Forecasts of geothermal development 2008-2020 in the EU 27

by

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Contents

Looking at the past.....

- Not knowing what happened before us is like remaining children for ever .....

CICERO

- Only looking at the past, we can look better into the future .....

CHURCHILL

This applies also to geothermal forecasts...

1. Overview and trends of geothermal development in the world 1950-2008

1.1) Table 1: Growth of geothermal energy 1950-2010 (after Cataldi-Passaleva, 2009)

Year (Dec.)	Power generation (MWe)	Annual growth rate (%)	Direct Uses * (MWt)	Annual growth rate (%)
1950	200		unknown	
		6.2		?
1955	270		unknown	
		7.3		?
1960	386		unknown	
		6.2		?
1965	520		2500	
		6.7		2.3
1970	720		2800	
		10.4		2.7
1975	1180		3200	
		12.3		2.4
1980	2110		3600	
		17.7		10.-
1985	4764		5800	
		4.1		3.8
1990	5834		7000	
		3.1		1.6
1995	6800		7579	
		3.6		12.2
2000	8100		13,500	
		2.2		14.8
2005	9000		27,000	
		2.8		c. 14.-
2010	10,300		52,000	

Average growth rate 1950-2010 (%/y)….. 6.8 ……………………………………… 8.-

%1. Overview and trends of the world geothermal development 1950-2008

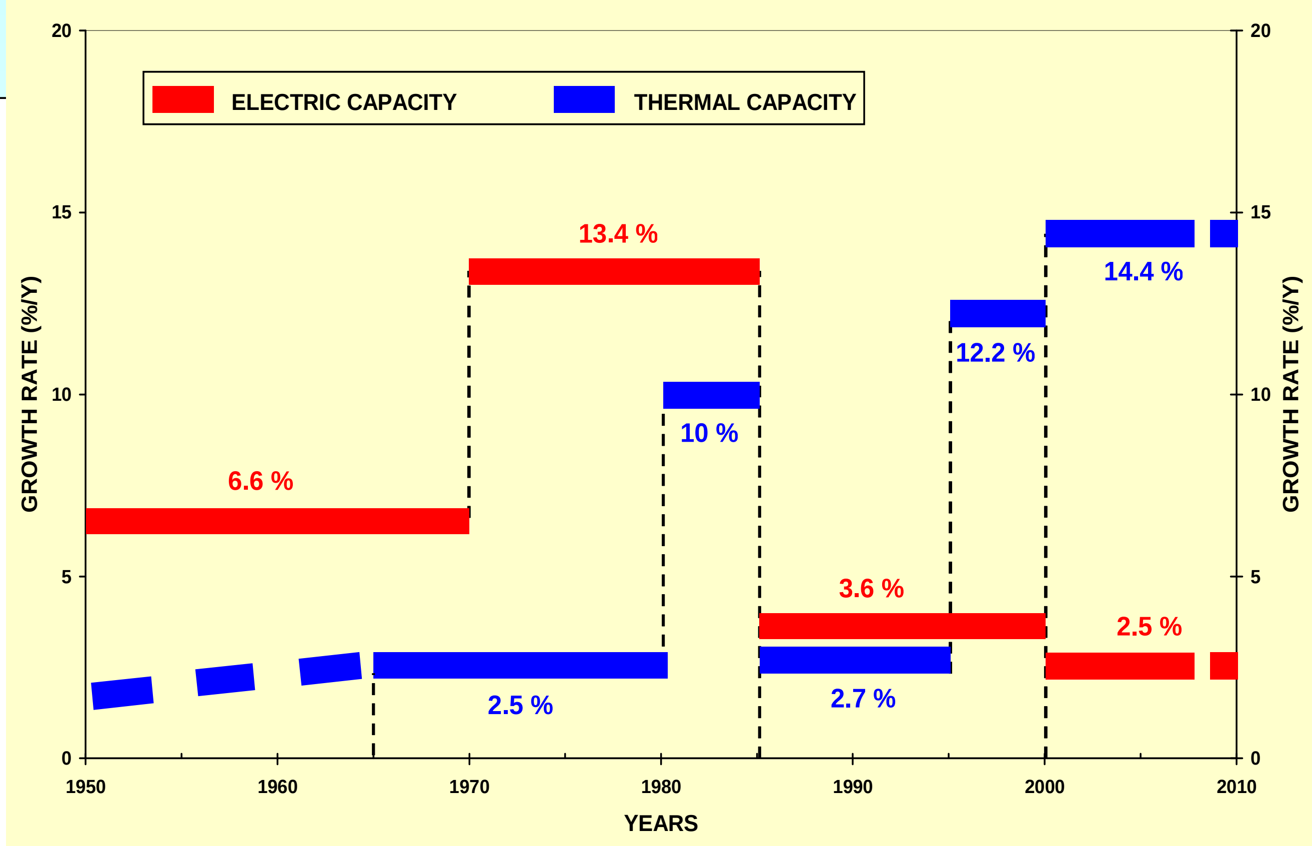

Fig. 1**: Levelled annual growth rates of geothermal development 1950-2010 by homogeneous groups of periods* ***(after Cataldi 2004, with up-datings)

