Project GEOELEC
"Develop Geothermal Electricity in Europe to have a renewable energy mix" - Regional Workshop: SE Europe
CRES, Athens, December 20, 2011

Current Status and Prospects for Geothermal Electricity in Europe

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Introduction

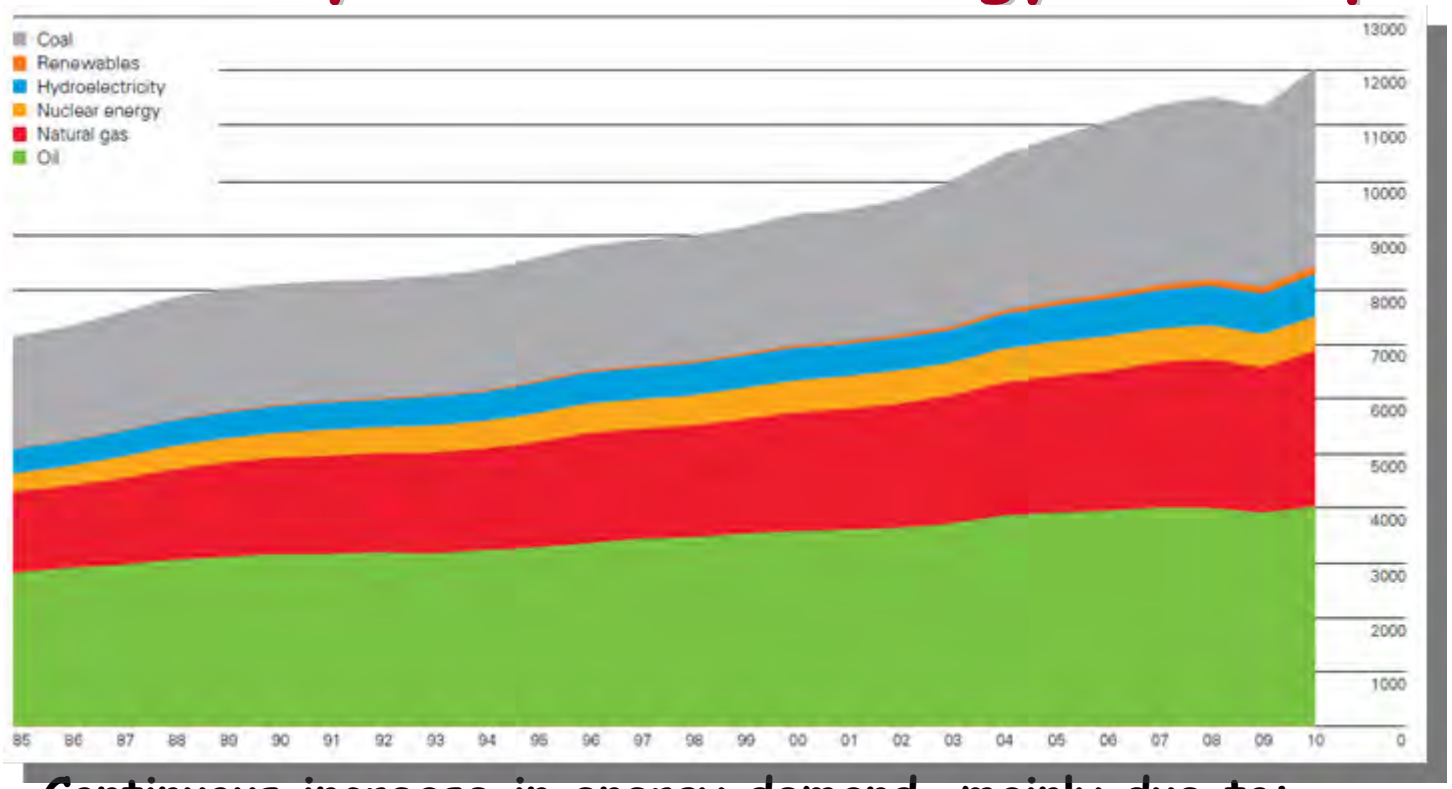
This presentation is mainly based on :

(1) Papers presented at the *World Geothermal Congress 2010*, Bali, Indonesia, April 2010.

(2) Papers, presentations, brochures by R. Bertani, B. Sanner, M. Antics, E. Knapek, EGEC and others

(3) Data by Eurostat, IEA, REN21, BP etc.

Primary world-wide energy consumption



1965 → 2010: ~3,2 times

2001 → 2010: ~27%

2009 → 2010: 5,6%

Continuous increase in energy demand, mainly due to:

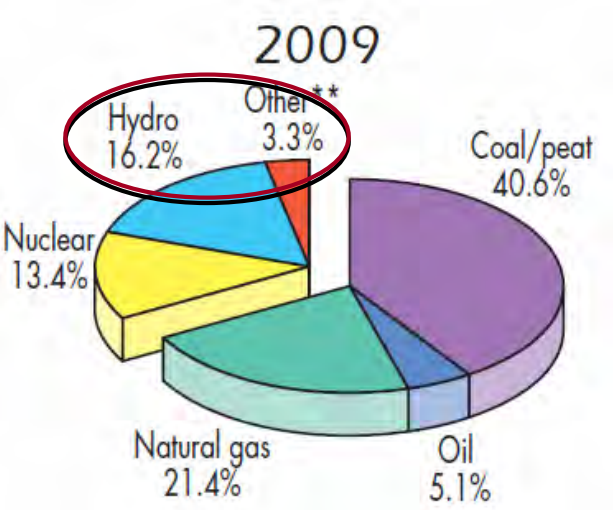
1)Economic growth,

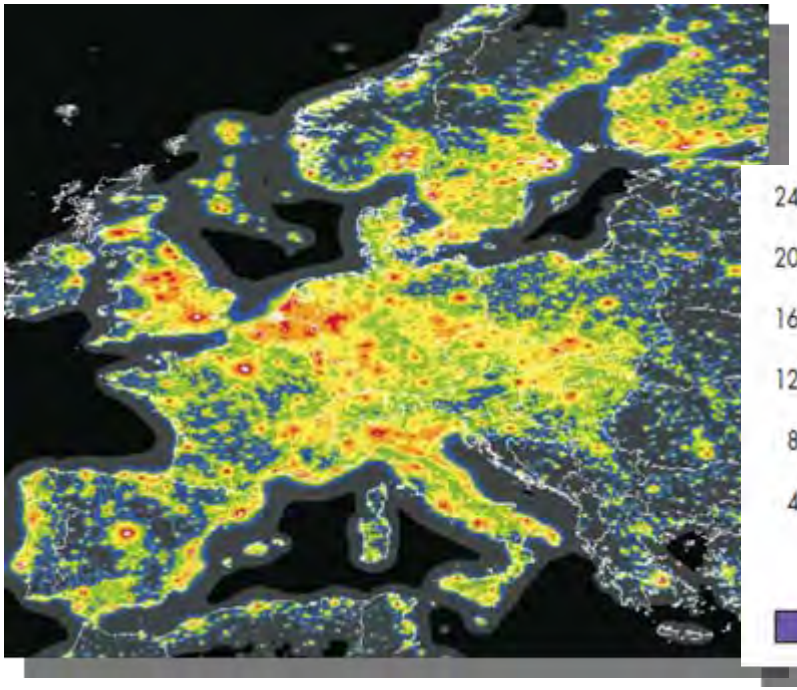
2) Population growth (7 billion, end of October 2011)

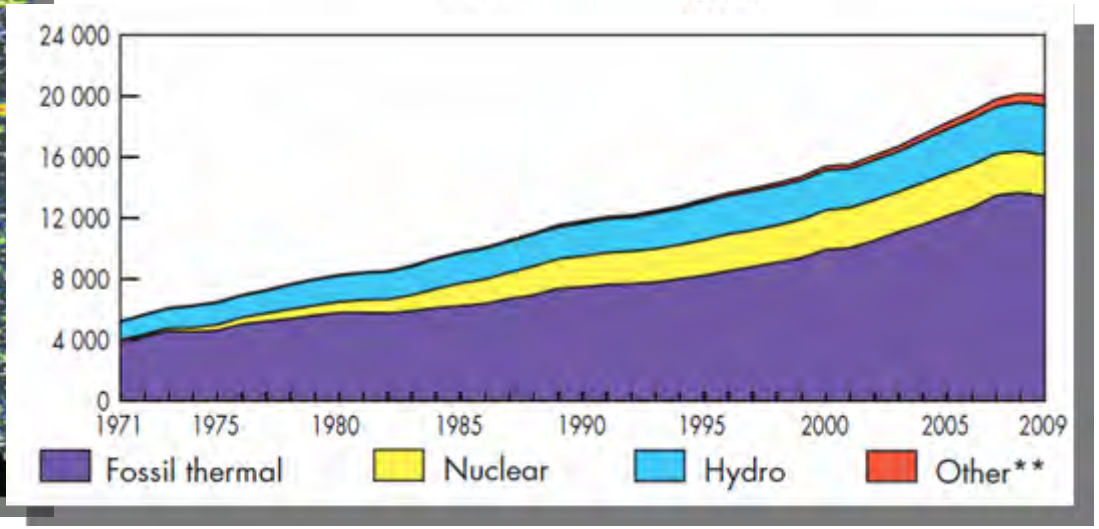
Conventional fuels dominate.

