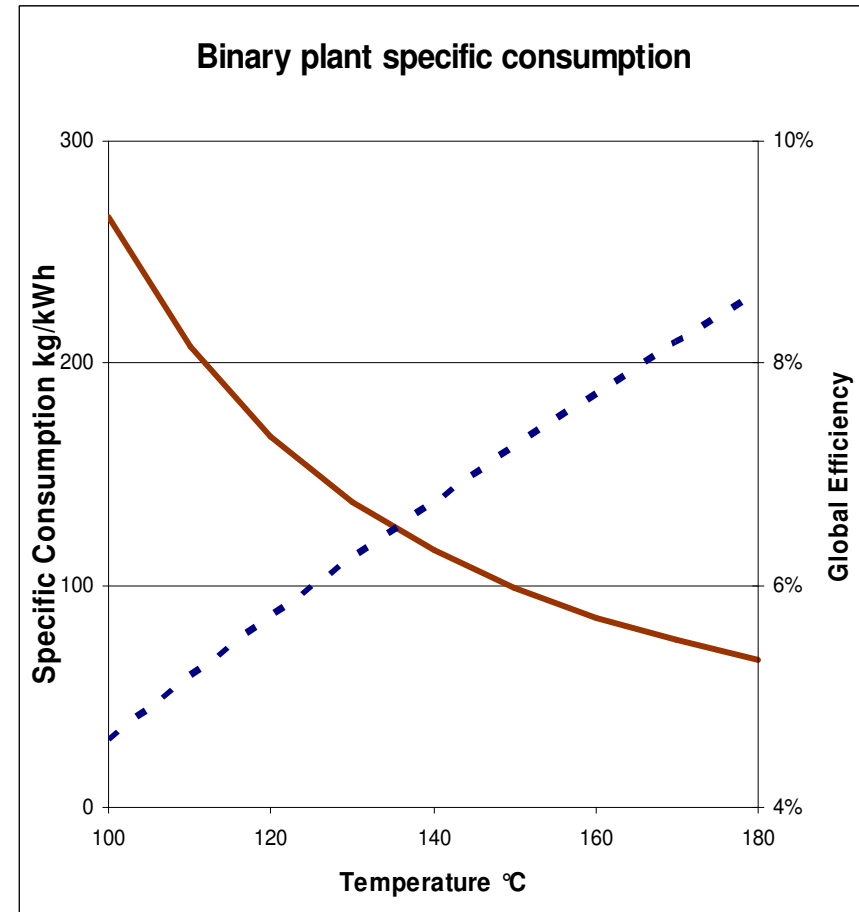
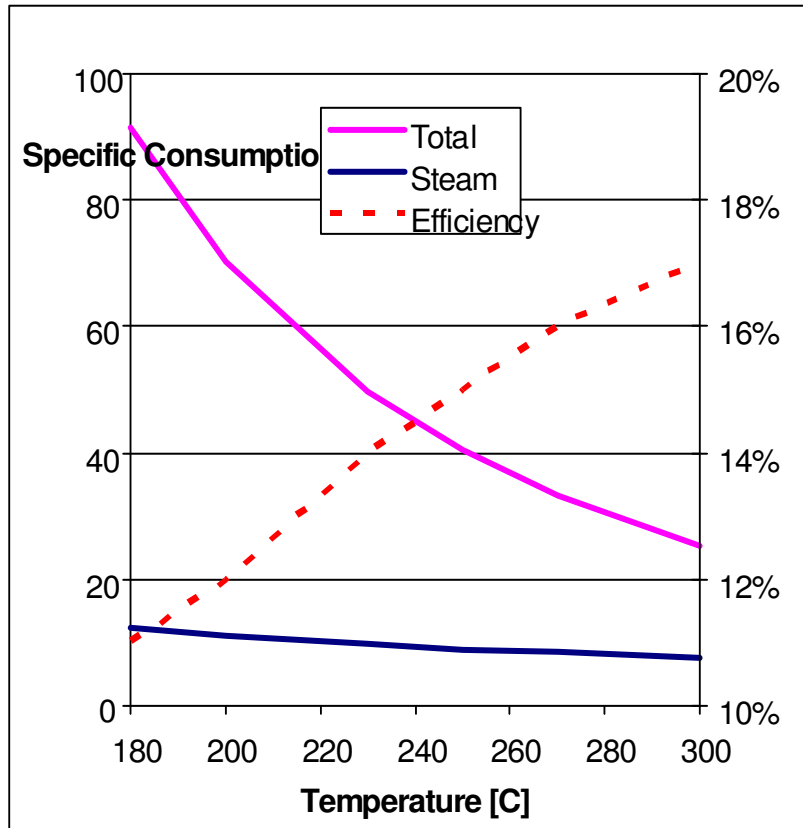
# Planned and unplanned unavailability



