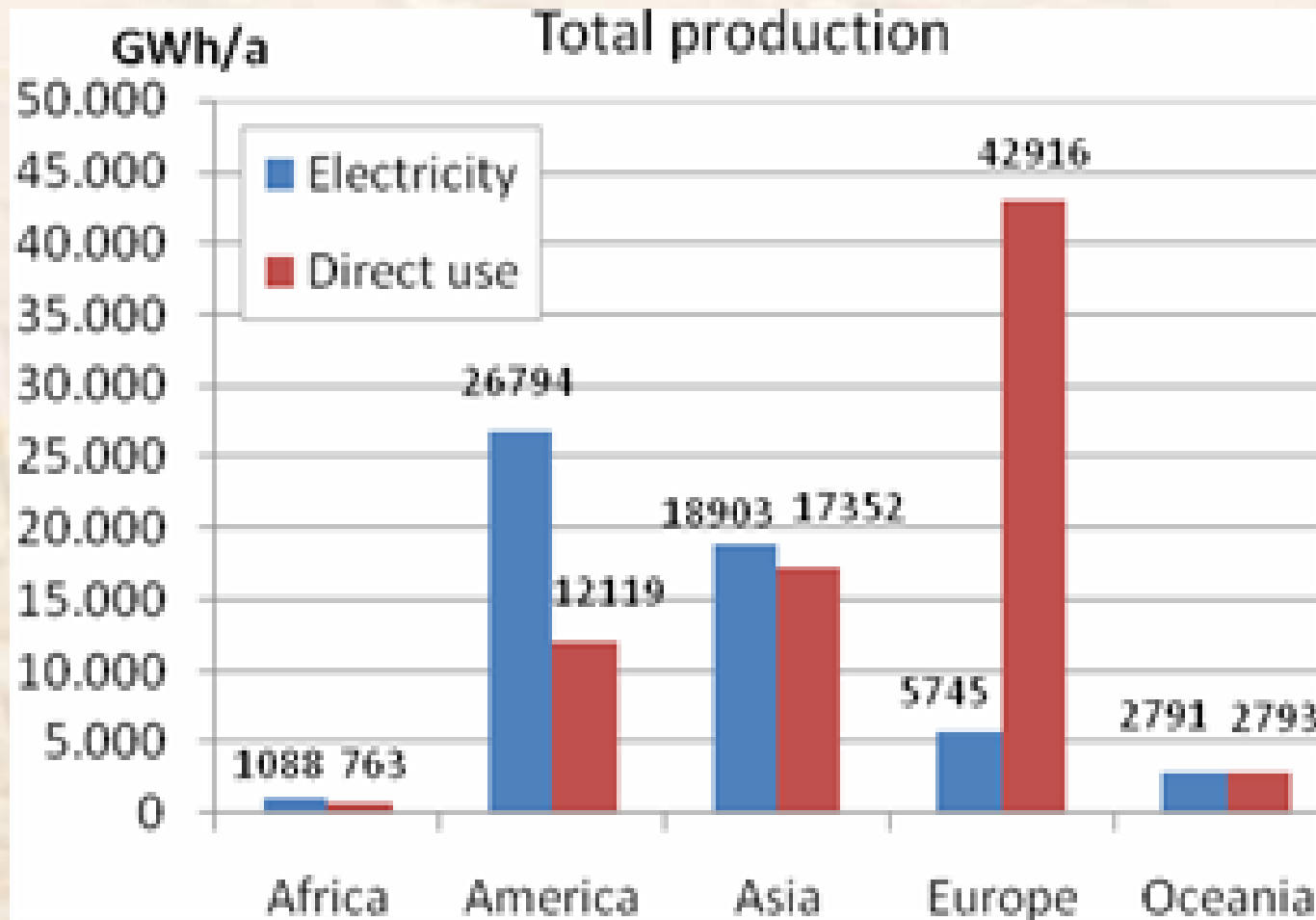




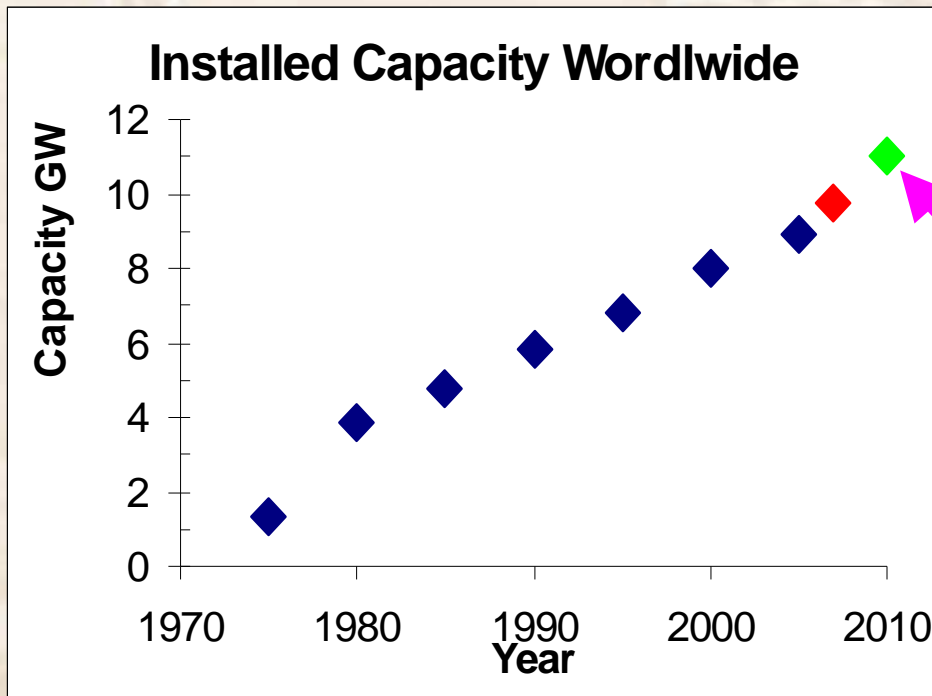
## Geothermal Energy in the World: Current Status and Future Scenarios

Ruggero Bertani  
Enel Green Power Italy  
Vice President IGA

# World Status



# Growing Trend



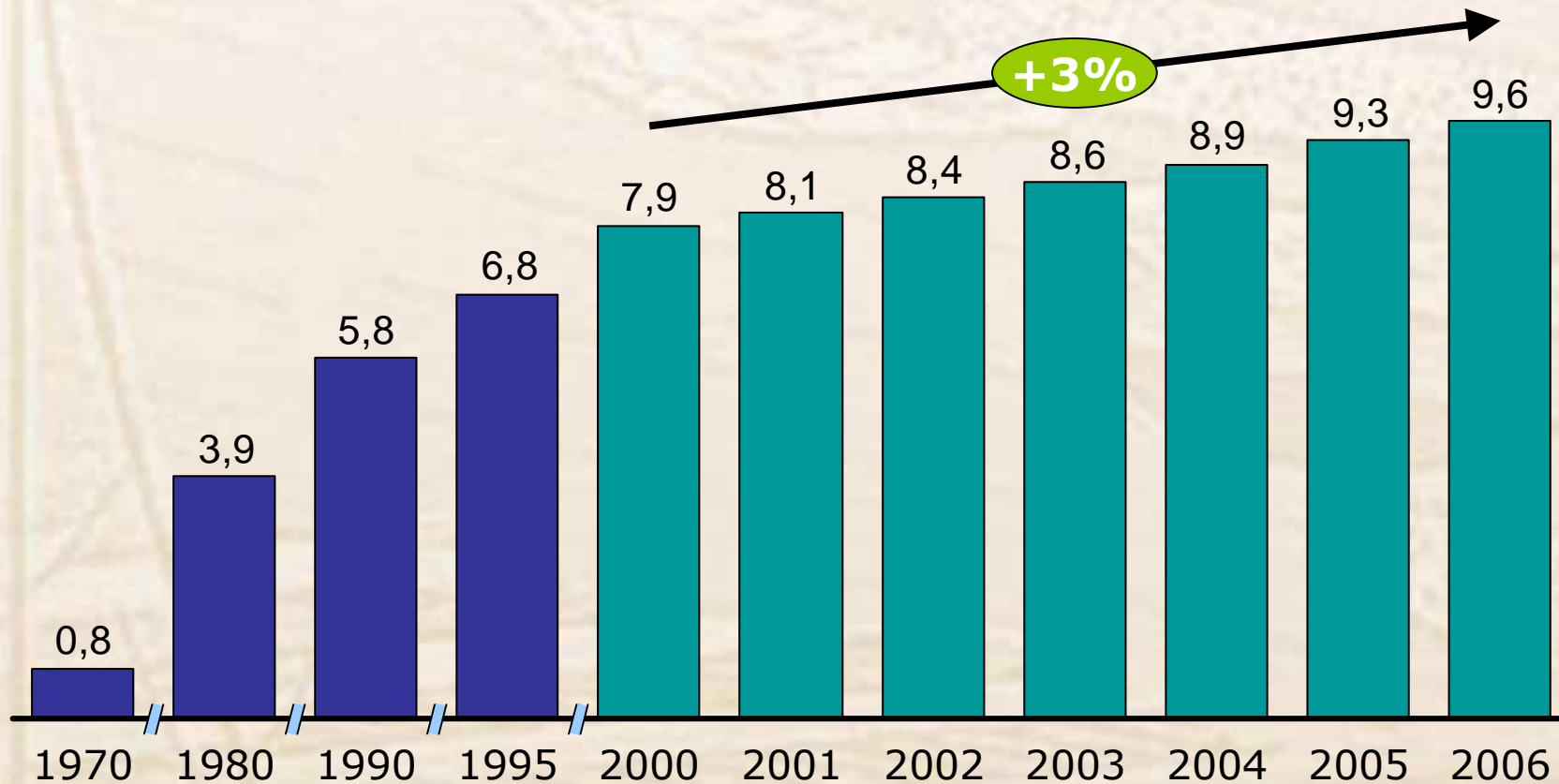
An increase of about **800 MW** in the three year term 2005-2007 has been achieved, following the rough standard linear trend of approximately **200/250 MW per year**

The geothermal electricity installed capacity is approaching the **10,000 MW threshold**, which can be reached before the next WGC2010 in Indonesia.