%1. Overview and trends of the world geothermal development 1950-2008

1.3) Synopsis of levelled growth rates (from Fig.1)

Since 1950, power generation and direct uses have grown at different rates:

- ***power generation*** **with 3 growth periods:**
  - **1950-1970 : 6.6 %/y;**
  - **1970-1985 : 13.4 %/y; and**
  - **1985-2010 : 2.5-3.6 %/y.**
- ***direct uses*** **with 4 growth periods, at times different from those above:**
  - **1950-1980 : < 2.5 %/y;**
  - **1980-1985 : 10 %/y;**
  - **1985-1995 : 2.7%/y ; and**
  - **1995- 2008: 12.2-14.4 %/y.**

  The latter is largely due to space heating, including a 30% contribution from GSHP.

In short, with reference to the last two decades, the annual growth rates have:

- ***for power generation*** **sharply declined after 1985, and are still facing a slow growth;**
- ***for direct uses*** **notably increased after 1995, and are running now a "flourishing age".**

AT THIS POINT A QUESTION ARISES ……….

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%1. Overview and trends of the world geothermal development 1950-2008

1.4) Why the decline of power generation after 1985 ?

There are three groups of main reasons causing the decline:

a) At the global scale:

- **scarce economic competitivenes of geo-electric energy till 2005 approx.**

b) At the country scale:

- **shortage of financial resources in most developing countries;**
- **inadequacy of legal provisions in the energy sector in many countries;**
- **no consideration given to the contribution of geothermal resources in the energy master plans of many countries *(including some countries with high geothermal potential)*;**
- **lack of human resources and technical means in most developing countries;**
- **uncertain political situation in some countries with high geothermal potential;**
- **no support given by international Institutions or Governments of rich countries to implementation of geothermal projects in developing countries.**

c) At the local scale:

- **environmental concern in most countries for development of high-T° resources;**
- **opposition to geo-electric projects by local populations due to concern for impact on economy, tourism, cultural traditions and life-style.**

Examples: *Argentina* (Copahue), *Costa Rica* (Rincòn de la Vieja), *Greece* (Milos and Nysiros), *Italy* (Mt. Amiata), *New Zealand* (Oaaki), and *USA* (Puna, Hawaii).

All the above should be taken into account when making forecasts at the continental scale.

2. Geothermal categorization of Europe

(after Cataldi, 1999 with revision)

2.1) General and background

- **Reference is made to the whole geographical Europe, including Asian parts of Russia and Turkey, and overseas territories of France, Portugal and Spain (total surface area: $28x10^6$ km^2 approx).**
- **Due to its complex geodynamic history, the thermal regime of Europe displays a wide variety of heat flow density values: from < 10 to > 300 mW/m^2 (*Fig. 2*).**
- **Based on heat flow and temperature data (*Fig. 3*), on tectonics, volcanology, litho-stratigraphy, and hydrogeology of the various geological provinces in Europe, and on information from deep drillings for oil and geothermal exploration, the regional categorization has been made of the entire Europe.**
- **Four categories of areas in decreasing order of potential interest have been singled out, which have been labeled Category I, II, III and IV, respectively.**
- **Categories I and II designate zones with high concentration of heat at T >150 °C within 3-5 km depth; Categories III and IV designate zones that, within the same depth, display moderate-to-low concentration of heat at T < 150 °C.**

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2. Geothermal categorization of Europe