Source: BP statistical review, 2011

Electricity demand







Sources of light across Europe

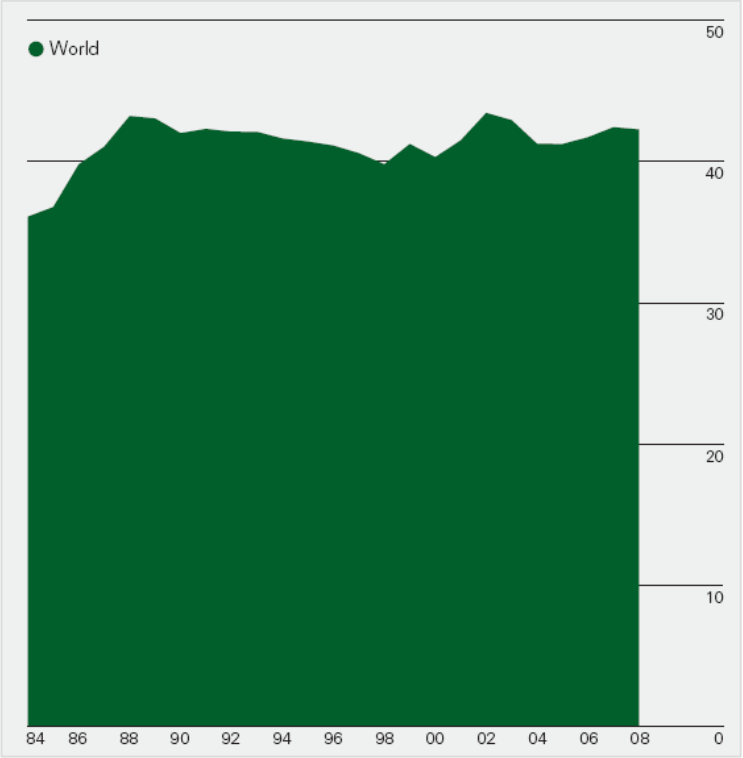
Source: Cinzano et al, Mon. Not. R. Astron. Soc. 328, 689–707 (2001)

World electricity generation from 1971 to 2009 by fuel (TWh)

Source: IEA

Energy resources and supply

- **Coal, oil and gas** are still the dominant players on the energy market.
- Increasing contribution is observed from **hydro-energy**, **new RES** and **nuclear energy**.
- Conventional resources are limited and will be depleted in the near future or it will become more expensive to retrieve them.

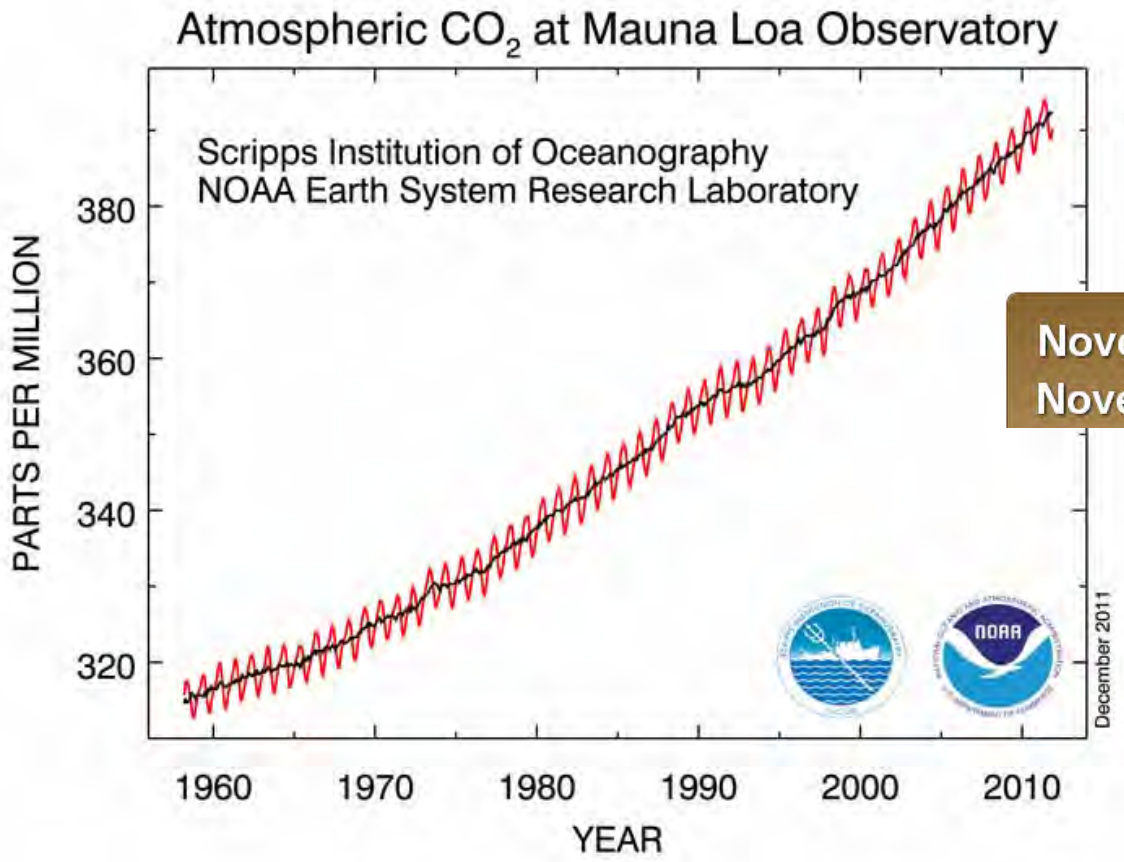


Reserves-to-production (R/P) ratio for oil

Source: BP statistical report 2009

Trends in Atmospheric Carbon Dioxide

(global warming)



November 2011: 390.20 ppm
November 2010: 388.59 ppm

Source: http://www.esrl.noaa.gov

Other Problems: energy dependence

- The EU is the world's largest energy importer, relying on imports for **54%** of its energy needs in 2009. More specifically for the S-E Europe:
- Bulgaria: 45%
- Greece: 68%
- FYROM: 44%
- Malta: 100%
- Romania: 20%
- Turkey: 70%

Solution

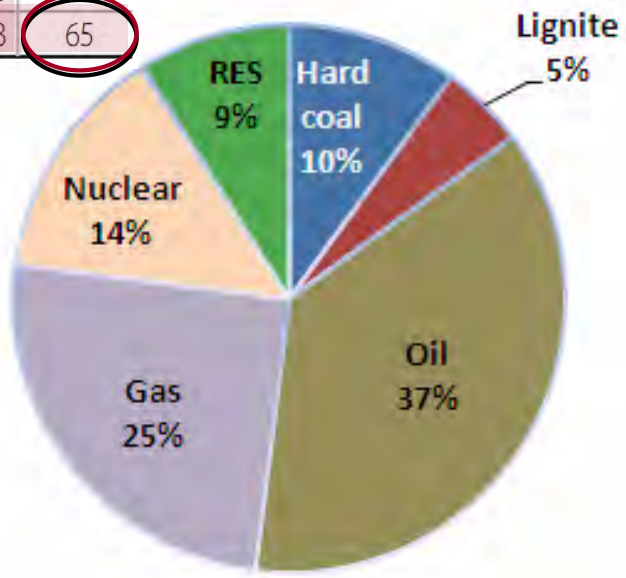
Major substitution of conventional sources by renewable energy sources and GEOTHERMAL ENERGY may play a significant role.

Energy consumption in EU-27

Gross inland consumption, by fuel, EU-27 (Mtoe) b/w 1999-2009

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Change (%)
Total	1 711	1 725	1 763	1 758	1 799	1 818	1 823	1 825	1 806	1 802	1 703	0
Oil	671	661	676	671	675	677	678	674	659	658	623	- 7
Gas	383	394	404	405	425	435	446	438	433	441	417	9
Nuclear	243	244	253	256	257	260	258	255	241	242	231	- 5
Hard coal	222	225	225	221	230	228	222	229	231	212	178	- 20
Lignite	91	95	98	98	101	99	96	96	97	94	90	- 1
RES	93	97	100	98	104	112	116	124	135	144	153	65

Distribution by fuel

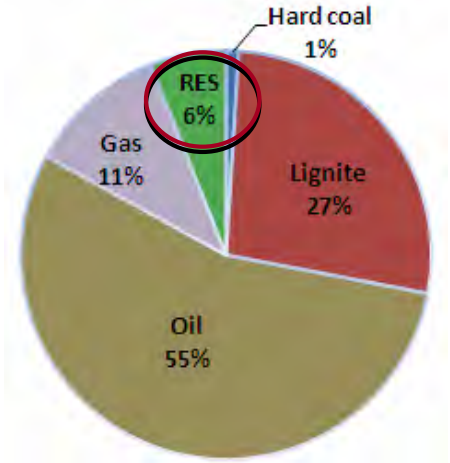


Source: EUROSTAT Pocketbook, "Energy, transport and environment indicators", 2011 ed.