# Geothermal Availability

Year	Installed	Produced	
	Capacity	energy	
	MW	GWh	
1950	200		
1955	270		
1960	386		
1965	520		
1970	720		
1975	1180		
1980	2110		
1985	4764		
1990	5834		
1995	6833	38035	63,54%
2000	7972	49261	70,54%
2005	8903	55709	71,43%
2010	10715	67246	71,64%

# Geothermal Efficiency



# Geothermal Efficiency

At the common temperature of 180°C,  
the two technologies have the following figures:

PARAMETER	BINARY	FLASH
Efficiency	7,5%	11%
Specific Consumption kg/kWh	76	92
Steam Specific Consumption kg/kWh		12
Steam Fraction		14%

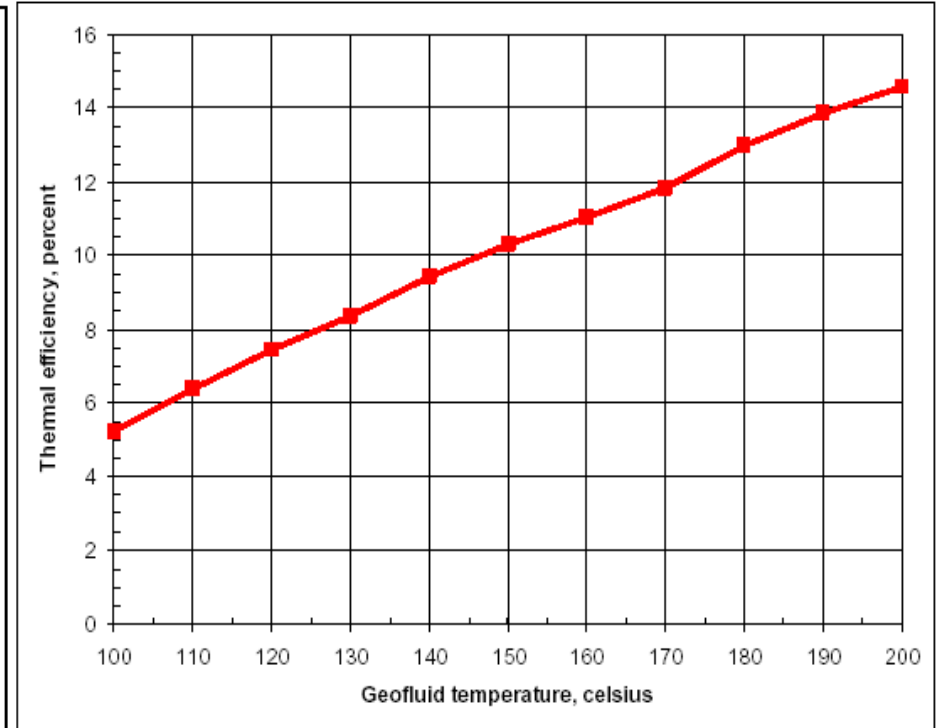
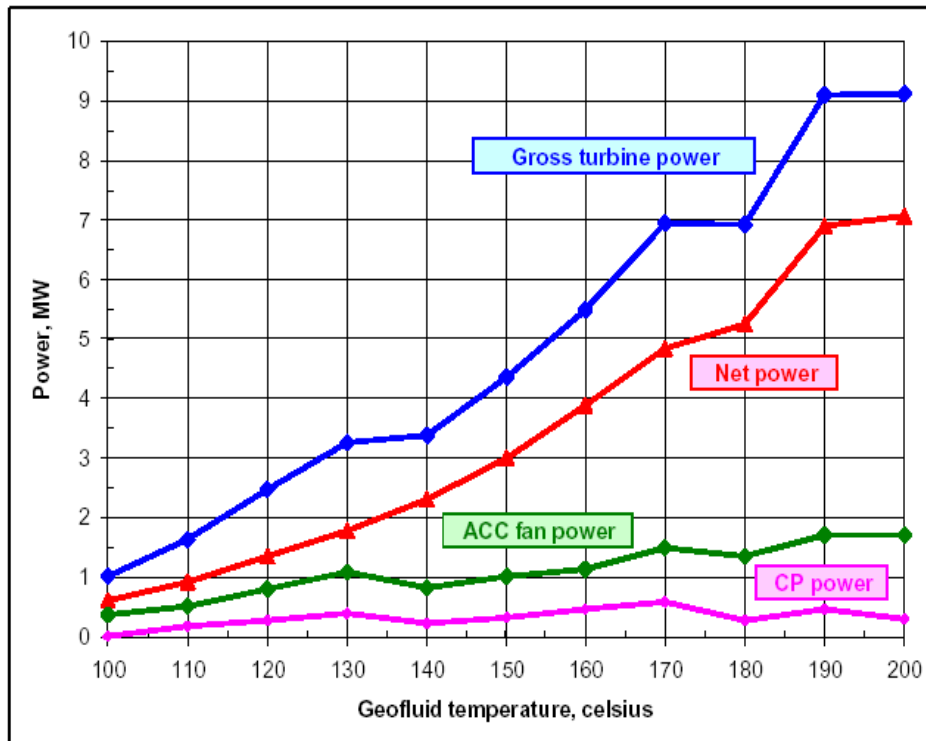
**Flash technology has better efficiency but a worst specific consumption on the total fluid.**