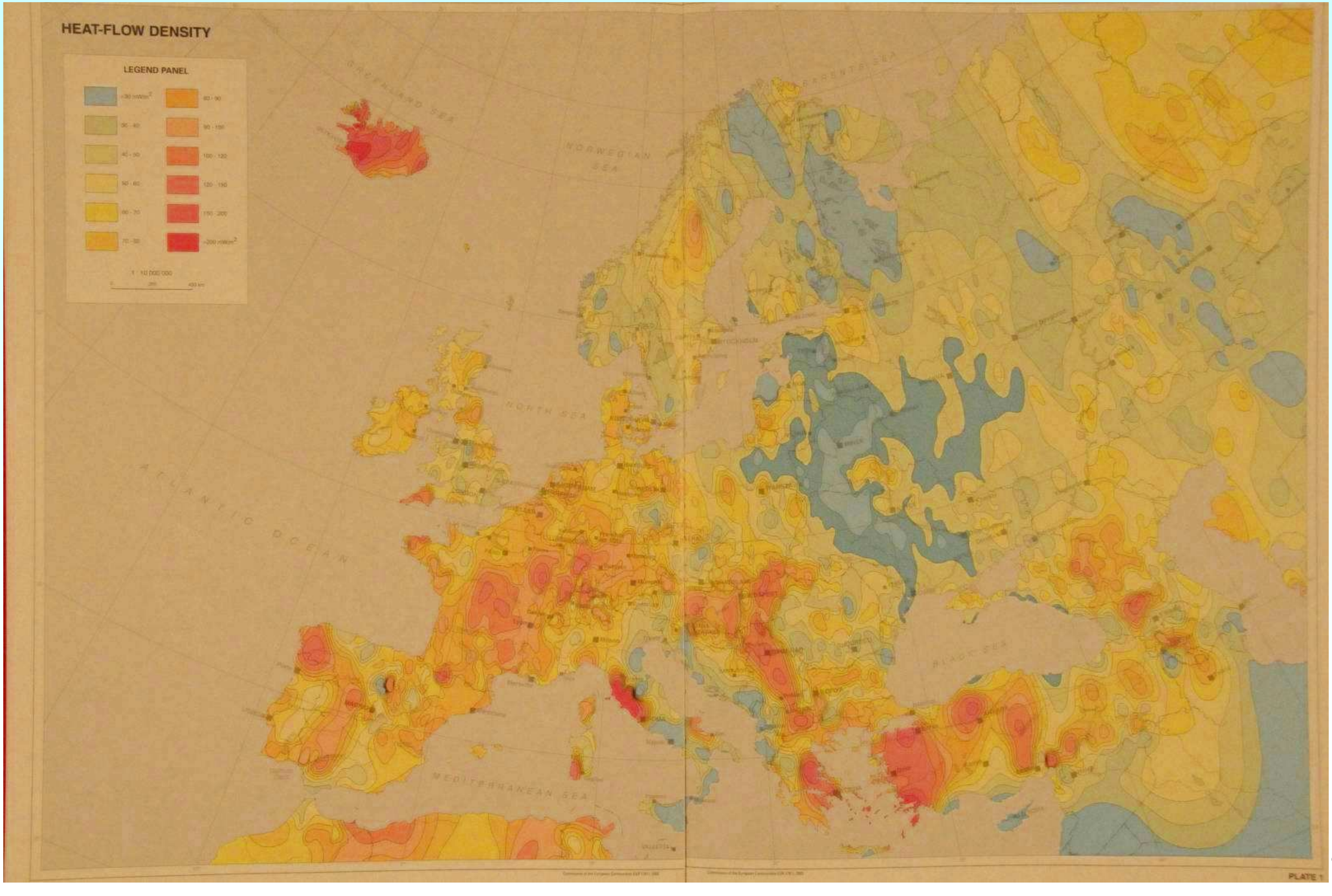

Fig. 2: Heat flow map of Europe (after Atlas of Geothermal resources in Europe, S.Hurter and R.Haenel Eds.)