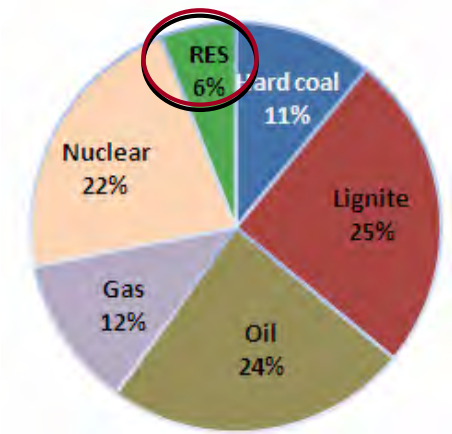
Energy consumption in selected SE-Eu countries

Distribution by fuel in 2009

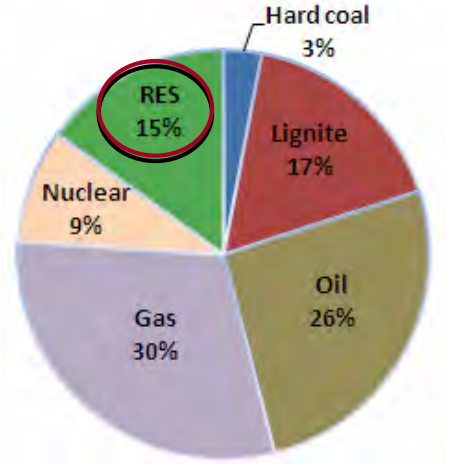
Greece



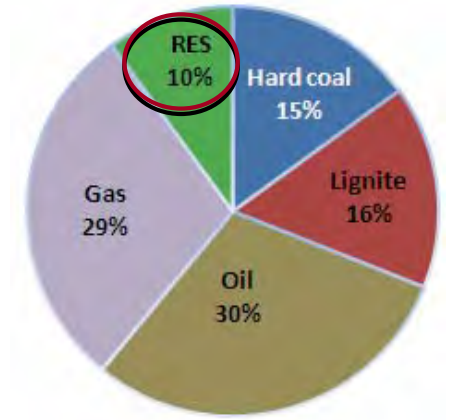
Bulgaria



Romania

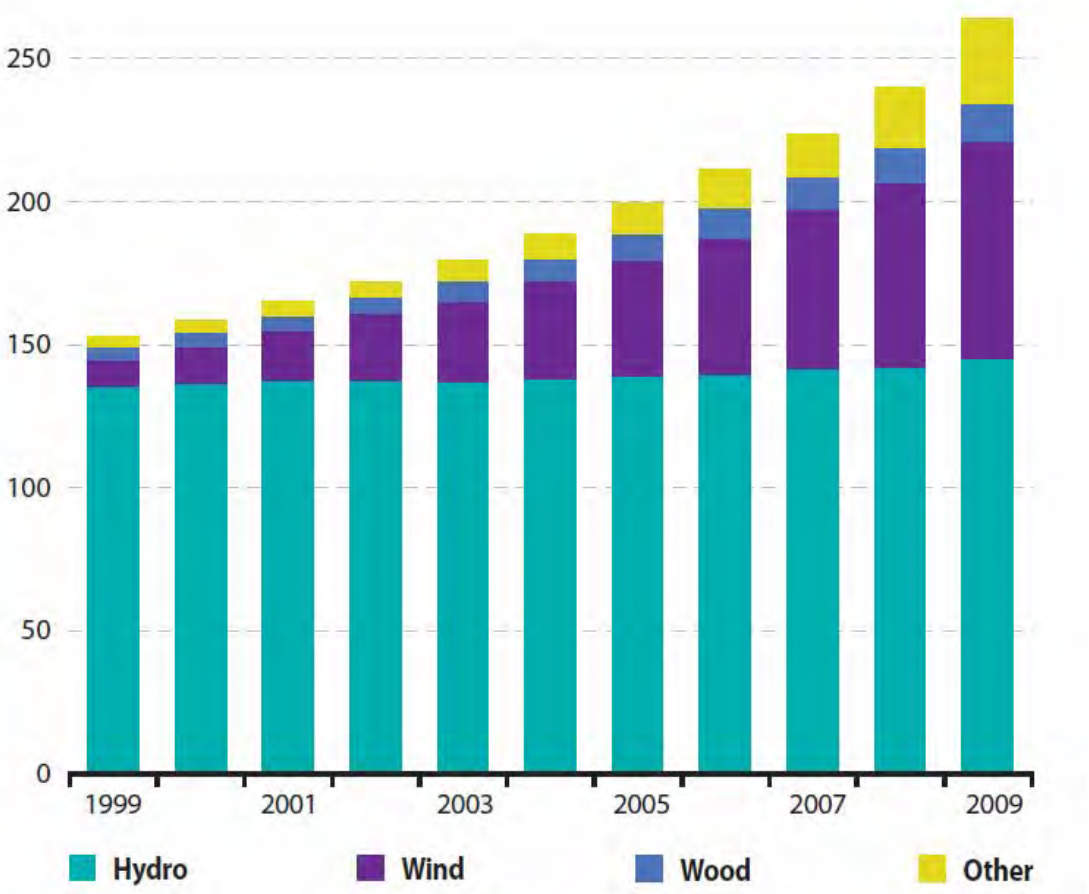


Turkey



Source: EUROSTAT Pocketbook, "Energy, transport and environment indicators", 2011 ed.

Installed capacity for electricity generation from renewables, EU-27 (GW)



Source: Eurostat (online data code: nrg_113a)

The "20-20-20" targets by EU

- **To limit global warming to 2°C, global emissions of greenhouse gases will need to stop increasing within 10 to 15 years and then be cut to around half of 1990 levels by 2050.**

Overall '20-20-20' goal for the Community

- A reduction in EU greenhouse gas emissions of at least **20%** below 1990 levels
- **20%** of EU energy consumption to come from renewable resources
- A **20% reduction** in **primary energy use** compared with projected levels, to be achieved by improving energy efficiency.

Definitions according to EU Directive 2009/28/EC

The following definitions also apply:

- **(a) 'energy from renewable sources'** means energy from renewable non-fossil sources, namely wind, solar, aerothermal, **geothermal**, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases;
- (b) 'aerothermal energy' means .....
- **(c) 'geothermal energy'** means energy stored in the form of heat beneath the surface of solid earth;

Geothermal Energy & Strategy in Europe

Geothermal energy development in Europe:

- In line with overall strategy for sustainable development in Europe.
- In line with addressing growing demand for energy.
- In line with reduction of CO_2 emissions to limit global warming ("20-20-20" strategy)
- In line with strategy for reducing energy dependency.