A better energy recovery is from the utilization of a bottoming binary cycle on the stream of the hot reinjected water



# Geothermal Efficiency

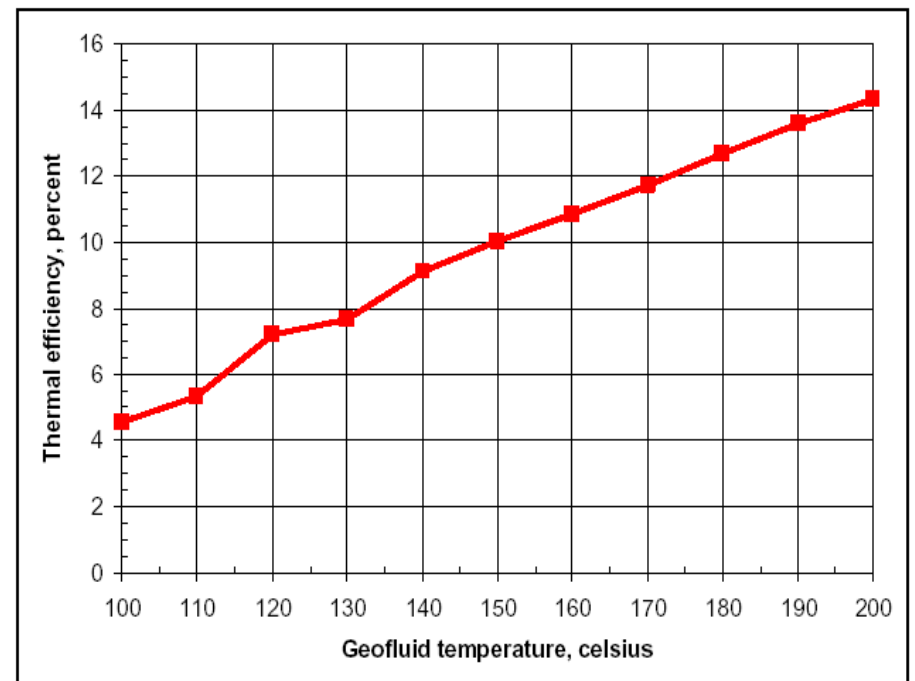
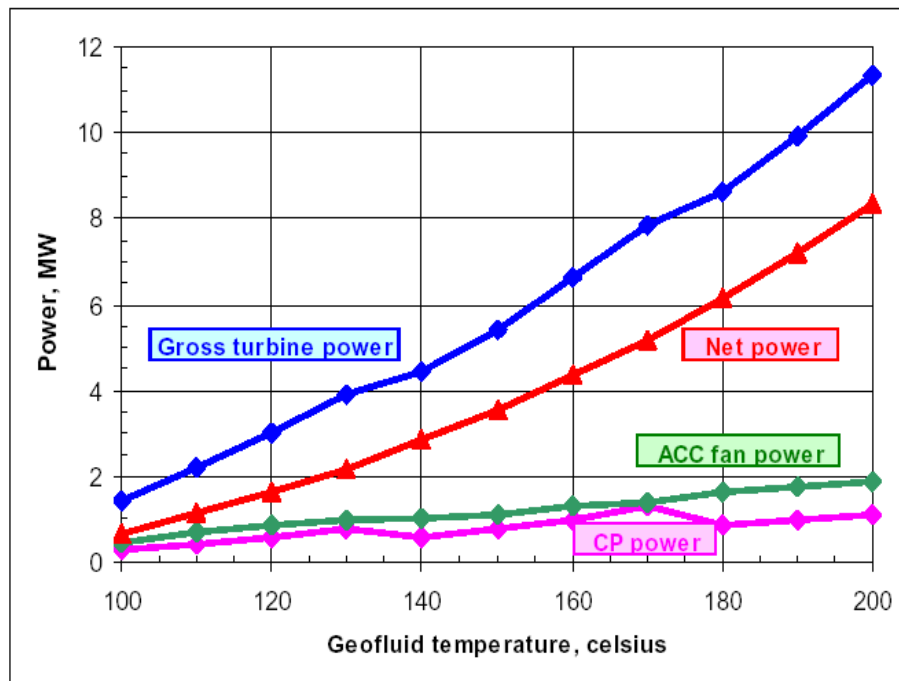
## Enel Development of Binary Cycle Technology