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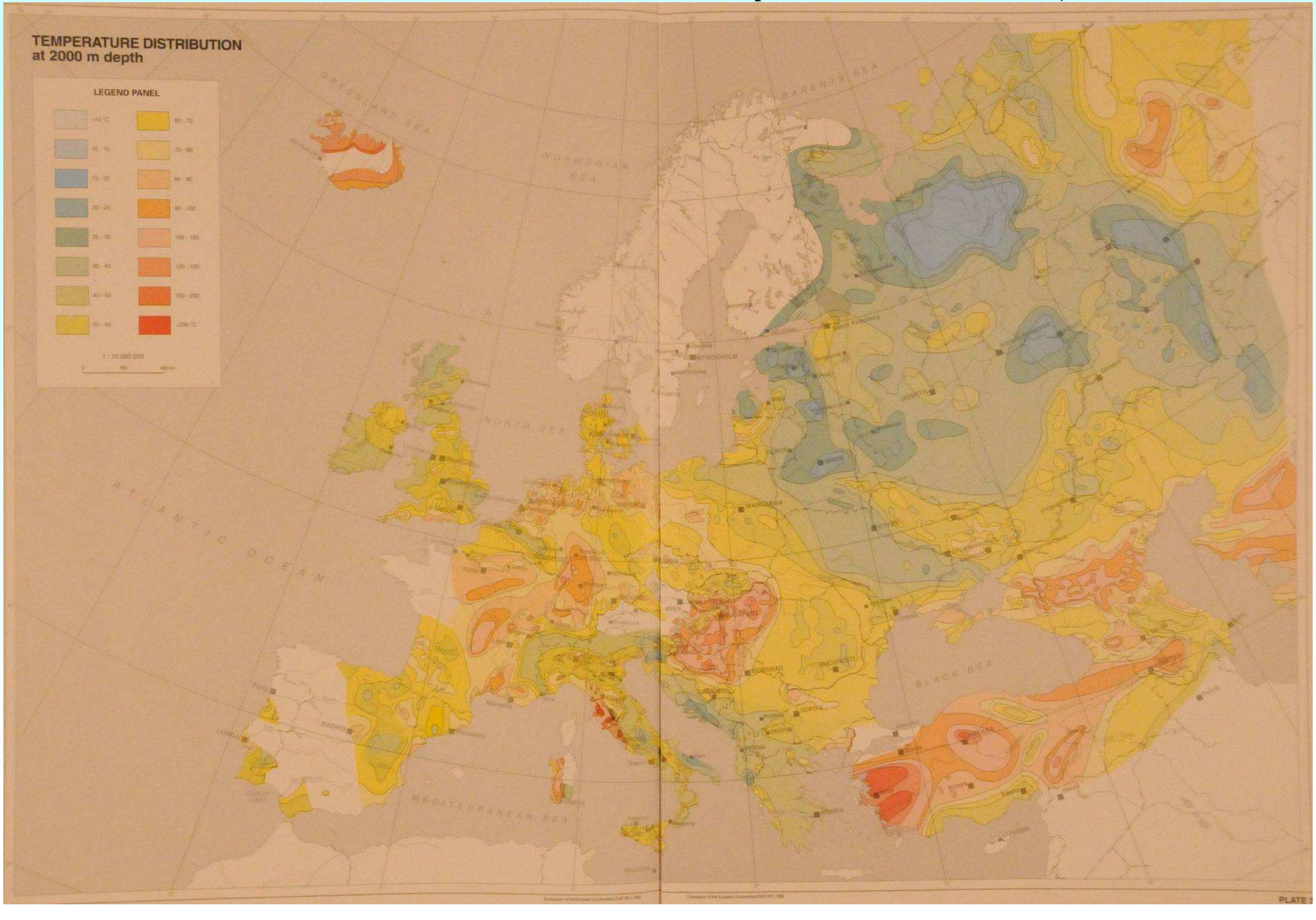
2. Geothermal categorization of Europe

Fig. 3: Temperature map of Europe at 2 km depth (after Atlas of Geothermal resources in Europe, S.Hurter and R.Haenel Eds.)



% 2. Geothermal categorization of Europe

2.2) Areas of Category I

They are located in some sectors of the main geothermal regions of the world (*Fig. 4*).

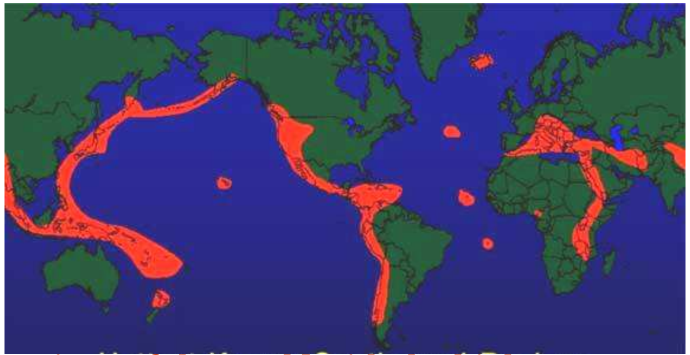


Fig. 4: The regions of the world with the highest concentration of heat flow

From West-East and roughly North-South, the areas of Category I are to be found in:

- **French Antilles (Guadalupe and Martinique, in the *Antillan volcanic arc*);**
- **Iceland, Azores, and Canaries (along the so-called *Middle-Atlantic ridge*);**
- **Eastern Russia (NE Siberia and Kamchatha, along the NW portion of the *Ring of fire)*;**
- **Pre-Apennine belt, Aeolian Archipelago and other volcanic islands of SW Italy (*);**
- **Islands of the Aegean volcanic arc (Southern Greece;) (*) and**
- **Western Anatolia (Turkey) (*).**

(*) These areas are located in the western sector of the *Alpine-Himalayan chain*.