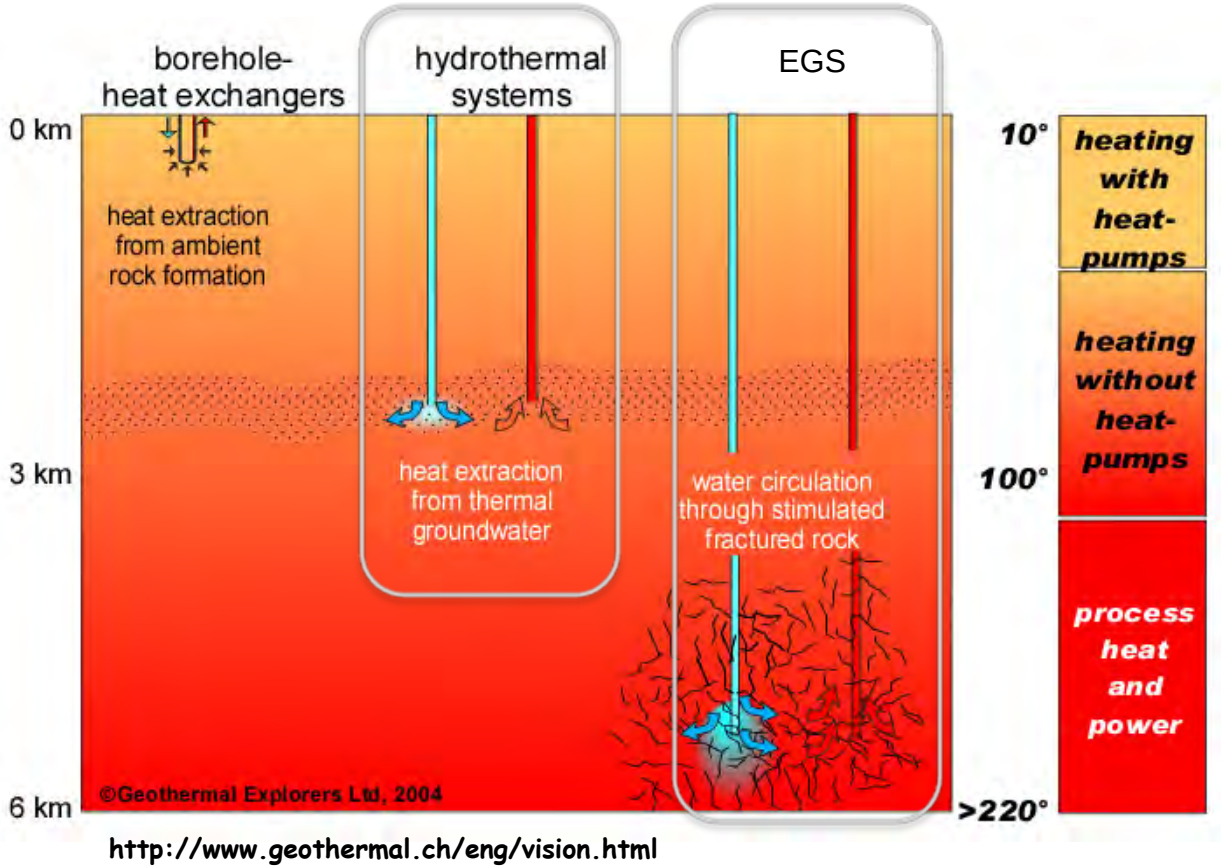
Benefits of Geothermal Electricity

- It is a renewable and a sustainable energy source.
- It generates continuous and reliable power at a low operational cost.
- It provides clean and safe energy.
- It requires the smallest land among RES.
- It mitigates energy dependence.
- Most of technology to exploit it known from Oil & Gas drilling and transport.

Problems

- Site specific and high installation cost.

Systems of Heat Extraction for g/t electricity



- Hydrothermal systems
- Enhanced geothermal systems (EGS)

Types of Geothermal Energy Plants

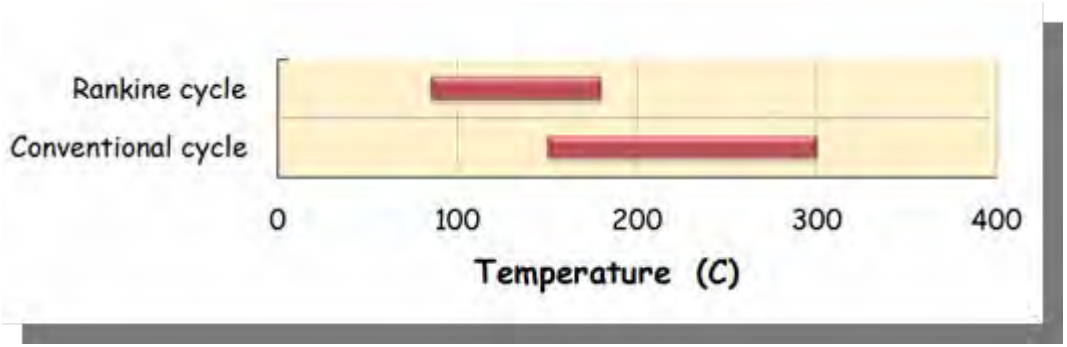
- Commercial geothermal power generation is an established industry.
- The first commercial geothermal plant in 1914 at Larderello.
- There are basically three types of geothermal plants used to generate electricity.

  (a) direct steam

  (b) flash steam

  (c) binary plant

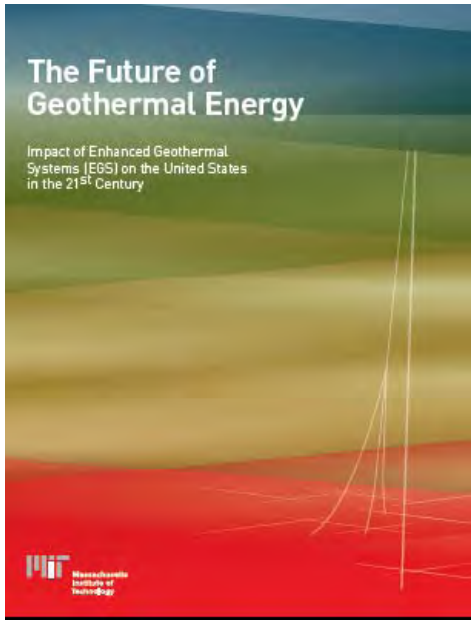
  + Hybrid



- The type of plant is determined primarily by the nature of the geothermal resource.
- Geothermal binary power plants have gained increasing interest in the recent years (also in relation to EGS)

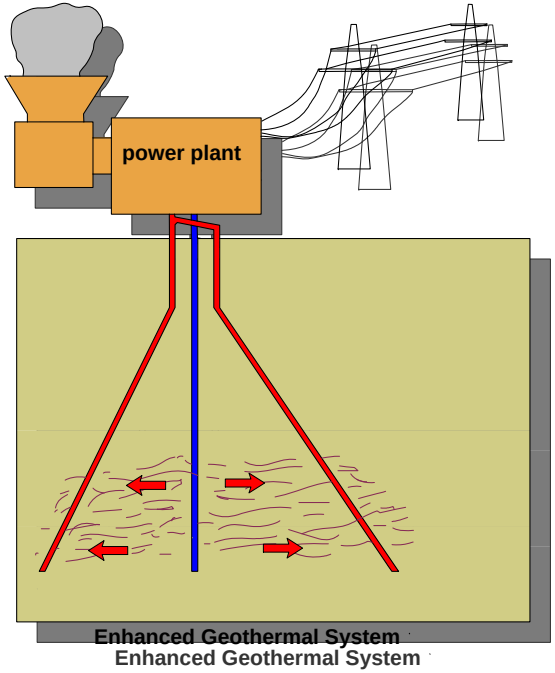
Enhanced Geothermal Systems

- U.S. Department of Energy: **Enhanced Geothermal Systems** (EGS) are engineered reservoirs that have been created to extract economical amounts of heat from low-permeability and/or porosity geothermal resources.
- The future commercialization of EGS depends on **solving technical** and **economic issues**.
- A major barrier are the **costs of drilling** the wells, **the supply of water** and the **pumping** of the produced hot water.
- EGS work is based on the concept outlined in a patent issued to the Los Alamos National Lab in 1974.
- Upper 10 km of crust in US has 600,000 times annual US energy (USGS)



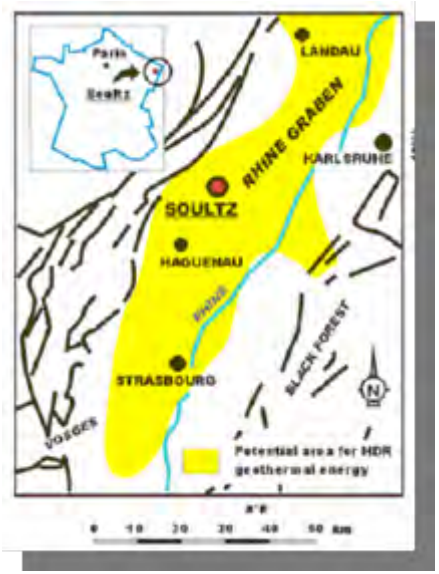
Tester et al, MIT, 2006

Enhanced Geothermal Systems



Enhanced Geothermal System

Principle of EGS system for geothermal power production



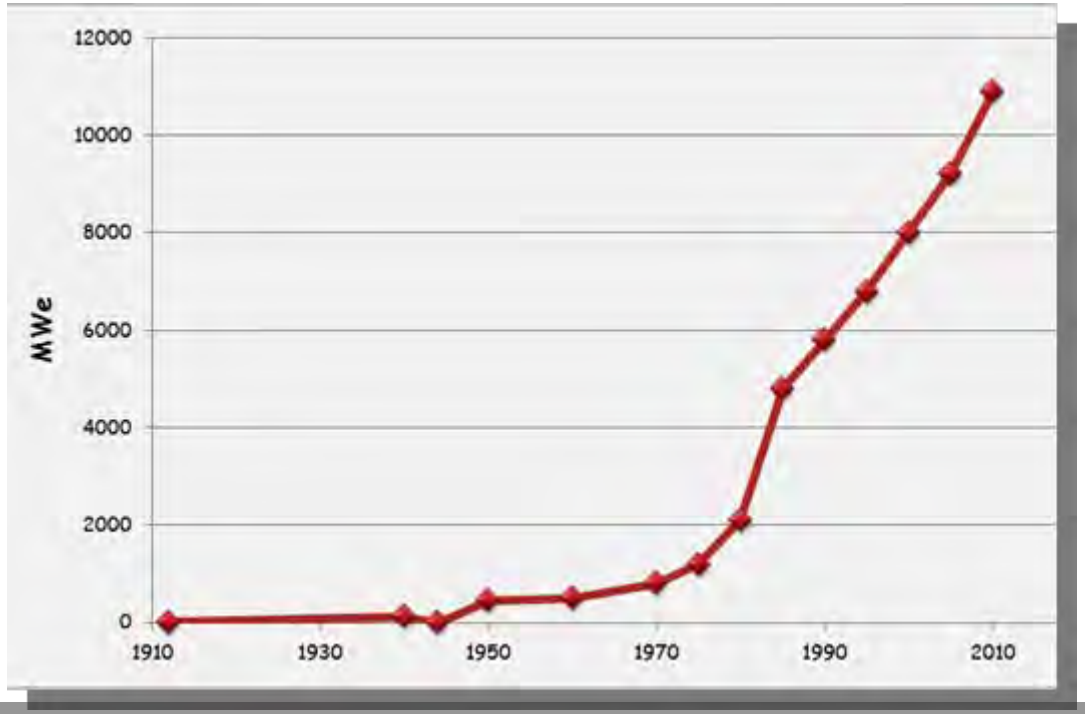
Interesting and challenging European research project at Soultz-sous-Forêts, France (5 km, 200°C, 100 l/s, 6 MWe)