# Growth has been very slow ...



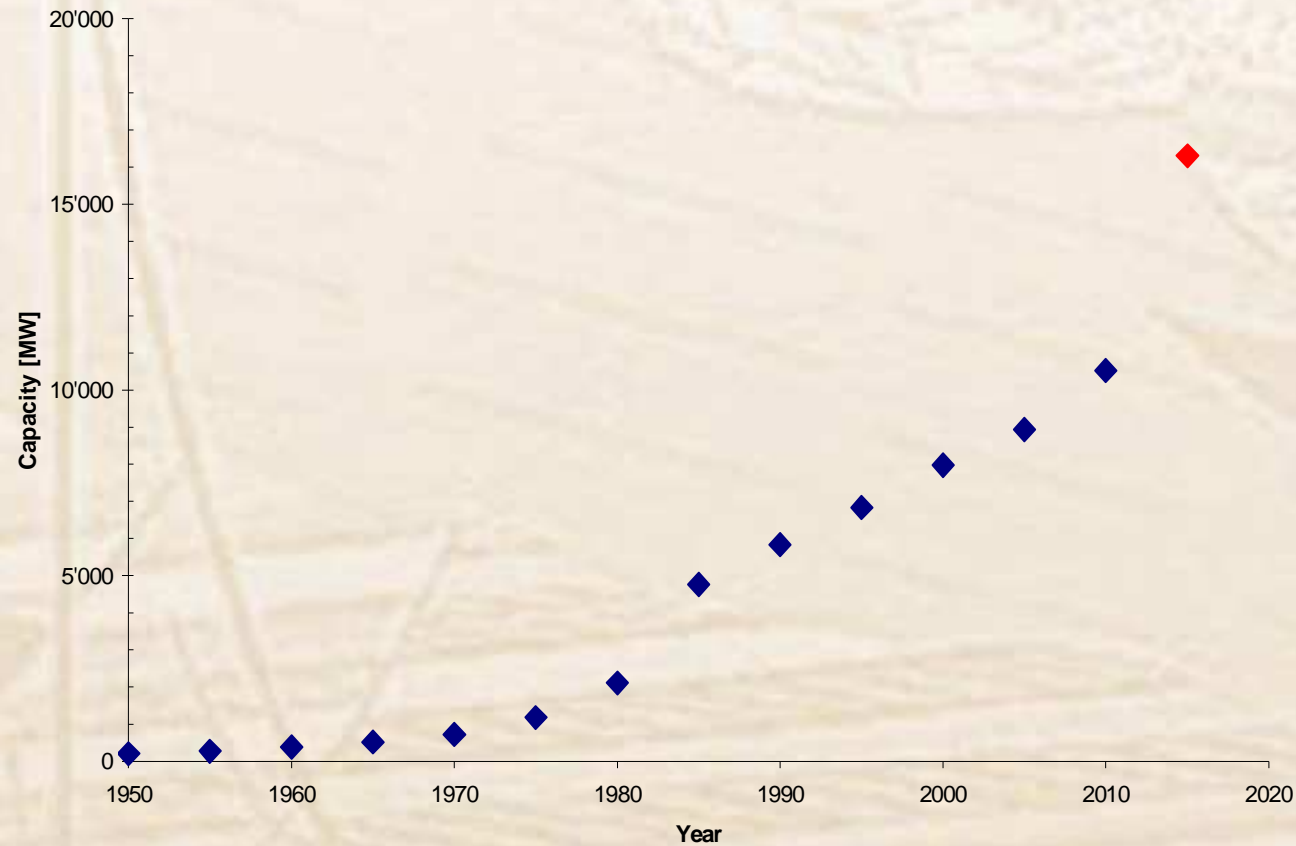
Installed capacity in GWe



# BUT...

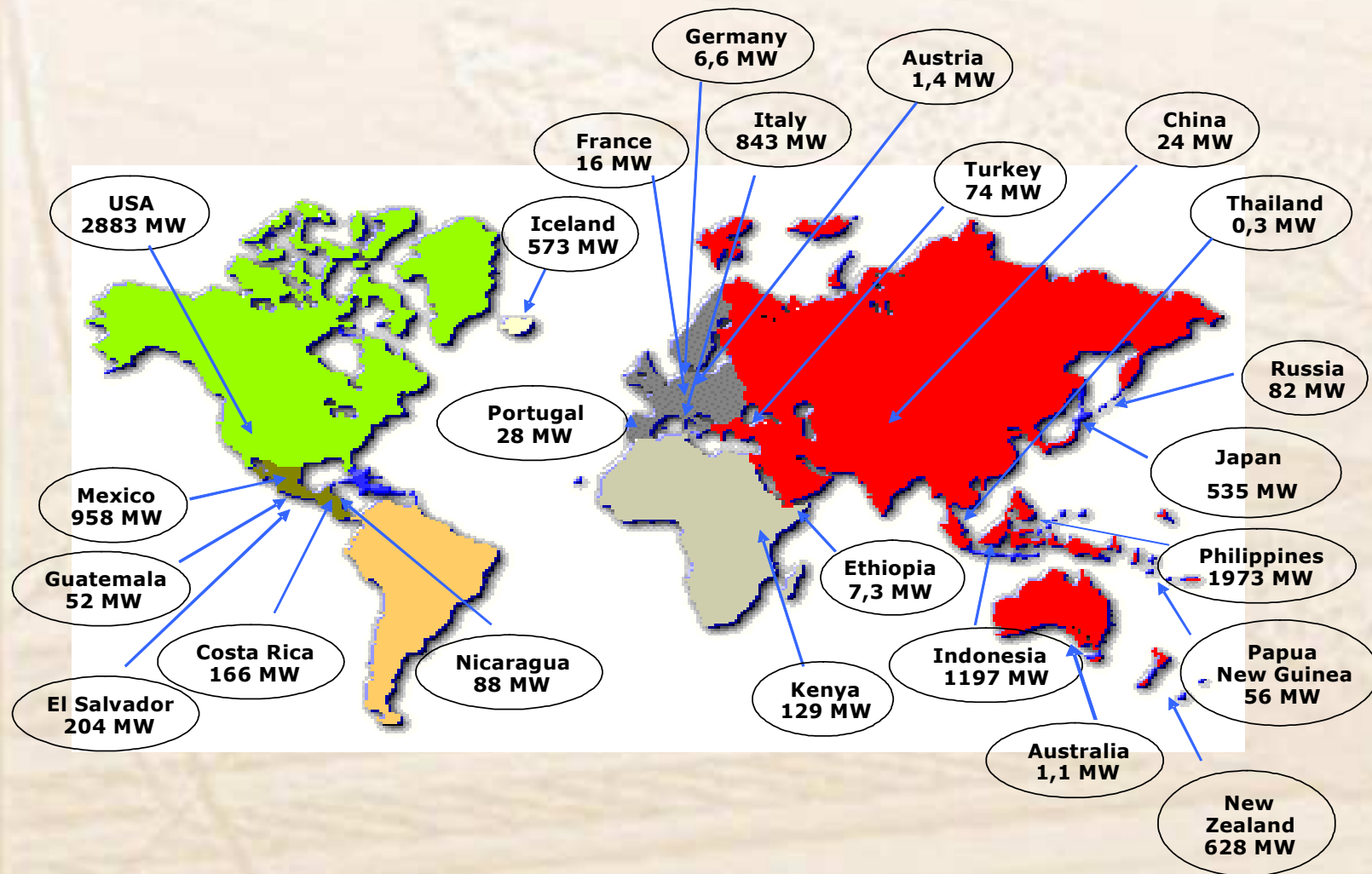


### Installed Capacity

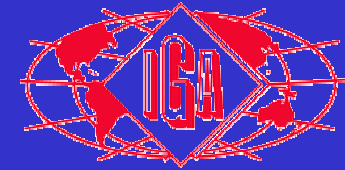


Year	Installed Capacity MW
1950	200
1955	270
1960	386
1965	520
1970	720
1975	1,180
1980	2,110
1985	4,764
1990	5,834
1995	6,833
2000	7,972
2005	8,933
2010	10,520
2015	16,000

# World Forecasting 2010



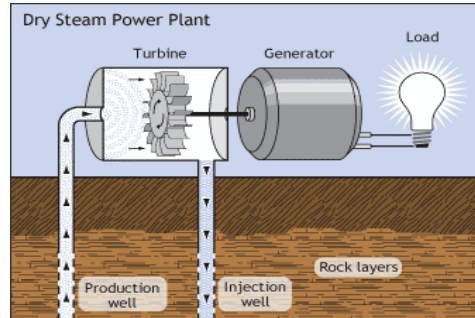
# New frontiers?



# Conventional Technologies

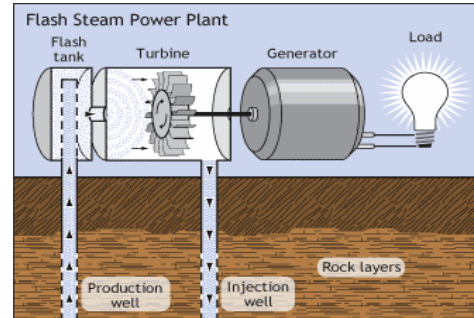


## •Dry steam power plants



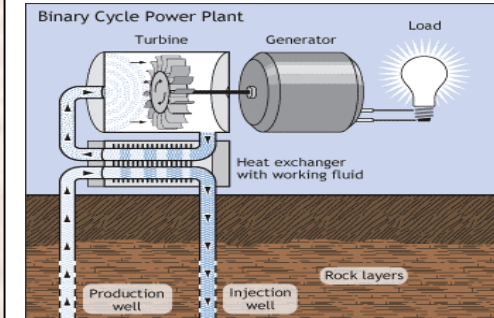
**Dry steam plants** use hydrothermal fluids that are primarily steam. The steam goes directly to a turbine, which drives a generator that produces electricity.