Altogether, the areas of Category I cover 50-60,000 km^2 (0.2 % of total).

% 2. Geothermal categorization of Europe

2.3) Areas of Category II

These areas always exist around those of Category I; but can also be found in some sectors of other zones, such as:

- **Central massif (France), and Rhine graben (France-Germany);**
- **Campidano graben (Sardinia, Italy);**
- **Pannonian basin (Hungary-Romania);**
- **Lesbos island (NE Greece); and**
- **Eastern Siberia (Russia).**

The areas of Category II cover together 600-700,000 km^2 (2.3% of total).

% 2. Geothermal categorization of Europe

2.4) Areas of Category III

These areas are found around those of Category II, but also exist in:

- **a sector of Portugal to the SE of Lisbon;**
- **Central and SE Spain;**
- **some sectors of the Pyrenean chain (France-Spain);**
- **Paris basin and SE France;**
- **some sectors of Germany between Stuttgard and Munich;**
- **Po valley and Eastern Sicily (Italy);**
- **some sectors to the North and South of the Tatra ridge (Poland-Slovakia);**
- **sectors of Balkan region (Slovenia, Croatia, Bosnia Erzegovina, Serbia, Macedonia, Albania, Bulgaria);**
- **Eastern Greece and Southern Rodope massif (Greece-Bulgaria);**
- **Central Anatolia (Turkey);**
- **Transcarpathian region and Lvov depression (Ukraina);**
- **sectors to the North and East of the Black Sea (Armenia, Azerbaijan, Georgia, and Ukraina), to the West of the Caspian Sea (Daghestan, SE Russia), and to the NE and East of the Caspian Sea (Kazakistan, Tajikistan, Turkmenistan, and Uzbekistan),**
- **several sectors to the West and East of the Ural chain, in the West-Siberian lowlands, and in the Central-Siberian uplands (Russia).**

Altogether, the areas of Category III cover 3.5x10^{6} km^{2} (12.5 % of total).

% 2. Geothermal categorization of Europe

2.5) Areas of Category IV

These areas extend outside those of Categories III, over the rest of Europe.

They cover aggregately some 24 million km^2 (85 % of total geographical Europe).