Drilling rig at the European R&D site Soultz-sous-Forêts

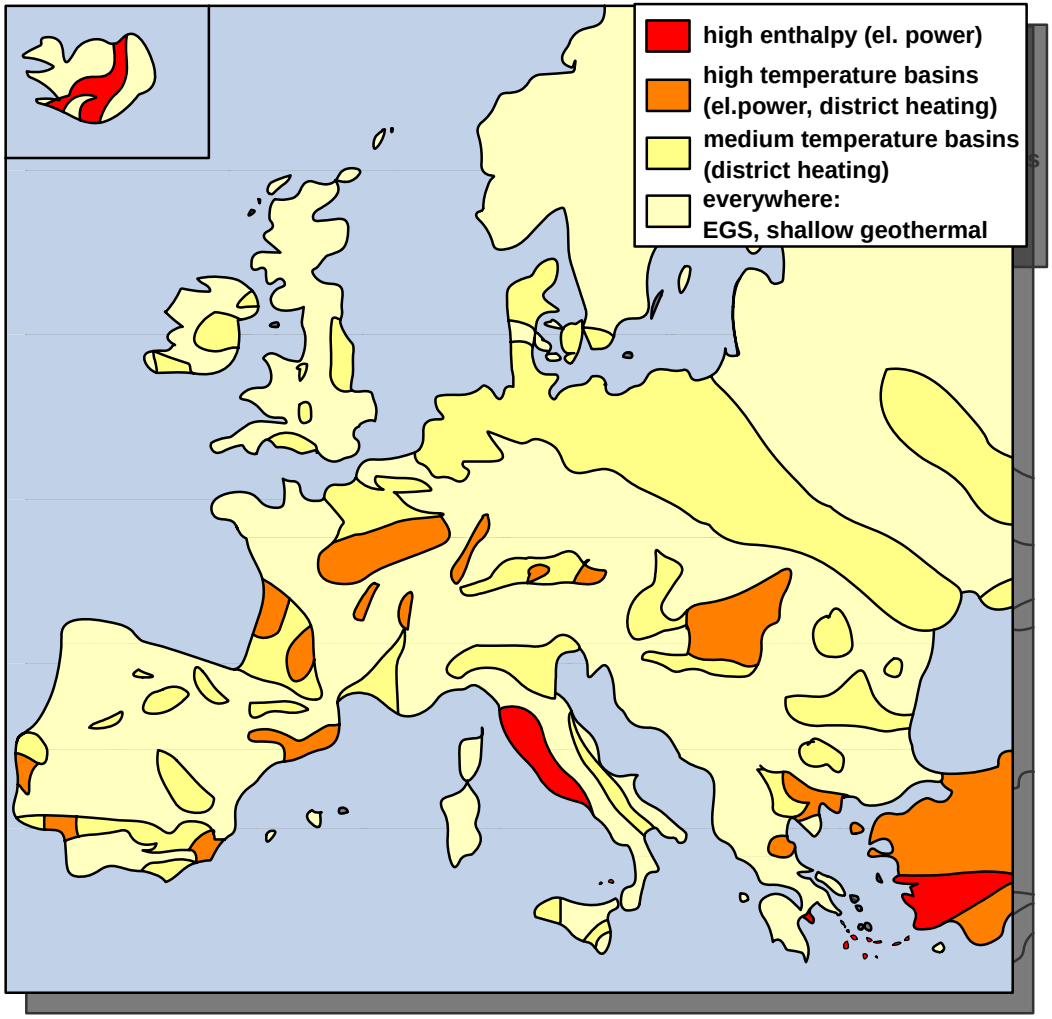
Source: B. Sanner, 2008

Geothermal power generation in the world (2010)

- **24 countries** now generate electricity from geothermal resources
- The total installed capacity worldwide: **10,898 MW**
- **Top 5 countries**: USA, Philippines, Indonesia, Mexico and Italy.

