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Institut für Energetik und Umwelt

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Forschung,
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- Energie
- Umwelt

Status of Geothermal Electricity Generation in Europe

- Requirements and Challenges for Power Plant Technology -

Workshop „Electricity Generation from Enhanced Geothermal Systems“

Strasbourg, September 14th, 2006

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in cooperation with
Institute of Environmental Technology and Energy Economics
Hamburg University of Technology

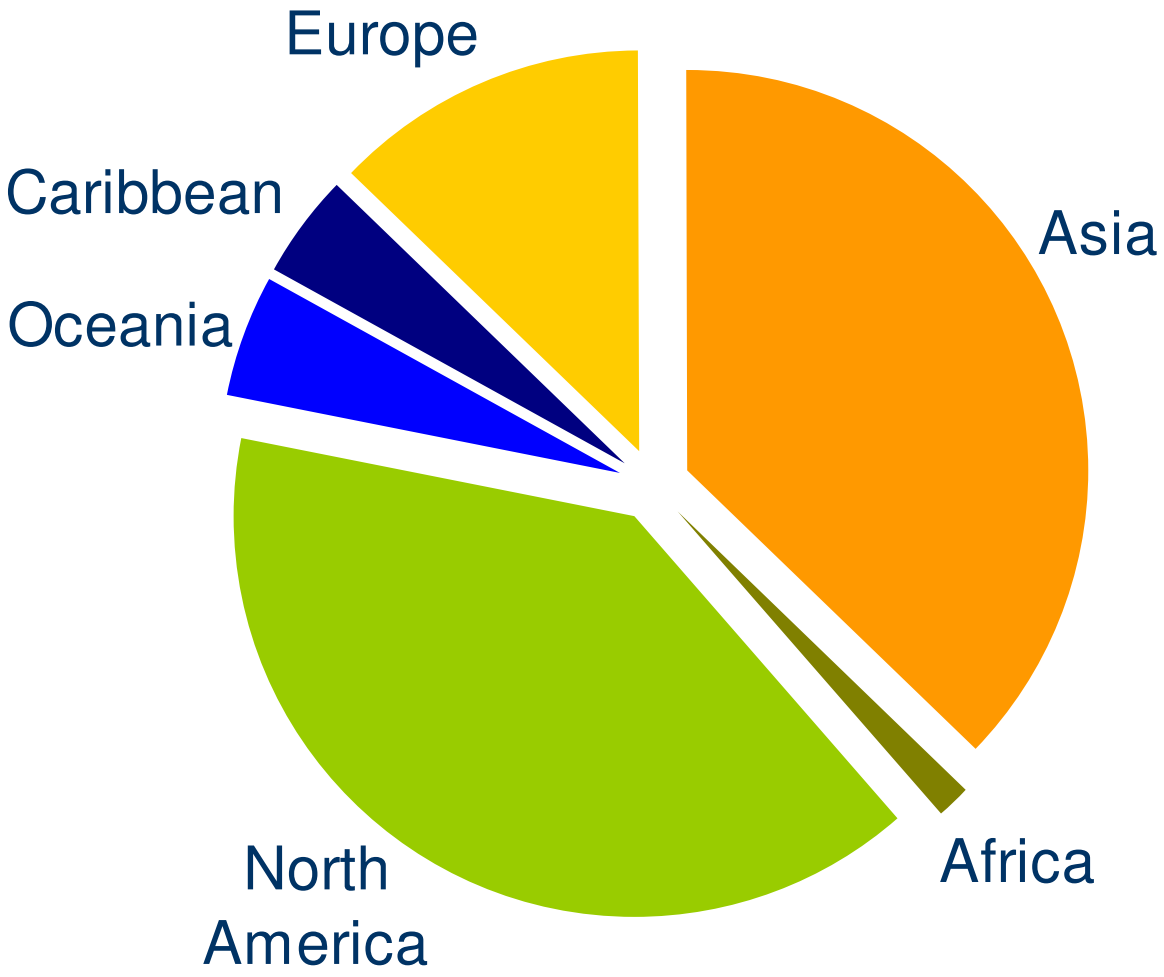
Agenda

- Introduction
- Status of geothermal power generation in European countries
- Analysis of the used power plant technology
- Conclusions