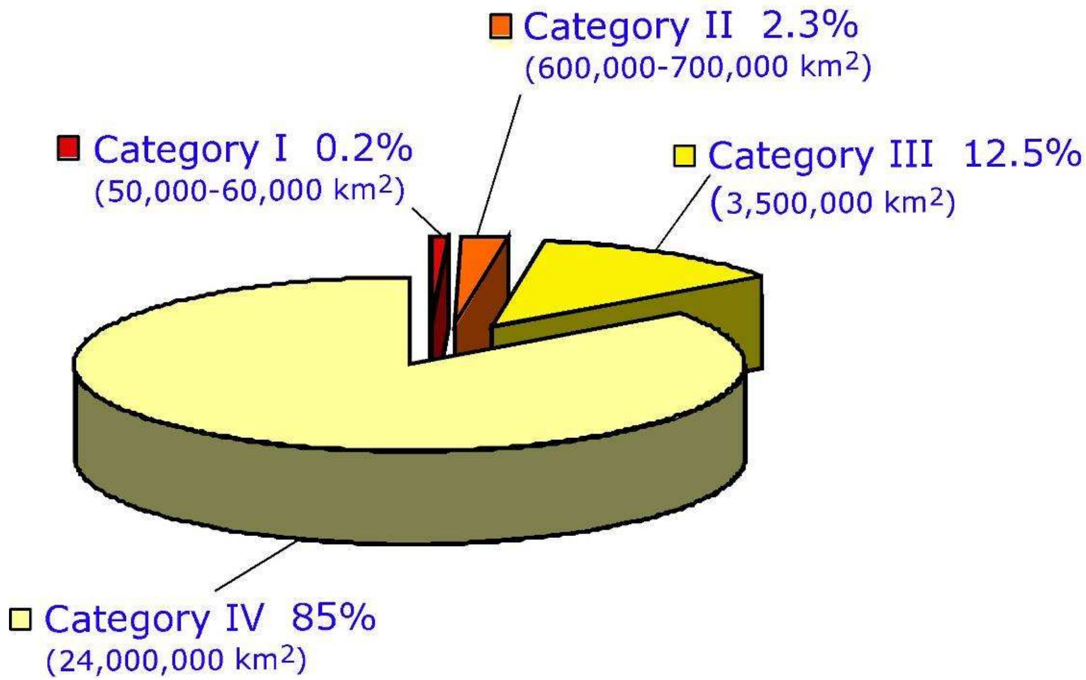


Fig. 5 **: Surface distribution of Categories I, II, III, and IV**

% 2. Geothermal categorization of Europe

2.6) A few comments on the categorization

- Categories I, II, III and IV are indicative of the type of hot fluid which is likely to exist at depth in each zone, and of its possible use.
- However, the existence in each zone of reservoir(s) with economically- exploitable resources must be proven case by case.
- From slides 10-14, and Fig. 5 can be seen that < 3% of geographical Europe displays temperatures > 150 °C within 3-5 km; whereas deep temperatures in the rest of Europe are, within the same depth, < 150 °C.
- This does not mean that natural heat can be harnessed in the sole areas of Category I and II. It means that, in the current economic conditions and with the present technology, power generation may become a viable target till 2020 in the first two categories of area only, whereas direct uses may be developed in principle in any category of area where sufficient demand for heat exists.
- In practice, however, taking into account that EGS and other unconventional geothermal systems are not mature as yet, and even considering the wider possible application of GSHP for climatization purposes, for many reasons we feel that geothermal development in Europe till 2020 cannot occur in more than 10 % of its geographical territory.

3. Status at Dec. 2007 and forecasts of geothermal development 2008-2020 in the EU 27

3.1) Methodology followed to make the forecasts

- **The 27 countries only forming at present the European Union are analyzed.**
- **For France, Portugal and Spain, the Overseas Territories are also included.**
- **Reference date of forecasts is Dec. 2007. When information at this date is not available, projections to 31 Dec. 2007 are based on growth trends known for previous years.**
- **Projections 2008 - 2010 for direct uses in most 27 EU countries are based on their average annual growth rates of the past 5 years (7 ÷ 14% per year).**
- **In the case of the EU countries with no report given so far of geothermal development (Cyprus, Estonia, Latvia, Luxemburg and Malta), a minimum initial activity in the field of direct uses (1 ÷ 3 MWt) is hypothesized by 31 Dec. 2010.**
- **Starting from the situation at Dec. 2010, growth forecasts to Dec. 2020 are made for each country according to two different Scenarios, whose results represent:**

  - in SCENARIO I, *prudently optimistic targets;* and

  - in SCENARIO II, *challenging targets*.

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% 3. Status at Dec. 2007 and forecasts of geothermal development 2008-2020 in the EU 27

% 3.1) Methodology followed to make forecasts

- **Forecasts of electric generation and direct uses for Scenario I are based on published data of envisaged growth till 2020, if such data exist. In other cases, information known on present growth trends together with the type of resources inferred from geological analysis of each country are considered.**
- **For power generation in Scenario I, since EGS and other unconventional systems (magmatic, supercritical fluids, pressurized, and hot brines) are far from commercial maturity, production from power plants of consolidated technology is mostly considered.**
- **For power generation in Scenario II, forecasts are obtained from values of Scenario I increased on a case by case analysis. Moreover, for few important countries, the possibility is also considered that an initial contribution may come from EGS and/or other unconventional high-temperature systems.**
- **Still in Scenario II, some possible "new entries" are envisaged: Netherlands, Poland, Slovenia, Sweden and U.K. For each of them an initial capacity of 5 MWe is considered.**
- **Forecasts of direct uses in Scenario II are obtained from values in Scenario I, with a 20-50 % increase depending on the situation in each country.**

% 3. Status at Dec. 2007 and forecasts of geothermal development 2008-2020 in the EU 27