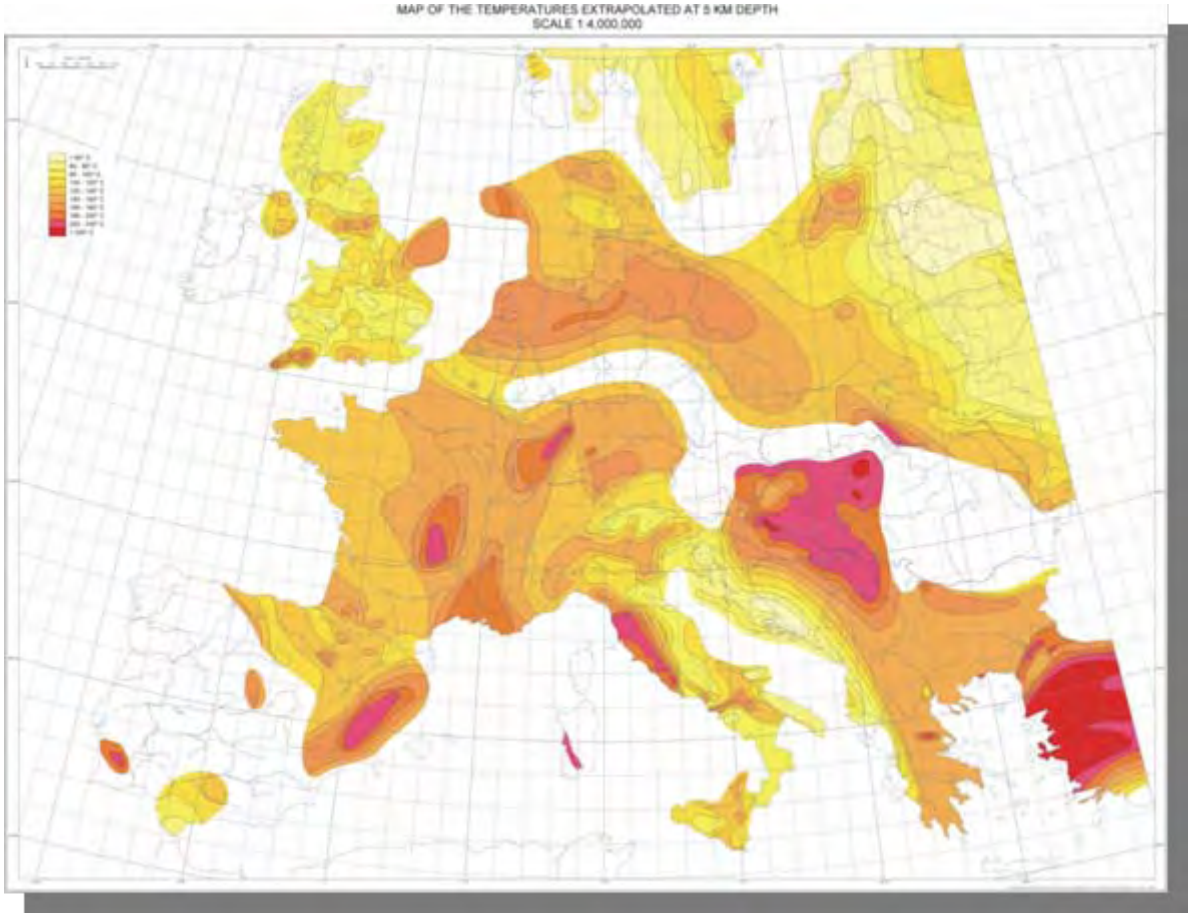


Geothermal Potential in Europe



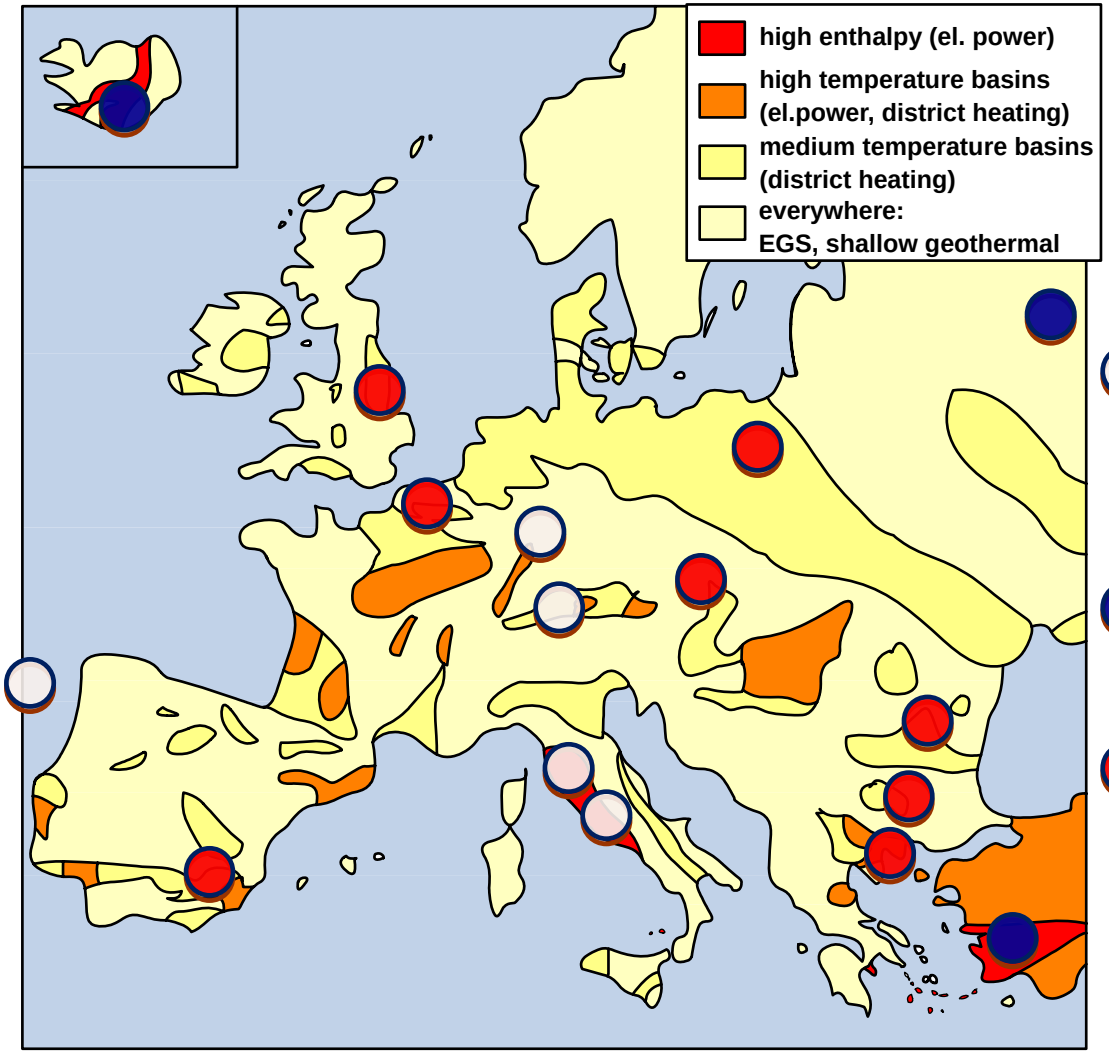
- Europe has significant geothermal resources both in volcanic and sedimentary basin environment.
- The map shows the main basins and high-enthalpy geothermal areas.

Geothermal Potential in Europe



Map of temperatures extrapolated at 5 km depth

Geothermal Electricity Generation in Europe



The map shows the sites of geothermal electricity generation.

EU-27: Italy, France (overseas), Portugal (Azores), Germany, Austria

Other: Iceland, Turkey, Russia

Possible Newcomers: Greece, Poland, UK, Hungary, Slovakia, Romania, Spain, the Netherlands

Geothermal Electricity in EU (Bertani, 2011)

	Capacity installed 2010 (MW)	Expected Capacity 2015	Geothermal resources
Italy	843	923	High/Low
Portugal	29	60	High
France*	17,4	35	High
Germany	6,6	15	Low
Austria	1.4	5	Low
Greece		30	High/Low
Spain		40	Low
Czech Re.		5	Low
Romania		5	Low
Slovakia		5	Low
Netherlands		5	Low
Poland		1	Low
Total	897,5	1134	

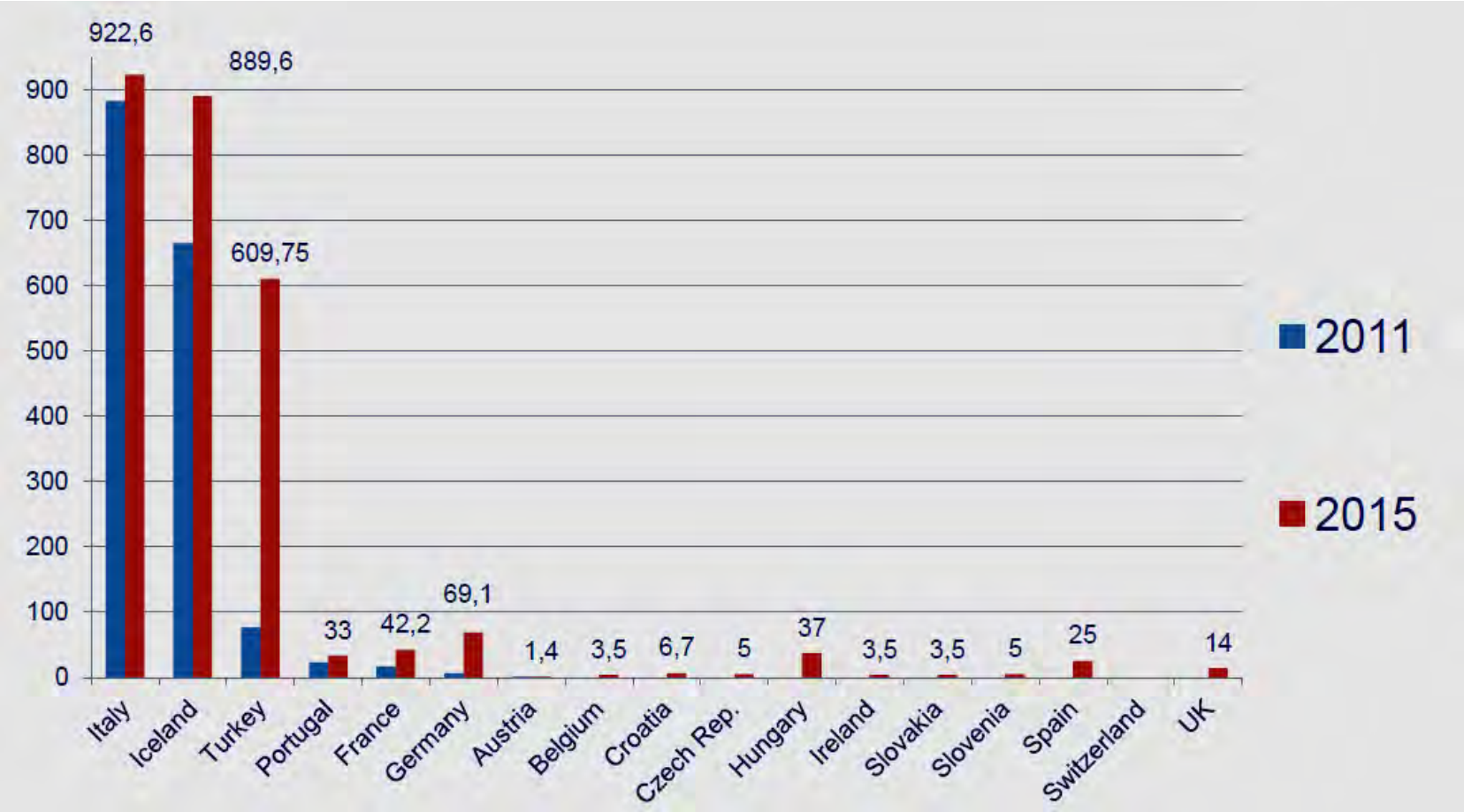
*Overseas departments included

Geothermal Electricity in other European countries (Bertani, 2011)

	Capacity installed 2010 (MW)	Expected Capacity 2015	Geothermal resources
Iceland	573	800	High
Turkey	87	206	High/Low
Russia	82	194	High
Total	742	1200	