Subcritical basic binary with optimization of working fluid

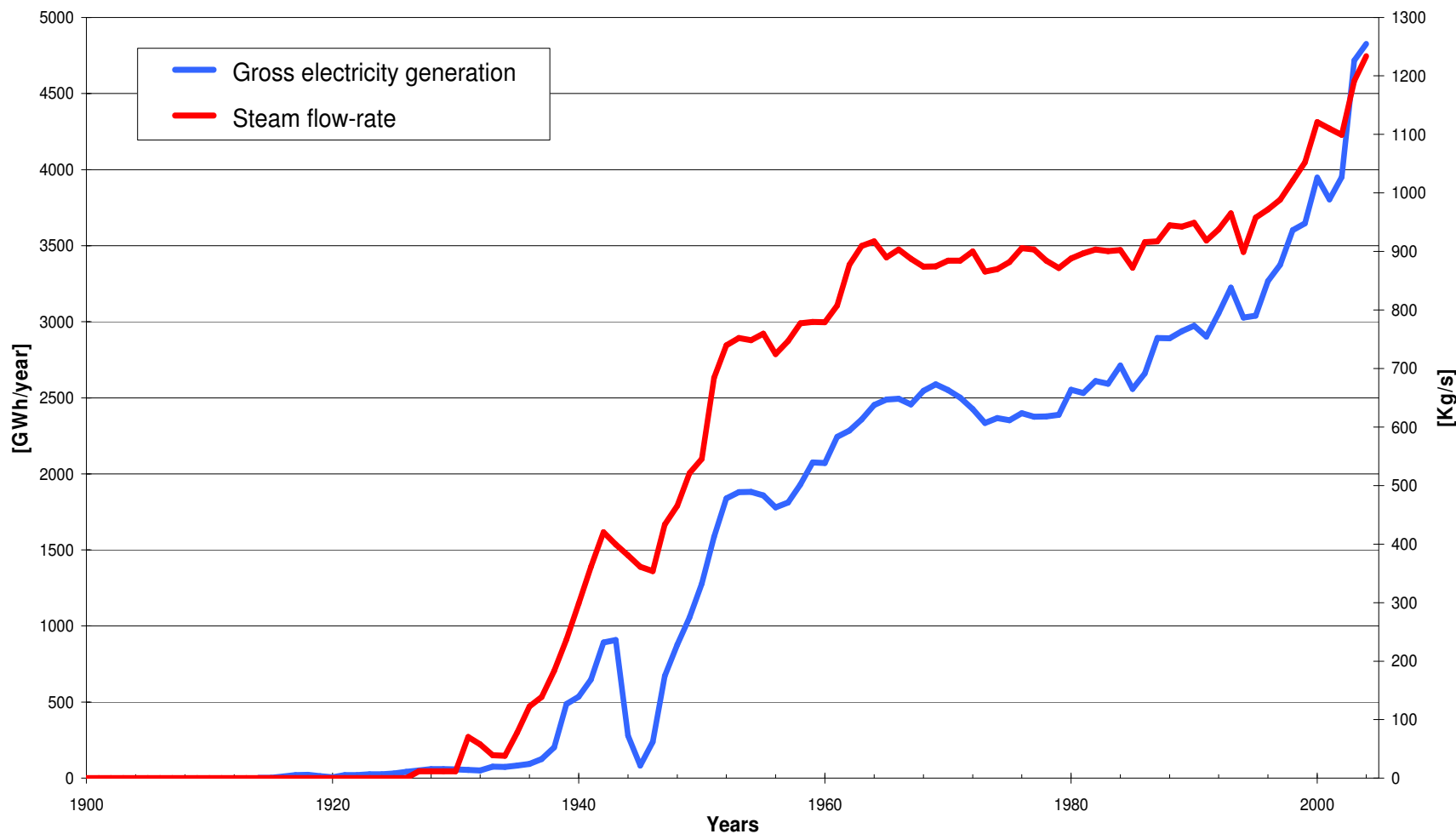
# Geothermal Efficiency

## Enel Development of Binary Cycle Technology



Supercritical basic binary with optimization of working fluid

# Electricity generation and steam flow-rate in the Larderello geothermal field



# Geothermal efficiency

- The conversion factors of geothermal power plants are mainly dependent upon the temperature of the geothermal fluid, which is in between 80 and 300 °C in practical use.
- With low temperatures and the use of binary powerplants, the conversion factors can be as low as <10 %, and typically some **7-12 %**.
- For higher temperatures, conversion factors can reach well over **12-20 %**.

# Geothermal efficiency

conversion efficiency electricity/heat			
<b>100-150</b>	<b>150-250</b>	<b>target GW hydro</b>	
<b>°C</b>	<b>°C</b>		<b>70</b>
<b>10,00%</b>	<b>20,00%</b>	<b>target GW EGS</b>	
conversion efficiency electricity/h			<b>70</b>
<b>EGS</b>		<b>target GW TOTAL</b>	
<b>5,00%</b>			<b>140</b>

# Summary

- Availability
- Specific Consumption (gross/net)
- Efficiency (total)
- Exergetic Efficiency  
(utilization efficiency)