## •Flash steam power plants



**Flash steam power plants** tap into reservoirs of water with temperatures greater than **182°C**. As it flows, the fluid pressure decreases and some of the hot water boils or "flashes" into steam. The steam is then separated at the surface and is used to power a turbine/generator unit

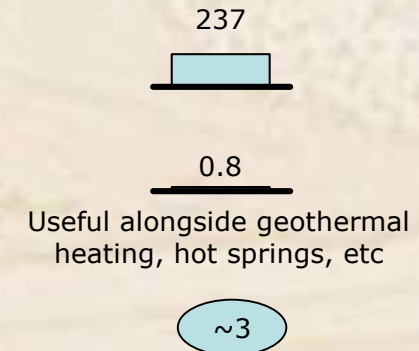
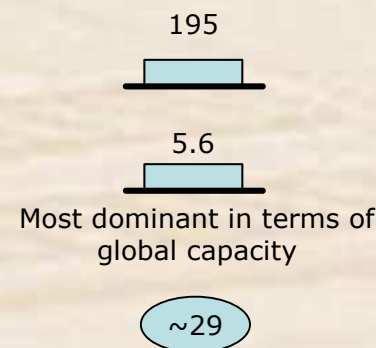
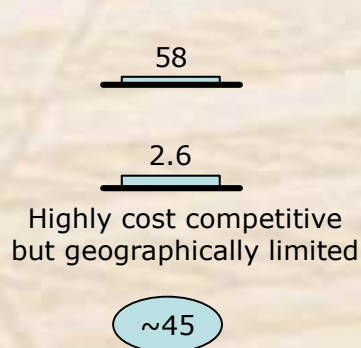
## •Binary cycle power plants



**Binary cycle power plants** operate on water at lower temperatures of about **107-182°C**. These plants use the heat from the geothermal water to boil a working fluid, usually an organic compound with a low boiling point.

**Global Installed capacity 2007**

<b>Units</b>
<b>Capacity</b> □□GW)
<b>Average size</b> □MW)



# World Forecasting

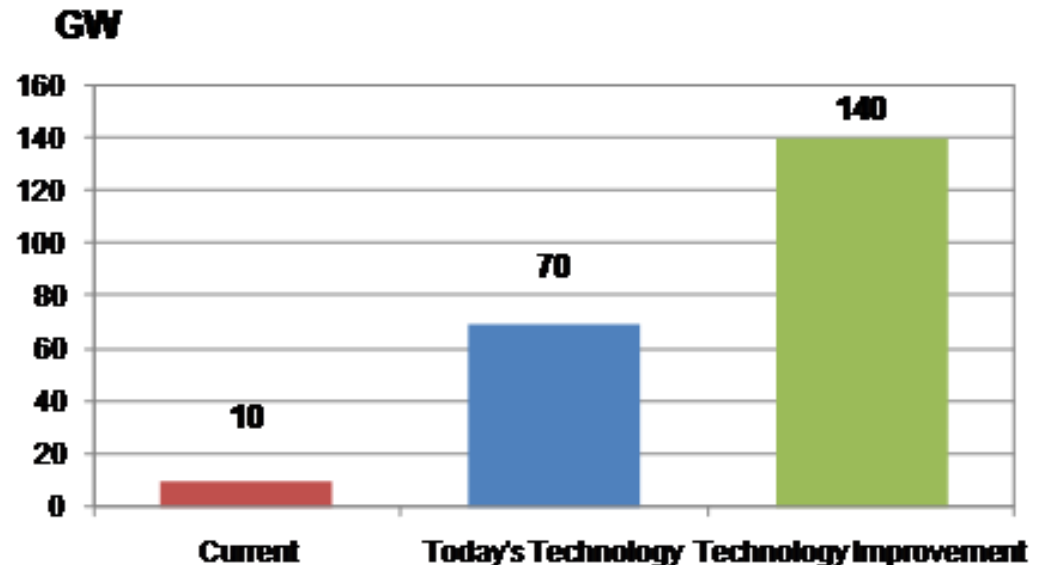


It's difficult to estimate the overall world-wide potential, due to the presence of too many uncertainties.

Nevertheless, it is possible to identify a range of estimations, taking into consideration also the possibility of new technologies:

- permeability enhancements
- drilling improvements
- enhanced geothermal system
- supercritical fluid.

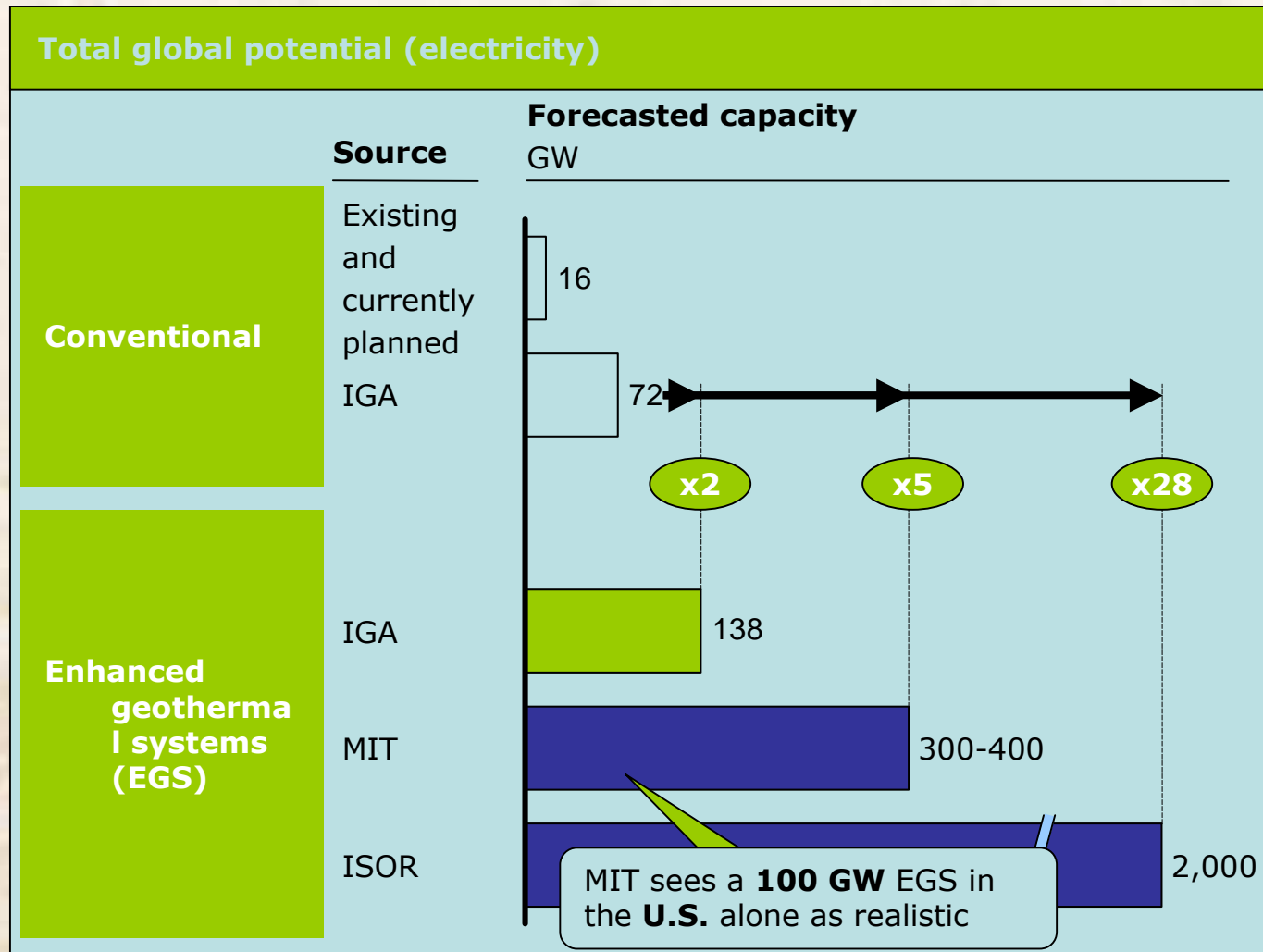
**Standard: 70 GW**  
**Improved: 140 GW**



It is possible to produce up **8.3%** of total world electricity production, serving **17%** of world population.