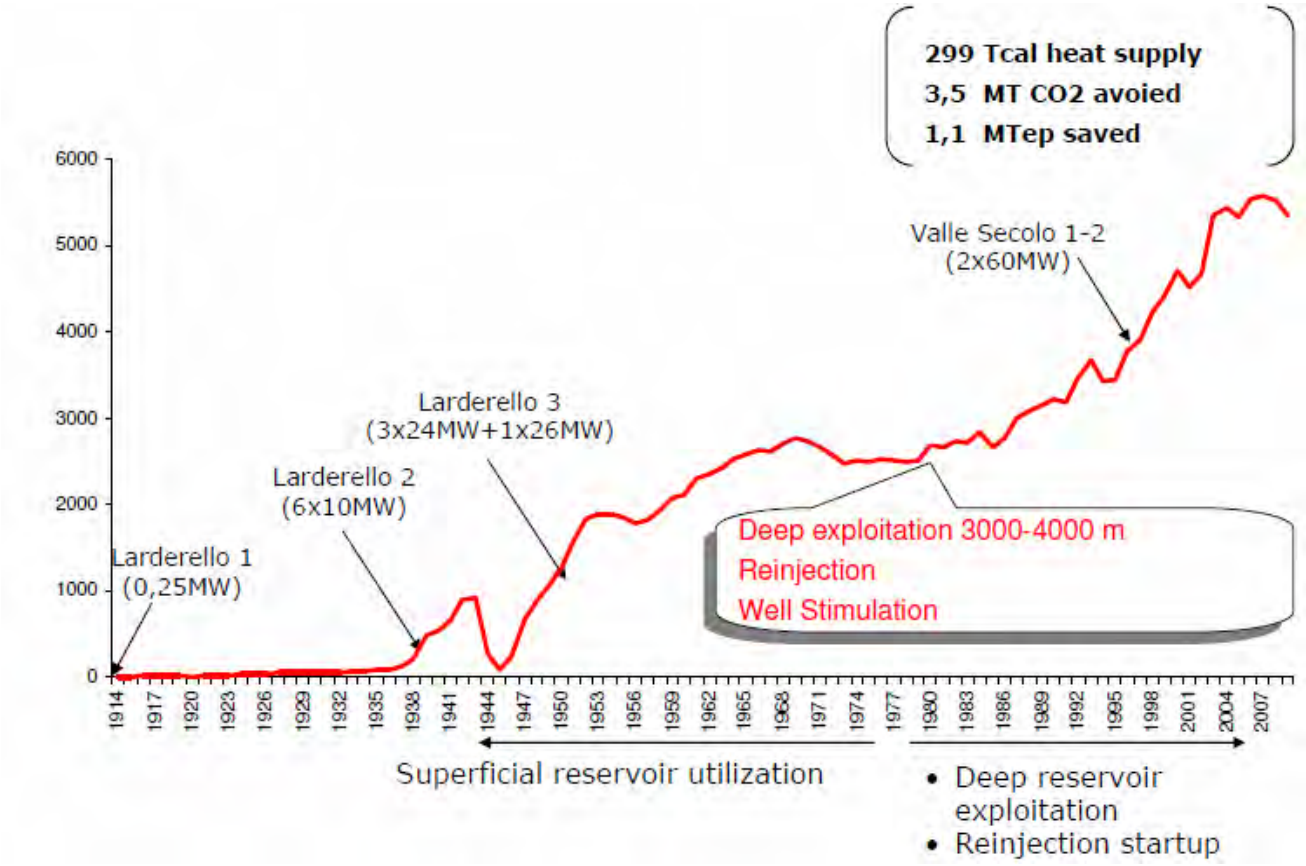
Currently 59 plants in Europe (47 in EU-27)

Installed and forecasted Capacity per Country



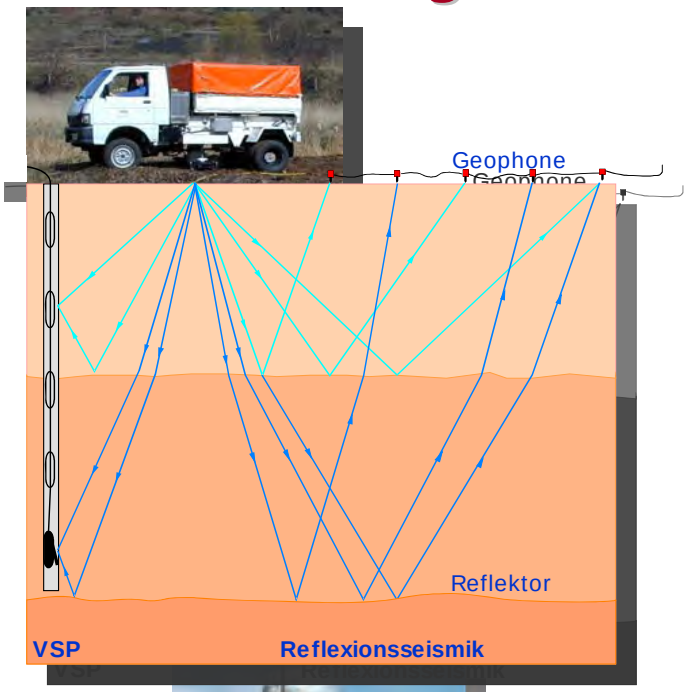
Source: J.P. Gibaud, Launch of the EGEC Deep Geothermal, 2011

History of Italian Production



Geothermal CHP: The Case of Unterhaching

- A city of 22000 inhabitants, SW of Munich
- **1998:** Analysis of energy consumption, basis for RES planning (solar, biomass, geothermal)
- **2001:** Decision to proceed with the geothermal project.
  - Some difficulties with the authorities in Bavaria, where 60% of electricity coming from nuclear energy.
  - Start with seismic exploration
  - Borehole design (plan for 26 MW)
- **2004, Sept. 24:** completion of borehole 1 (150 l/s, 123°C, vertical depth 3.350 m)
- **2007, Jan. 17:** completion of borehole 2 (>150 l/s, 133°C, vertical depth 3.580 m, much better injectivity)



Source: Dr. E. Knapek, Feb. 2011

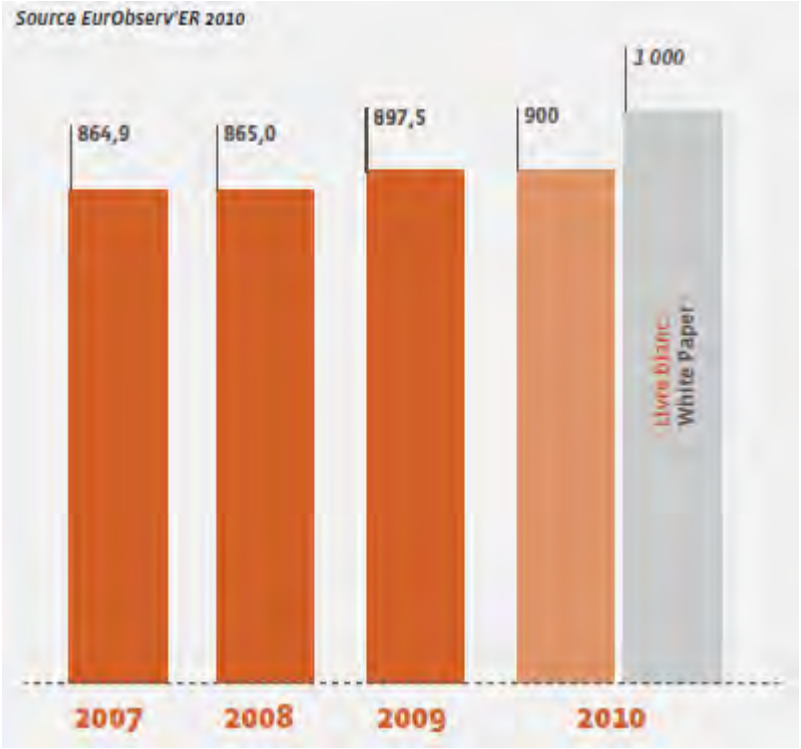
Geothermal CHP: The Case of Unterhaching (II)

- Power generation: Base load 125 l/s
- Kalina cycle (NH_3+water: 85%-15%)
- Cost of 2 wells: € 20 mil.
- Start: summer 2008

In 2010

- Heat power demand at the customer's side: 46,5 MW
- Peak of necessary geothermal power: **26 MW**
- Peak electrical power: **2.9 MW**
- Electricity price: 230 €/MWh (constant for 20 years)