COUNTRY	POWER GENERATION *(MWe)*				DIRECT USES, including heat pumps *(MWt)*			
	At Dec. 2007 *(1)*	At Dec. 2010	Forecasts by Dec. 2020 *Scenario I*	*Scenario II*	At Dec. 2007 *(2)*	At Dec. 2010	Forecasts by Dec. 2020 *Scenario I*	*Scenario II*
Austria	1	2	15	20	380	500	1200	1400
Belgium	-	-	-	-	70	90	250	300
Bulgaria	-	-	10	20	120	160	350	500
Cyprus	-	-	-	-	-	1	20	30
Czech Republic	-	-	-	-	225	300	800	1100
Denmark	-	-	-	-	360	470	1100	1300
Estonia	-	-	-	-	-	3	30	40
Finland	-	-	-	-	280	380	800	1000
France (*)	15	15	60	100	335	500	1500	1800
Germany	3	10	100	150	1030	1500	4000	5500
Greece	-	-	20	35	80	110	300	450
Hungary	-	-	20	30	750	1000	2500	3400
Ireland	-	-	-	-	25	35	150	250
Italy	811	850	1200	1500	650	850	4000	6000
Latvia	-	-	-	-	-	3	40	50
Lithuania	-	-	-	-	23	35	150	250
Luxemburg	-	-	-	-	-	1	30	40
Malta	-	-	-	-	-	2	30	40
Netherlands	-	-	-	5	280	380	1000	1200
Poland	-	-	-	5	230	310	800	1100
Portugal (*)	23	23	40	60	40	50	200	300
Romania	-	-	20	20	160	220	600	900
Slovak Republic	-	-	5	20	200	260	600	800
Slovenia	-	-	-	5	55	80	300	400
Spain (*)	-	-	10	20	25	35	150	200
Sweden	-	-	-	5	4170	5200	9000	11,500
United Kingdom	-	-	-	5	12	25	100	150
TOTAL	**853**	**900**	**1500**	**2000**	**9500**	**12,500**	**30,000**	**40,000**

% 3. Status at Dec. 2007 and forecasts of geothermal development 2008-2020 in the EU 27

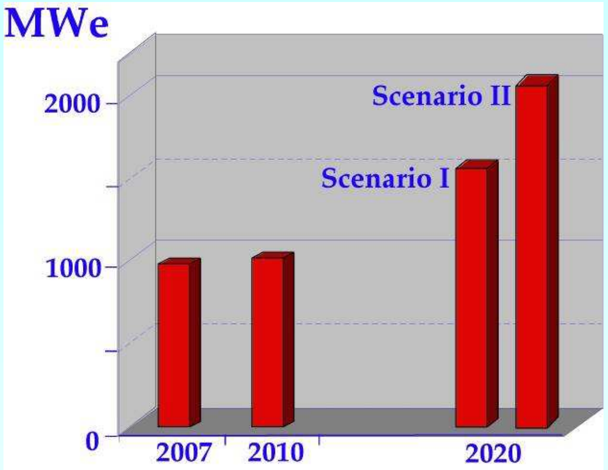

Fig. 6: Power generation

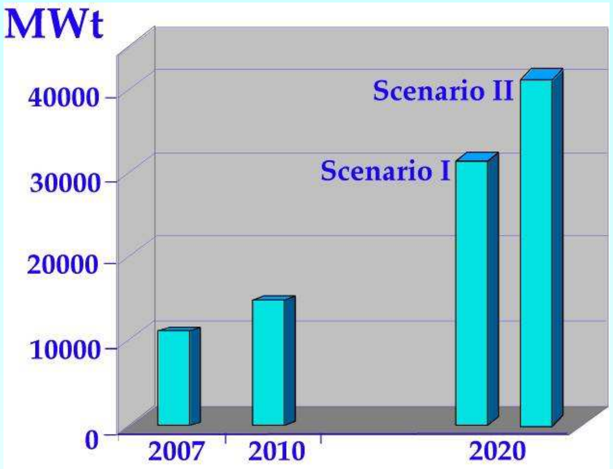

Fig. 7: Thermal capacity

3.3) Comments on forecasts

By comparing forecasts at Dec. 2020 with the situation at Dec. 2010, we see that the average annual growth rates for the group of EU 27 are:

- **for power generation: 5.4 %/y and 8.4 %/y, for Scenario I and Scenario II, respectively;**
- **for direct uses: 9.2 %/y and 12.3 %/y, for Scenario I and Scenario II, respectively.**

These are sizeable growth rates, which:

- **for electric generation are values notably higher than the average annual growth rate occurred in the world in the period 2000-2010 (2.6%/y, as shown in Fig.1);**
- **for direct uses are values somewhat lower than the average annual growth rate occurred in the same period in the world (14.4 %/y, as shown in Fig.1).**

From the latter viewpoint, we should consider that some countries of EU 27 are "new entries", with almost no development of the Earth's heat due to their limited geothermal potential and small extension.

4. Foreseeable contribution of EGS and other unconventional geothermal systems for power generation by Dec. 2020 in the EU 27

4.1) Definitions and characteristics of UGS

Unconventional Geothermal Systems (UGS) are those systems whose technology is not commercially mature as yet. They include:

- **Enhanced Geothermal Systems (*EGS*, formerly called HDR and/or HFR)**
  Geothermal systems with rocks at high temperature and low or very low permeability.
- **Magmatic Geothermal Systems (*MGS*)**
  Geothermal systems whose temperature is controlled by magma chambers at shallow depth.
- **Pressurized Geothermal Systems (*PGS*)**
  High temperature systems where fluid pressure in the reservoir is controlled by the lithostatic load.
- **Supercritical fluids (*SFl*)**
  Fluids at very high temperature and pressure, in supercritical conditions, characterized by very-high energy density.
- **Hot Brines (*HBr*)**
  Reservoir fluids at high temperature and very high salinity (>> 10 g/l).