**39** countries (located mostly in Africa, Central/South America, Pacific) can be 100% geothermal powered.

# EGS

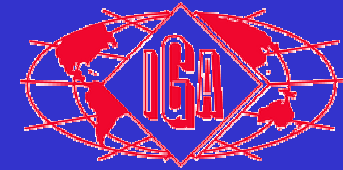


Consensus that **conventional is limited to ~ 70GW**

Conservative estimate that **EGS will double potential** geothermal

However, also **huge variance** on expected size of potential

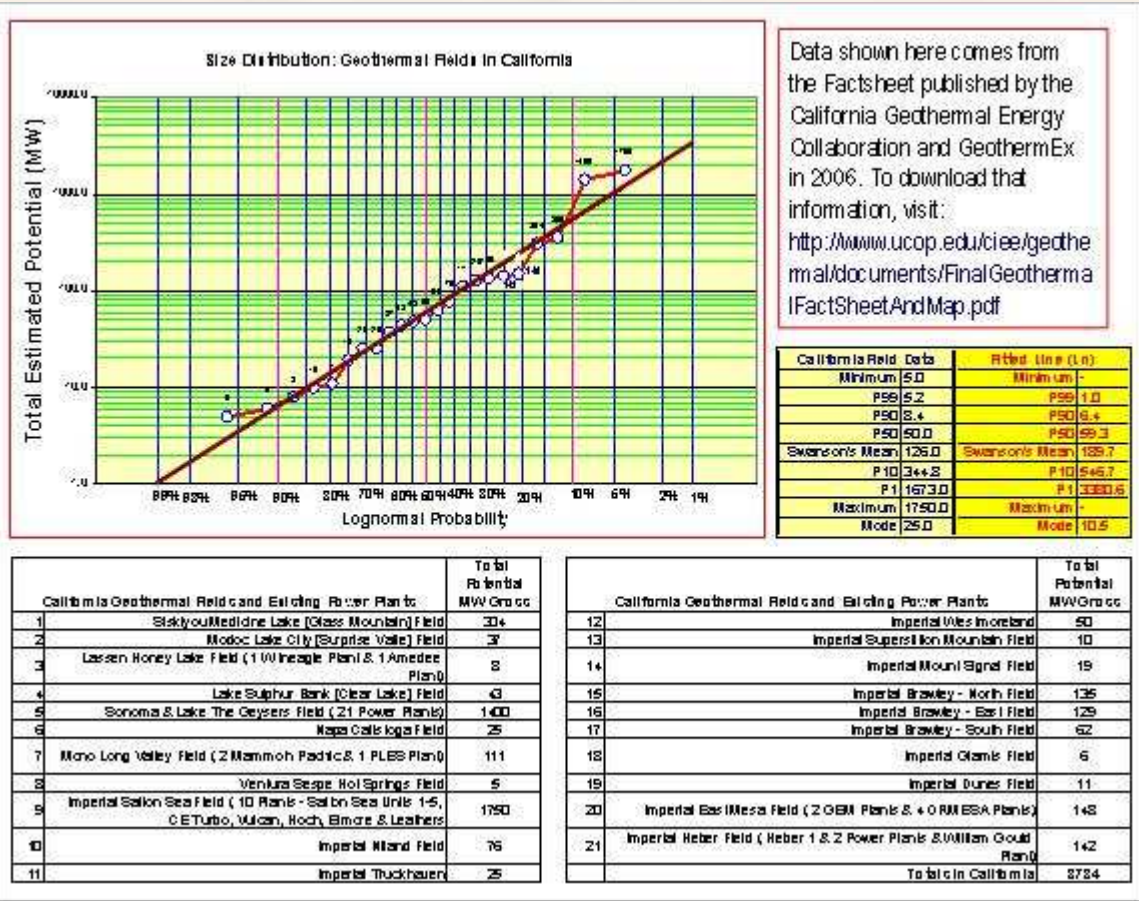
# World Forecasting



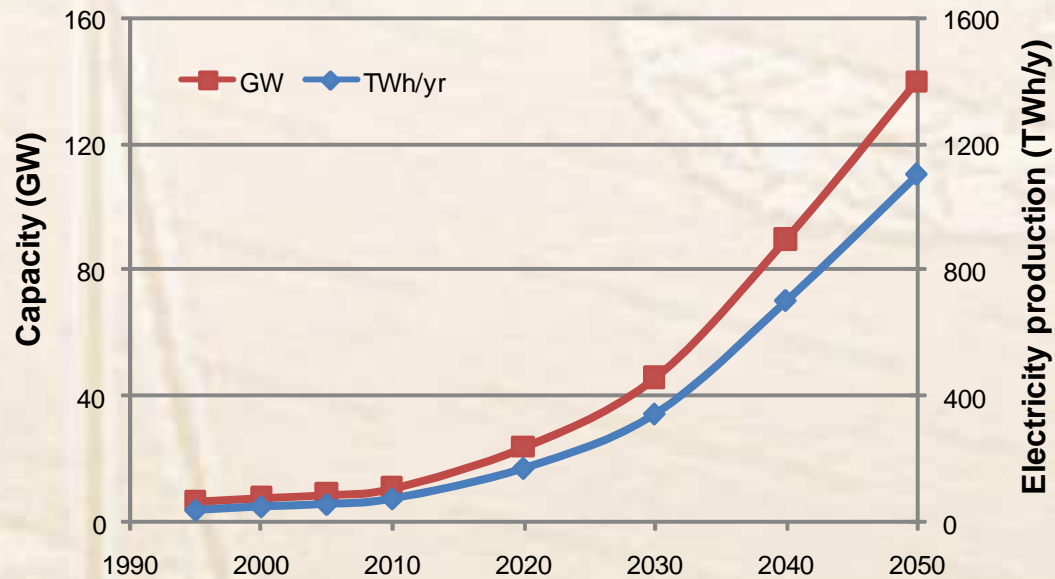
Statistical analysis: lognormal distribution of the underground heat, with 99% probability of having 10 MW and using the MIT assumption on potential scaled on world basis for P10.

For year 2050 the exploitation of at least additional **70 GWe** from EGS, which could be possible with **15%** probability of exploiting the world average weighted EGS potential

(but within the condition of the success of the medium/long term experimentation of the present EGS pilot plants).

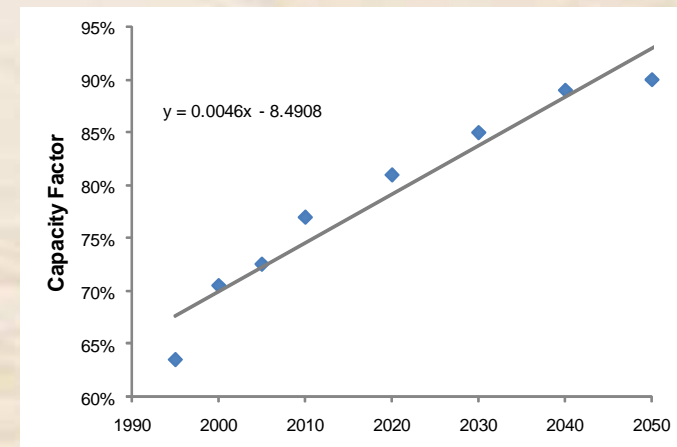


# World Forecasting



It is expected that the next generation will see the implementation of **Enhanced Geothermal System (EGS)** and an intensive increase in low-to-medium temperature applications through **binary cycles** and **cascade utilisations**, expanding its availability on a worldwide basis. Geothermal energy is not so considerable, but its **base-load capability** is a very important factor for its success.

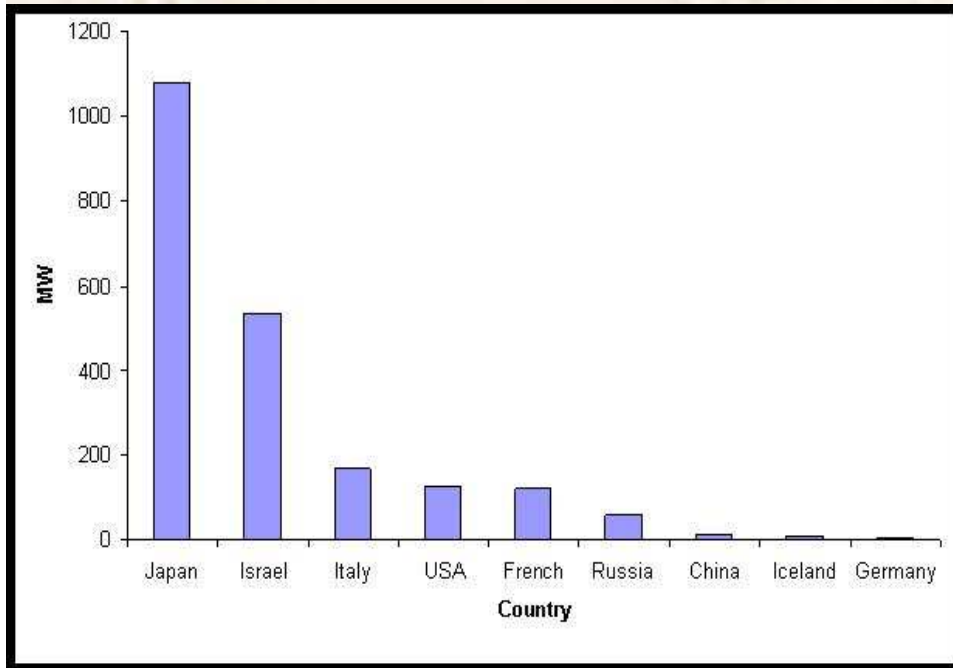
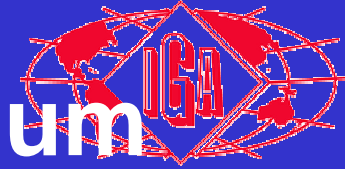
Long-Term Forecasting of  
Electricity Production  
Installed Capacity  
Capacity factor