Geothermal Electricity in EU



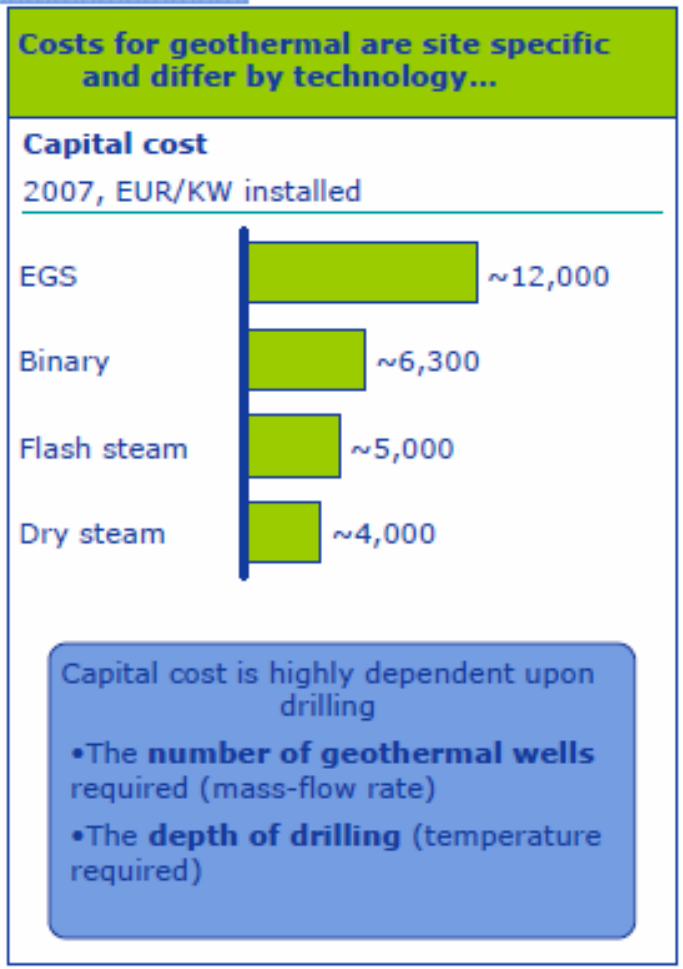
Comparison of current trend with White Paper objectives for geothermal electricity production in MW_e (10th EurObserv'ER Report, 2011)

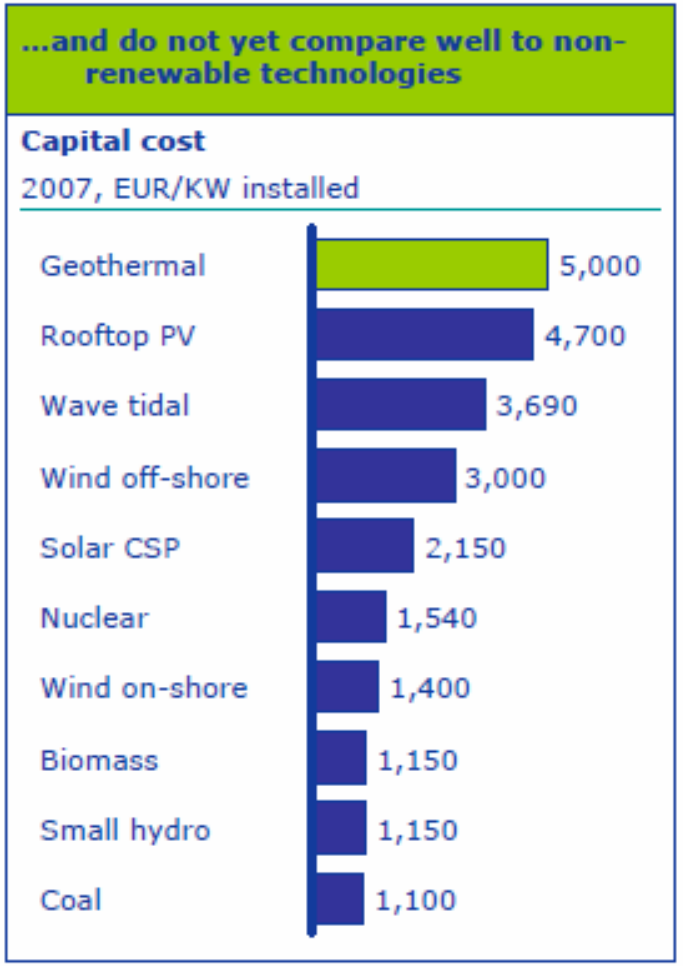
Cost Factors

- Temperature and depth of resource
- Type of resource (steam, liquid, mix)
- Type of g/t systems (hydrothermal, EGS)
- Available quantity of resource
- Chemistry of resource
- Permeability of rock formations
- Size and technology of plant
- Infrastructure (roads, transmission lines)

Modified, http://www.worldbank.org/html/fpd/energy/geothermal/cost_factor.htm

Capital costs for Geothermal & other plants





Source: R. Bertani, 2011

Geothermal Power Capital Costs by Project Development Phase (2004 US$)

Table 2.6: Geothermal Power Capital Costs by Project Development Phase (2004 US$)

Item	*200 kW Binary Plant*	*20 MW Binary Plant*	*50 MW Flash Plant*
Exploration	300	320	240
Confirmation	400	470	370
Main Wells	800	710	540
Power Plant	4,250	2,120	1,080
Other	1,450	480	280
Total	**7,200**	**4,100**	**2,510**

Source: ESMAP Technical Paper 121/07, December 2007

Future of Geothermal Electricity in EU

According to EGEC

- Geothermal energy can substantially contribute electricity production, with ~20% of the total EU consumption
- **By 2020**: Strengthening the European geothermal industry by developing hydrothermal resources in Europe and expanding the EGS concept,
- **By 2030:** Towards a competitive source of energy by bringing down EGS plant cost, and transferring EGS technology outside Europe.
- **By 2050:** Powering Europe and the world from geothermal with EGS developed everywhere at a competitive cost, replacing conventional base-load power plants (coal, nuclear, fuel, etc.)

Future of Geothermal Electricity in EU

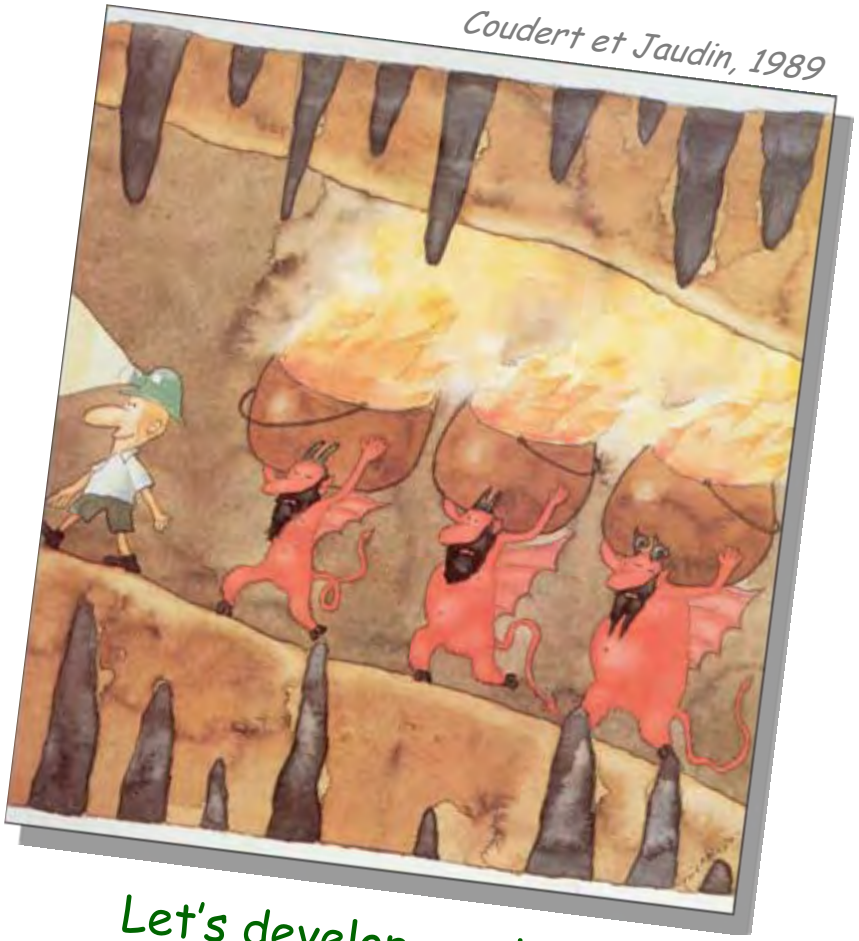
Table 1 Geothermal Electricity and Heating & Cooling up to 2050

Geothermal Electricity - EU-27	2010	2020	2030	2050
Electricity conventional (MWe)	990	1,500	*7,000*	*10,000*
Electricity EGS (MWe)	10	4,500	*15,000*	*90,000*
Total Installed Capacity (MWe)	1,000	5,000	20,000	100,000
Yearly Electricity Production (TWh)	8	50	234	780
Heating & Cooling - EU-27 (Mtoe)	2010	2020	2030	2050
Geothermal Heat Pumps	2.3	6	*12*	*70*
Geothermal Direct uses	1.8	2.5	*6*	*20*
Heating from CH&P	0.2	2	*12*	*60*
Total Heat and Cold Production	4.3	10.5	30	150

EGS in Europe…

Source: J.P. Gibaud, Launch of the EGEC Deep Geothermal, 2011

Thanks for your attention!



Let's develop our local energy sources