% 4. Foreseeable contribution of EGS and other unconventional geothermal systems for power generation by Dec. 2020

- **Analysis of geo-dynamic, deep temperatures, surface heat flow, tectonic, litho-stratigraphic, hydro-geologic, anatectic and volcanological conditions of the EU 27 lead us to think that many tens sectors in these countries have potential interest for development of UGS projects for power generation, when mature technology is reached.**
- **Preferential zones in these sectors are found in Austria, France, Germany, Greece, Italy, Hungary, Poland, Portugal, Romania, Slovak Republic and Spain within 3-4 km depth, and in these and other countries (Netherland, Slovenia, Sweden and UK) within 5 km depth.**
- **The aggregate surface area of the aforesaid preferential zones is in the order of *10,000* km^2.**

% 4. Foreseeable contribution of EGS and other unconventional geothermal systems for power generation by Dec. 2020 in the EU 27

4.3) Concerning foreseeable future of UGS for power generation by Dec. 2020, we should observe, first of all, that:

- **No resource associated to UGS has reached so far in the world the technological maturity needed to start its commercial development.**
- **The two types of resource which seem less far from such maturity are those associated to *EGS* and *PGS*. For them, a time-lapse of 6-7 (or perhaps 10) years are still needed, in our opinion, to reach the commercial maturity.**
- **The other three types of resource (associated to *MGS*, *SFl*, and *HBr*) might become commercially viable not before 10 years from now.**
- **Regardless of which of the resources in question may first reach the technical maturity in a specific country, power generation from UGS by 2020 will have for sure a marginal role in the world, as compared to the generation from hydrothermal systems by means of power plants using consolidated technology.**

- **Therefore, we feel that the geothermal capacity supplied in 2020 by UGS in the EU 27 may barely reach, in the best case of Scenario II, 150 ÷ 200 MWe (1÷1.5 TWh/y).**
- **This means that, compared to the capacity forecasted by Dec. 2020 (1500 MWe for Scenario I and 2000 MWe for Scenario II), the contribution of the UGS in the EU 27 may hardly reach, in the most optimistic case, 10 % of the total.**

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5. Recap. & Conclusions

5.1) After 1985 power generation has undergone a notable decrease in annual growth rates everywhere in the world (*Fig. 1*); in the last 10 years, the growth has been 2.5 %/y only. Direct uses, on the contrary, have strongly grown in the last 15 years at a rate of 14%/y. Similar trends have occurred also in Europe.

6.2) The geothermal categorization of the whole Europe shows that some 2.5 % only of its total territory has high-temperature resources suitable for power generation by consolidated technologies.
On the contrary, moderate-to-low temperature resources for direct uses could be harnessed everywhere, provided that sufficient demand for heat exists or may be created.

6.3) The forecasts made up to 2020 for the EU 27 according to two growth scenarios show that, subject to taking appropriate fostering measures:

- **power generation might grow at a pace of 5.4 and 8.4 %/y for Scenarios I and II. This would enable adding about 650 MWe and over 1100 MWe to the present capacity for the Scenarios I and II, respectively;**
- **direct uses, are expected to grow at a rate of between 9.2 ÷ 12.3 %/y, which would lead to a capacity of 30,000 and 40,000 MWt for Scenarios I and II, respectively by 2020.**

cont/d

% 5. Recap. & Conclusions

6.4) Concerning power generation in particular, the contribution that might come from development of UGS by 2020 is in the order 150 ÷ 200 MWe, which means 10 % at most of 1500 ÷ 2000 MWe estimated in the EU 27 for Scenarios I and II.

6.5) In short, due to the huge amount of moderate-to-low temperature resources, and the limited amount of high-temperature resources economically available in the EU 27, we think that the development of geothermal energy up to 2020 should be focussed primarily on:

- direct uses (mainly, but not only, space heating and cooling); and
- power generation by using consolidated technologies.

- Concerning UGS (EGS in particular), regardless of the possible installation within Dec. 2020 of 150 ÷ 200 MWe as said above, a strong R&D effort should be made to accelerate the solution of the problems that still prevent them to form a commercial energy source.

In this sense, we wish that the European Union and the Governments of all farsighted EU countries will decide to support consistently such R&D program.

THANKS