# World Forecasting



# Geothermal in the Third Millennium

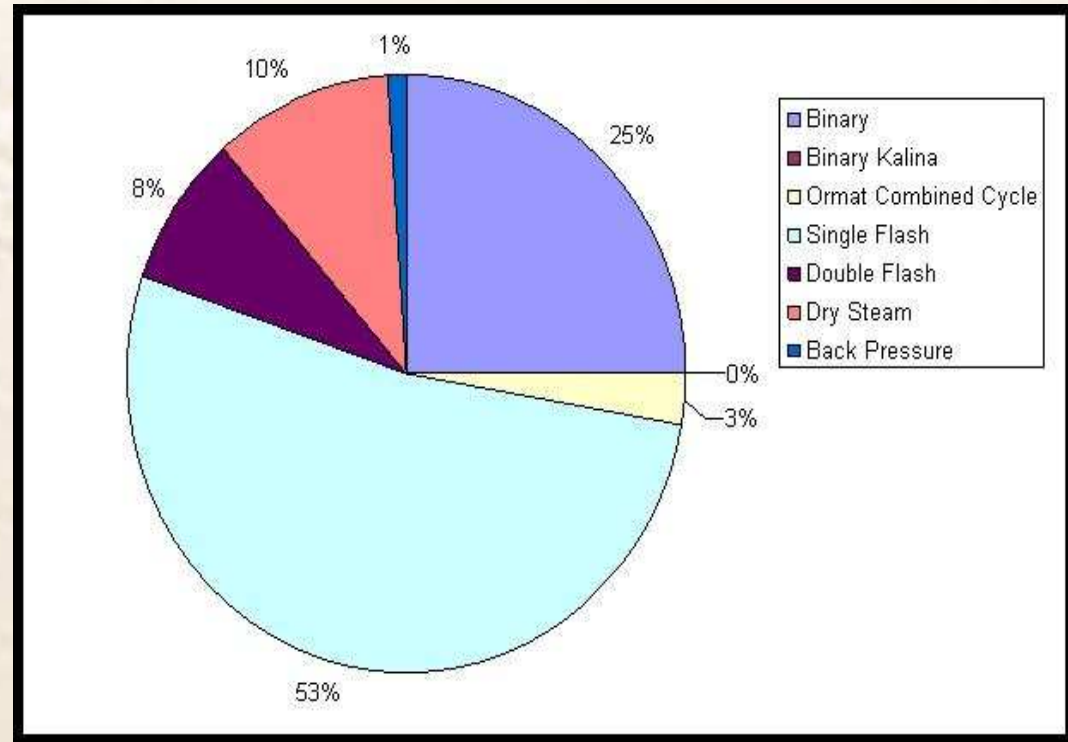


Manufacturer	MW	Units
Mitsubishi	572	15
Ormat	534	37
Fuji	474	9
Nuovo Pignone	164	8
Alstom	120	7
Mafi Trench	67	6
Kaluga Turbine Works	57	6
General Electric	56	2
Toshiba	33	1
Harbin	10	2
Enx	9	1
Siemens	4	2
Turboden	3	3
Elliot	2	1
UTC Power	0,4	1
GMK	0,2	1
Other	122	6
<b>TOTAL</b>	<b>2228</b>	<b>108</b>

# Geothermal in the Third Millennium

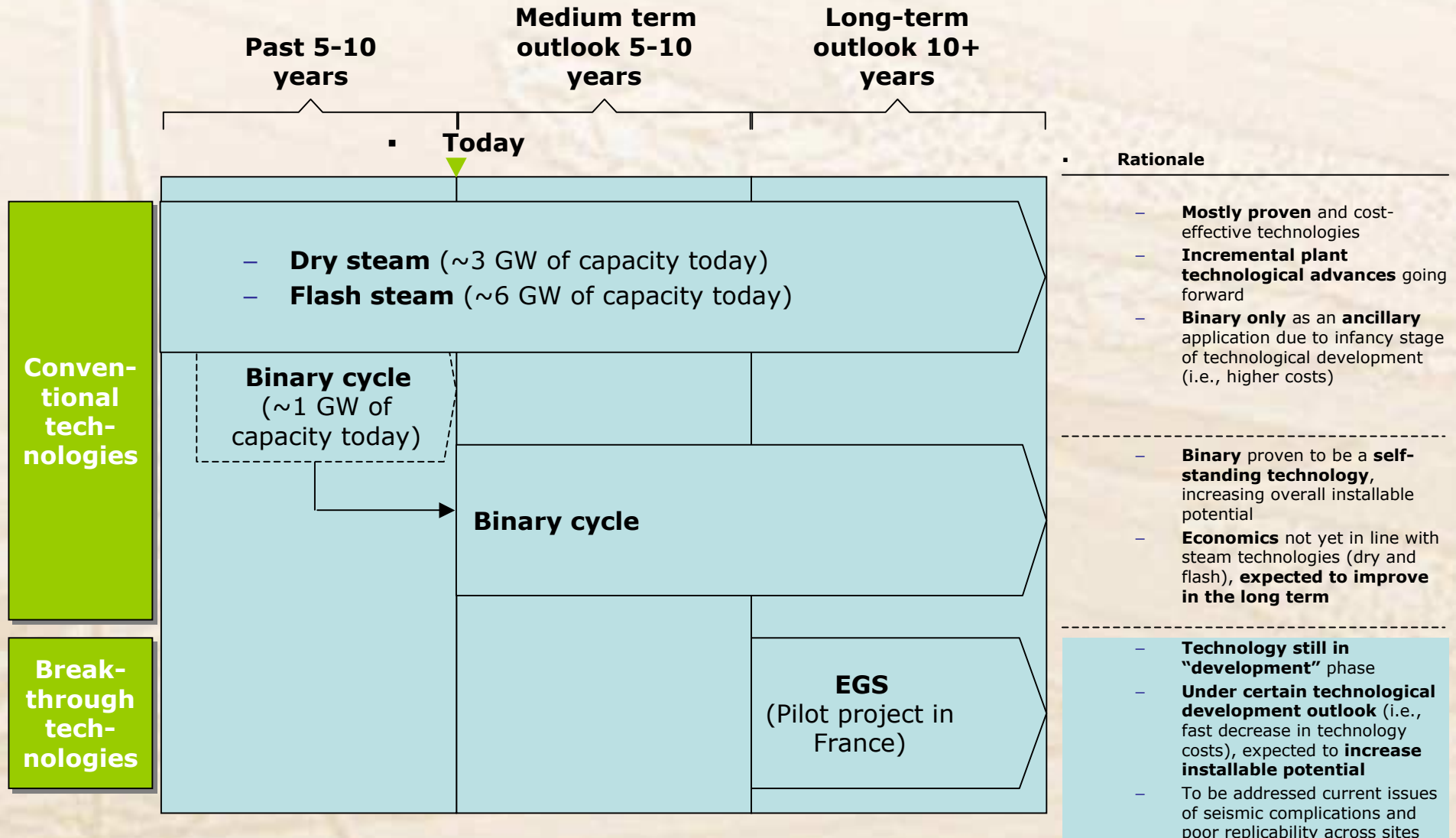


It is noticeable the very strong importance of the Japanese manufacturer, whereas the geothermal development in that country is still stuck due to lack of supporting measures for the new field deep investigation phases, as in the recent past when NEDO or other public bodies will be actively present in the applied research on geothermal energy and the lack of incentives for the renewable energy sources.



Considering as a single category the Binary, Binary Kalina and Ormat Combined Cycle, they will account for 30% of the capacity and 5% of the units, whereas the Single Flash, Double Flash and Back Pressure reach 60% of the capacity and 40% of the units.

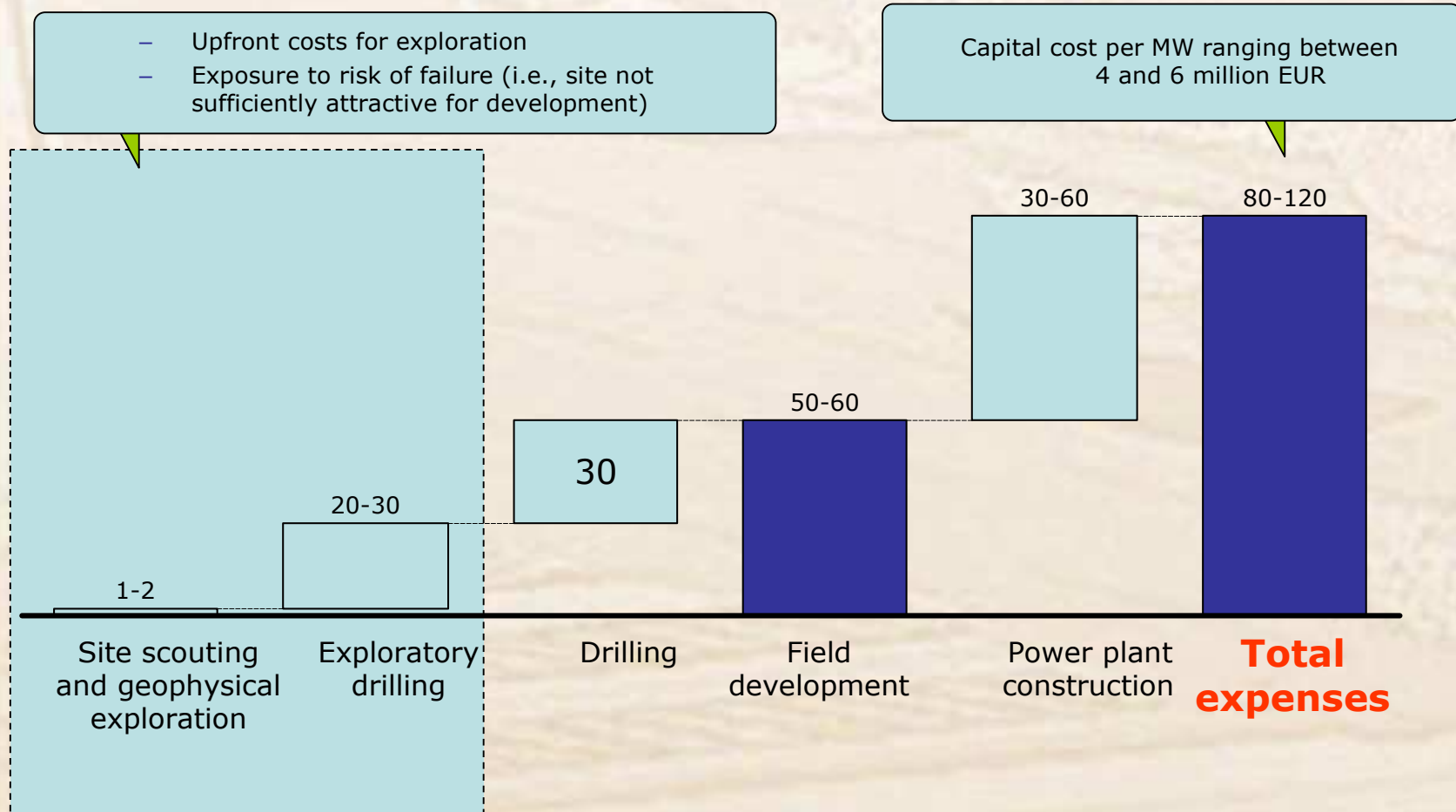
# Forecasting



# CAPEX Implications



EUR million, based on a 20 MW plant



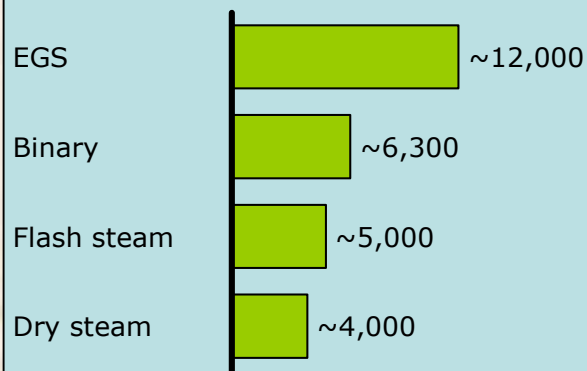
# CAPEX Implications



## Costs for geothermal are site specific and differ by technology...

### Capital cost

2007, EUR/KW installed



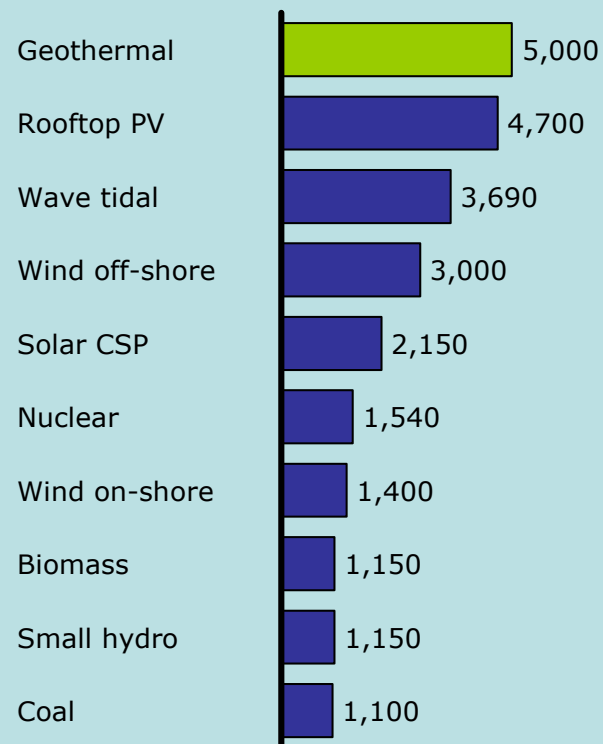
Capital cost is highly dependent upon drilling

- The **number of geothermal wells** required (mass-flow rate)
- The **depth of drilling** (temperature required)

## ...and do not yet compare well to non-renewable technologies

### Capital cost

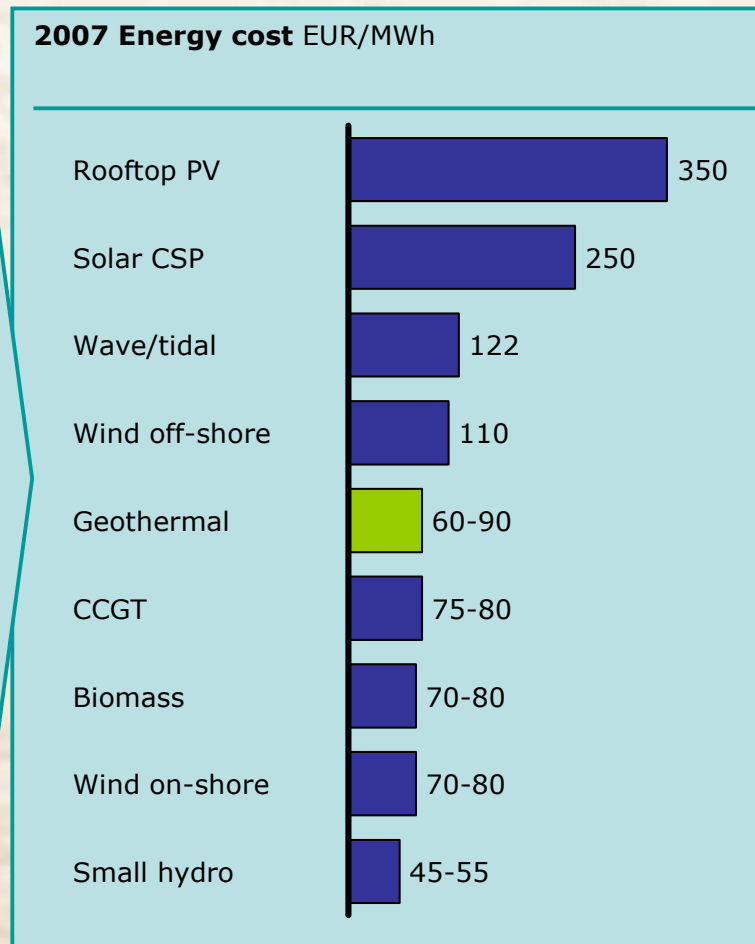
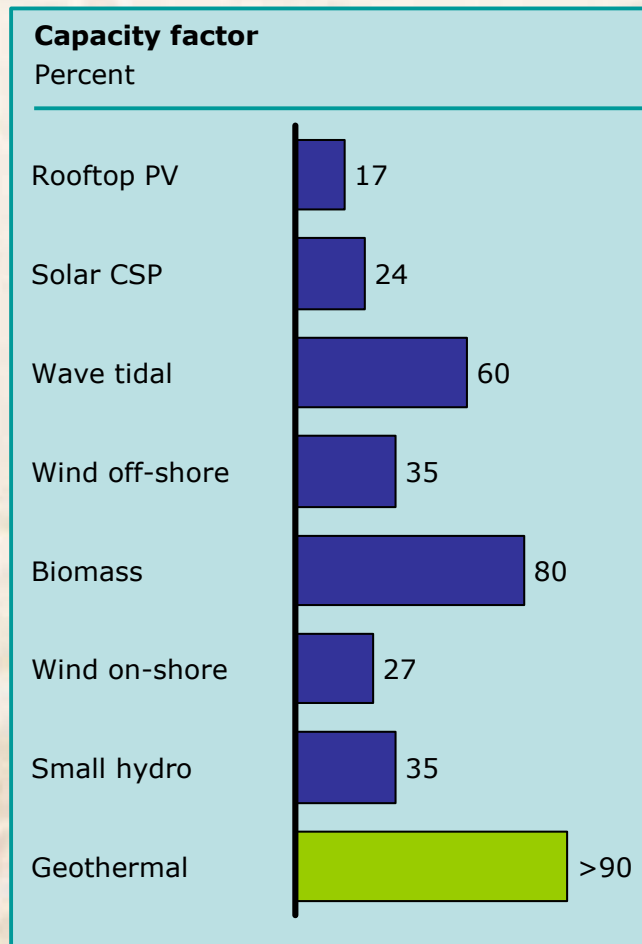
2007, EUR/KW installed



### Geothermal generation capital costs

- Are large and highly dependent upon the specific site and technology
- Require a greater investment than all other renewable and conventional technologies

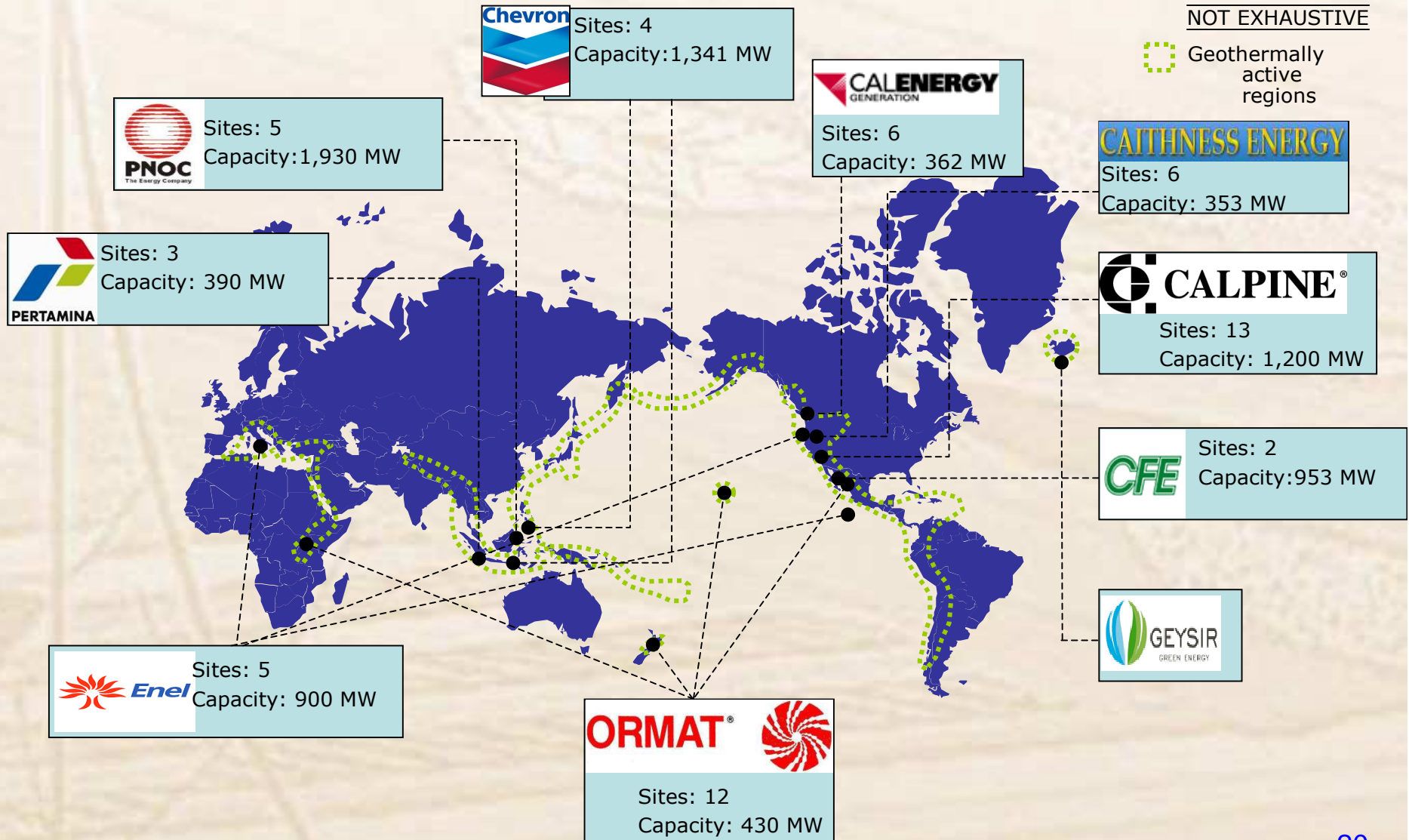
# CAPEX Implications



Among the renewable, **geothermal energy is best suited for base load capacity**, having

- High capacity factors
- Low full generation costs

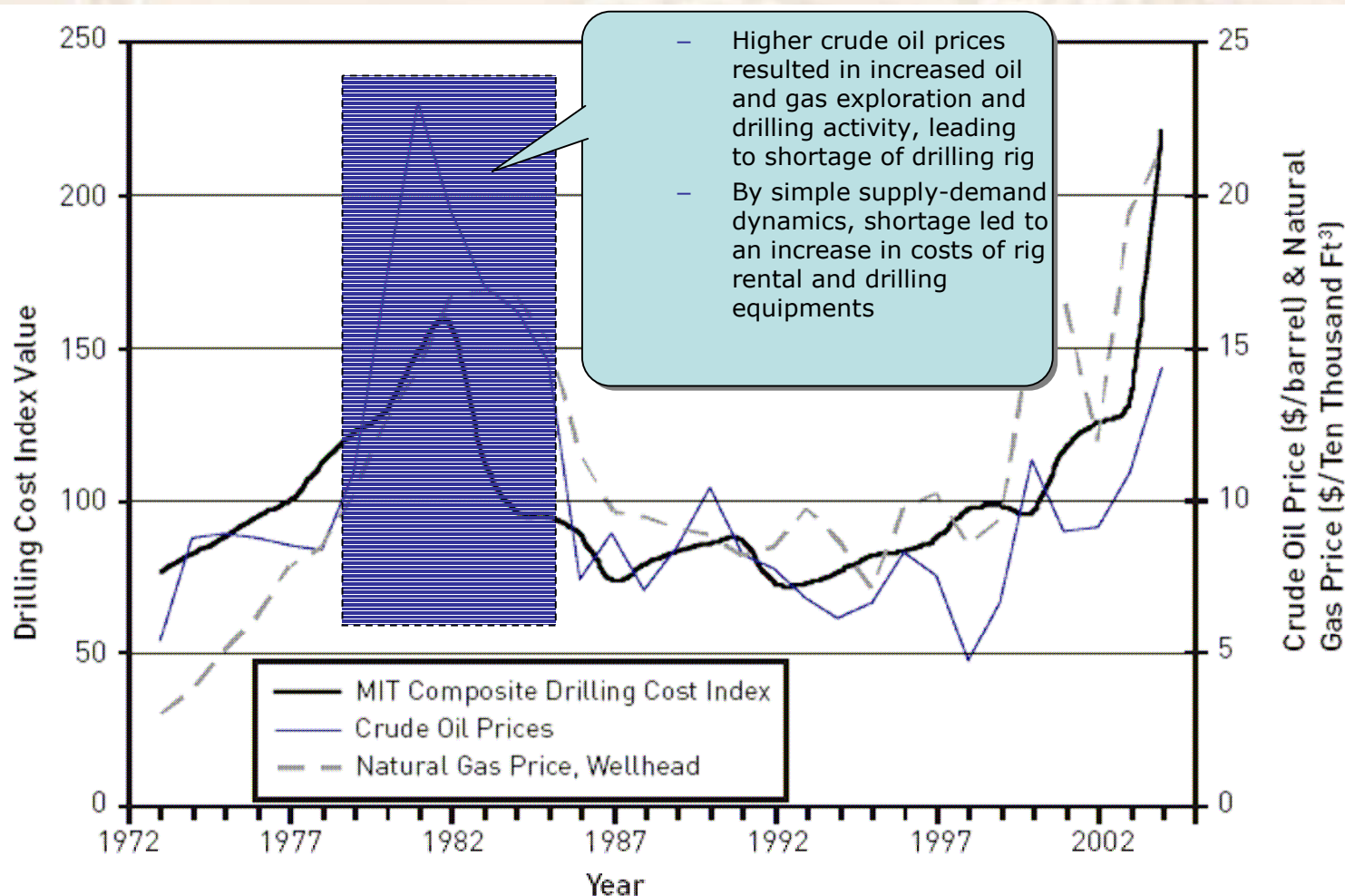
# Industry Implications



# Drilling



Comparison of drilling costs (indexed) to crude oil and natural gas prices



- Historically, significant correlation between drilling cost and crude oil prices
- Current scenario of low crude oil prices, offers attractive opportunities to:
  - Scale up drilling plans
  - Investigate partnerships with drilling players at attractive conditions

# Drilling



## Current oil/gas drilling technologies adaptable to geothermal

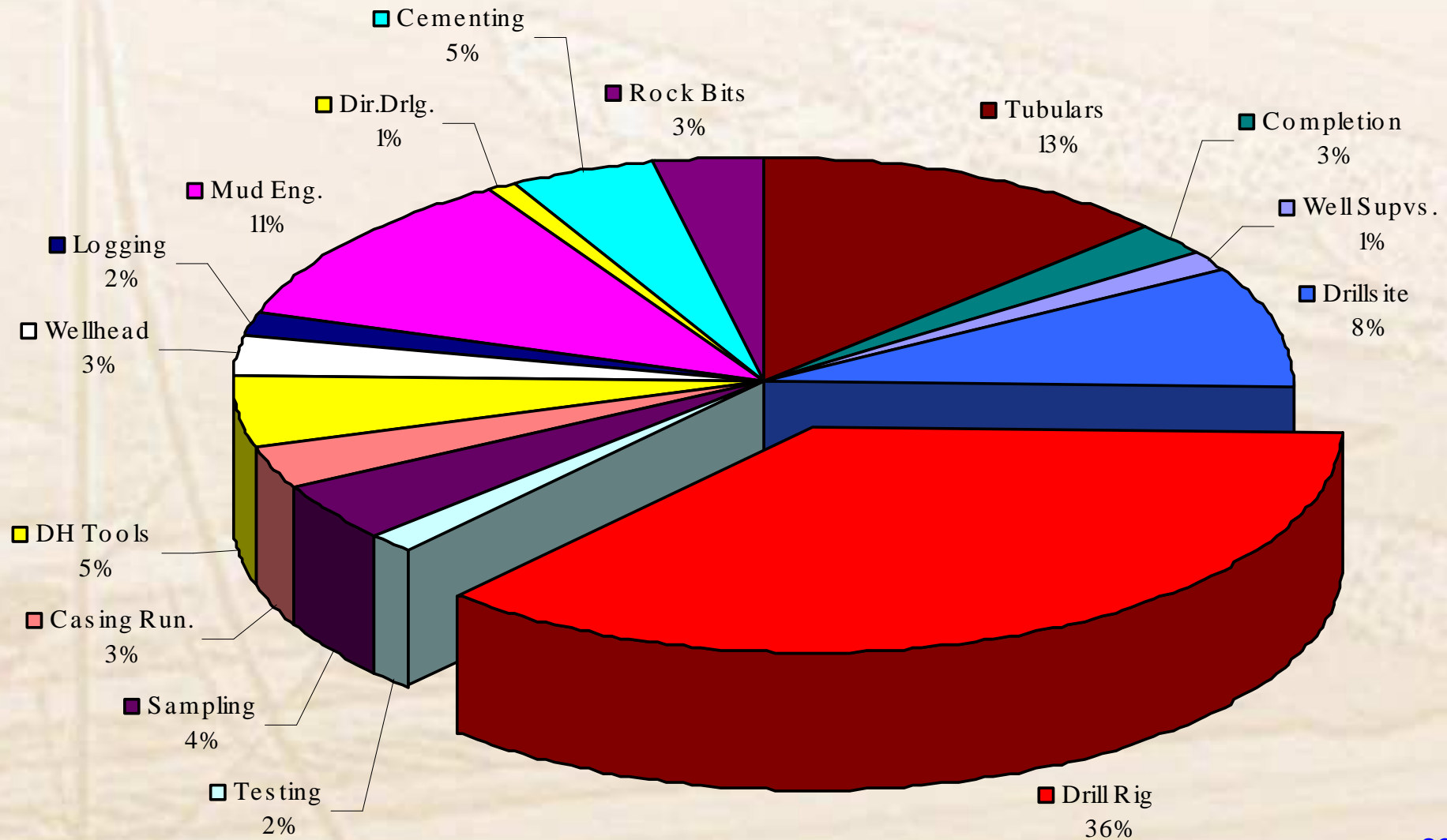
- **Expandable tubular casings:** Shell technology which allows for in situ plastic deformation of tubular casing
- **Under-reamers:** provides cementing clearance for casing strings
- **Low clearance casing design:** accepts lower clearance to use expandable tubulars (under-reamer may be required)
- **Drilling with casing:** permits longer casing intervals and thus results in fewer strings
- **Multilateral completions/stimulating through sidetracks and laterals:** sequentially stimulation of geothermal reservoirs
- **Well-design variations:** extended length of casing intervals will reduce number of casing strings

## Revolutionary new drilling techniques

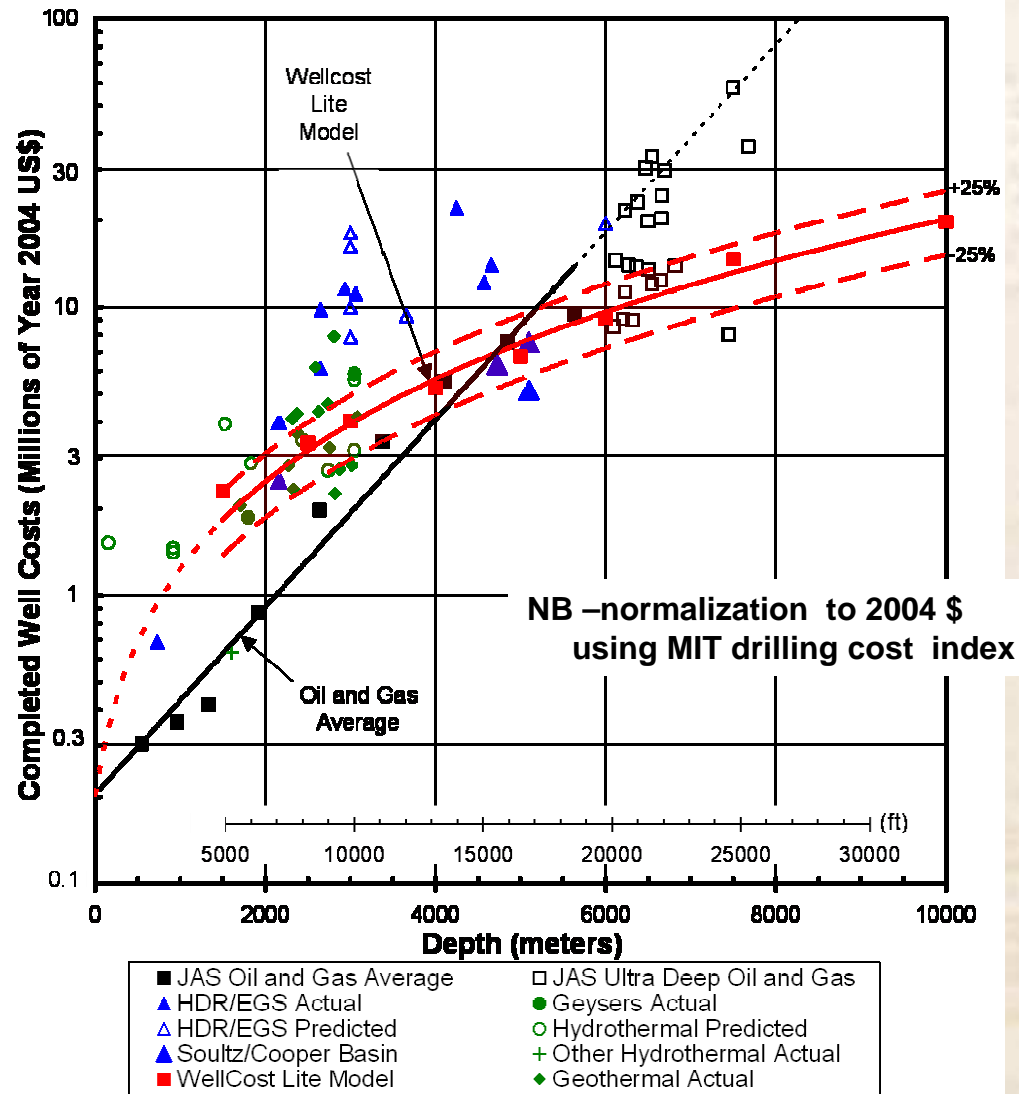
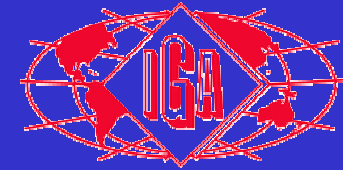
- **Projectile drilling:** projecting steel balls at high velocity using pressurized water to fracture and remove the rock
- **Spallation drilling:** uses high-temperature flames to rapidly heat rock surface and causing it to fracture
- **Laser drilling:** uses laser pulses to rapidly heat rock surface and causing it to fracture
- **Chemical drilling:** involves use of strong acids to break down the rock; may be used in conjunction with conventional drilling techniques

- Impact of adaptation of current drilling technologies may be less significant than lower drilling cost driven by oil sector dynamics
- Effect of revolutionary drilling could instead be significant

# Drilling Cost Distribution

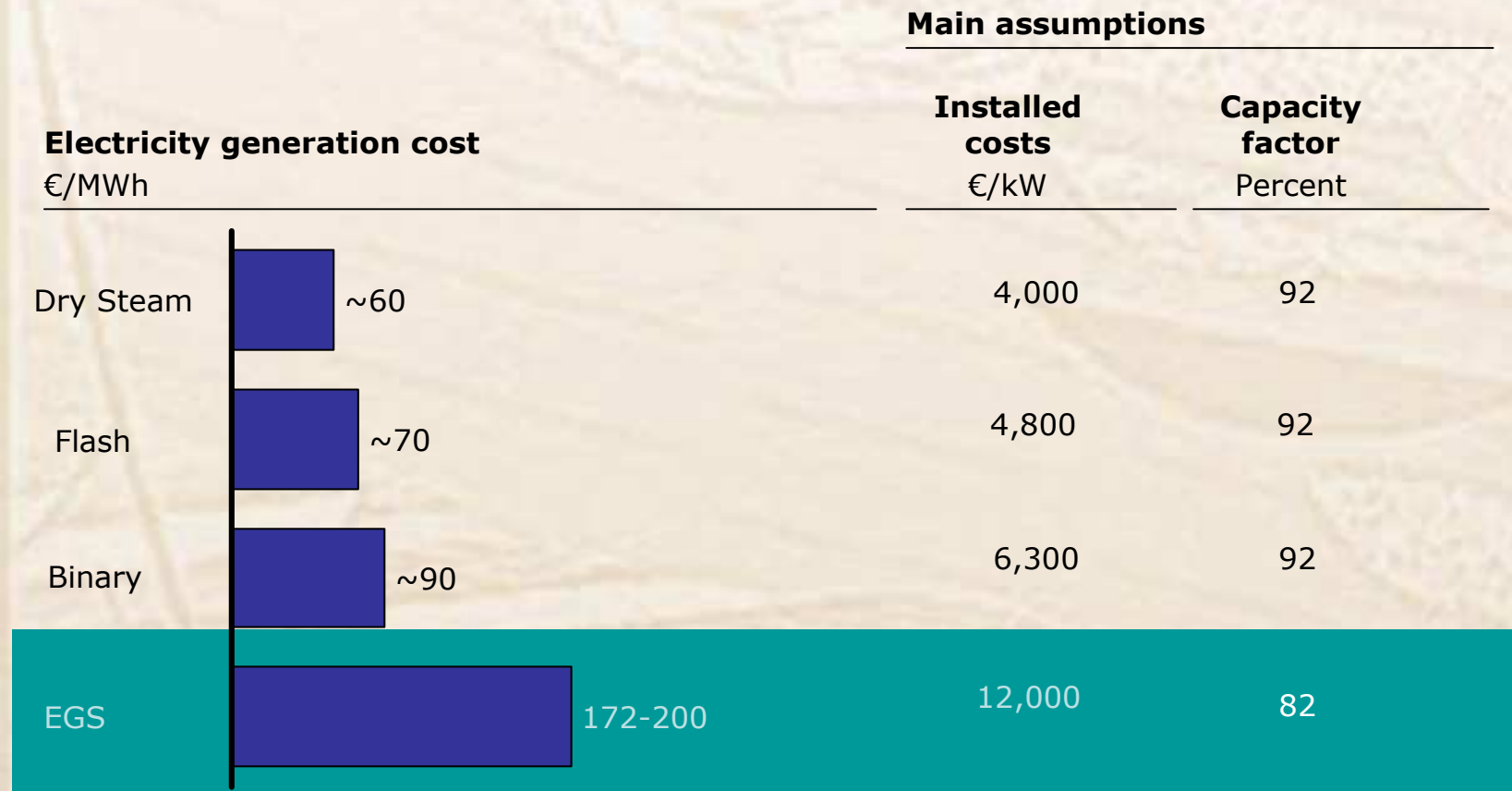


# Drilling Cost

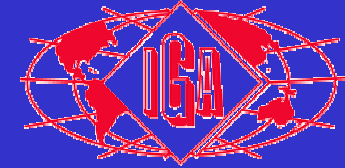


## Drilling Costs – Actual and Predicted

# EGS



# Conclusion



The maximum reduction of CO<sub>2</sub> will be 1000-500 million of tons for electricity and 200 million tons for direct utilizations

- Total geothermal electricity is reaching the value of **9,7 GW** in 24 countries, with 800 MW of increase since 2005; the forecasting for 2010 is about **11 GW**.
- Geothermal energy is not widely diffuse, but its base-load capability and its high availability are key elements for its penetration into the energy market
- Binary plant technology is playing a very important role in the modern geothermal electricity market.
- The possibility of production from enhanced geothermal systems (to be considered as a possible future developments) can expand its availability on a worldwide basis.