Electricity generation from renewables

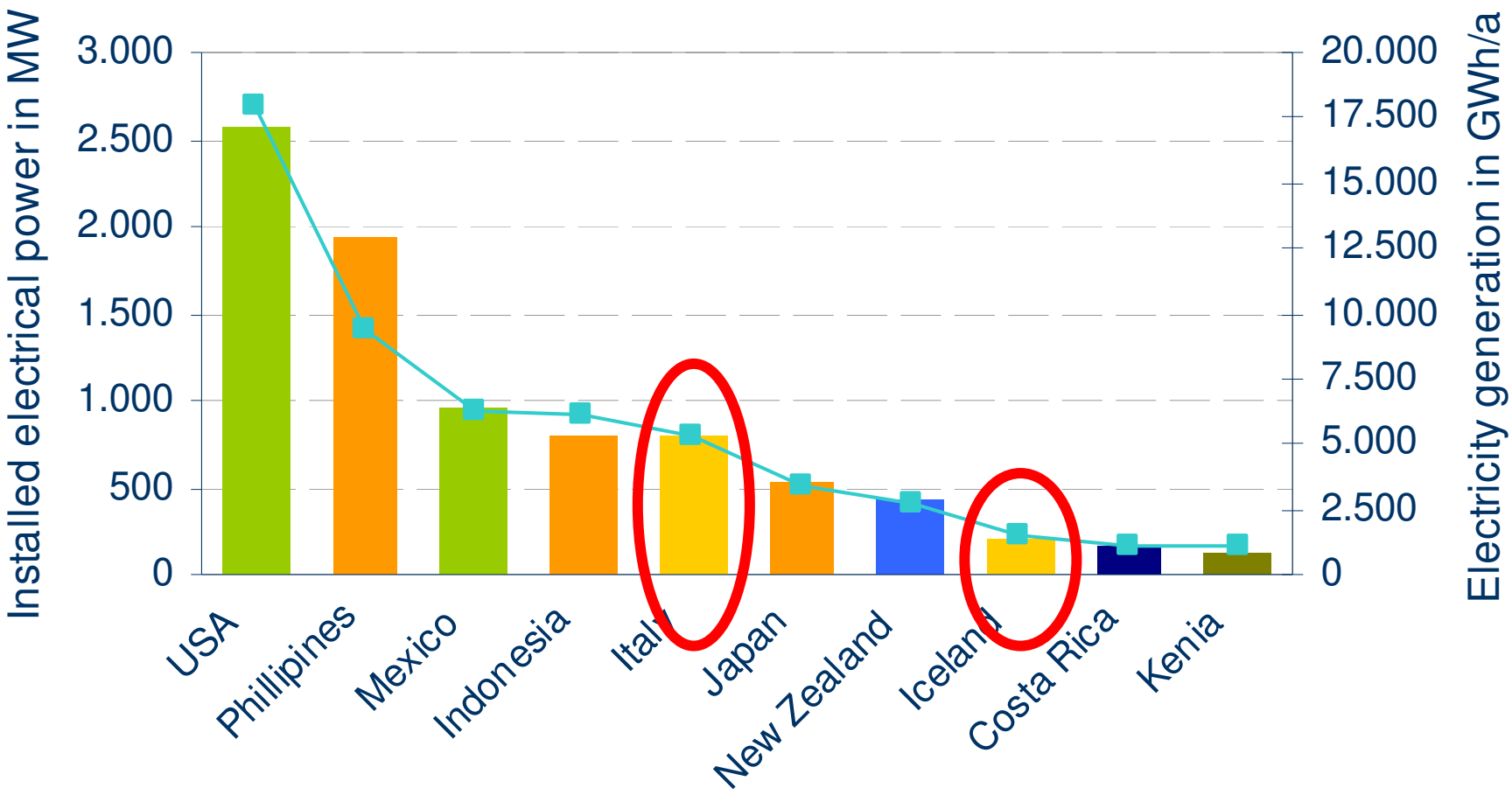
	Installed capacity in GW_{el}		Electricity generation in TWh/a	
	World	**EU**	**World**	**EU**
Hydro power	750.0	127.0	2,804	741
▪ Run-off-river/Storage plants	750.0	127.0	2,803	740
▪ Tidal power plants	0.3	0.2	< 1	< 1
Wind energy	47.9	34.4	74 – 88	55
Solar energy	3.0	1.0	3 – 4	< 1
▪ Solarthermal systems	0.4		< 1	
▪ Photovoltaic systems	2.6	1.0	2 – 3	< 1
Geothermal energy	8.9	0.8	57	6
Biomass	47.8	11.3	190 – 300	57
▪ Solid biofuels	37.0	6.2	150 – 260	35
▪ Organic waste	7.6	3.3	21	10
▪ Biogas (OECD-countries)	3.2	1.8	19	12
Total	approx. **857.6**	approx. **174.5**	approx. **3,190**	approx. **859**

Worldwide electricity generation from geothermal energy



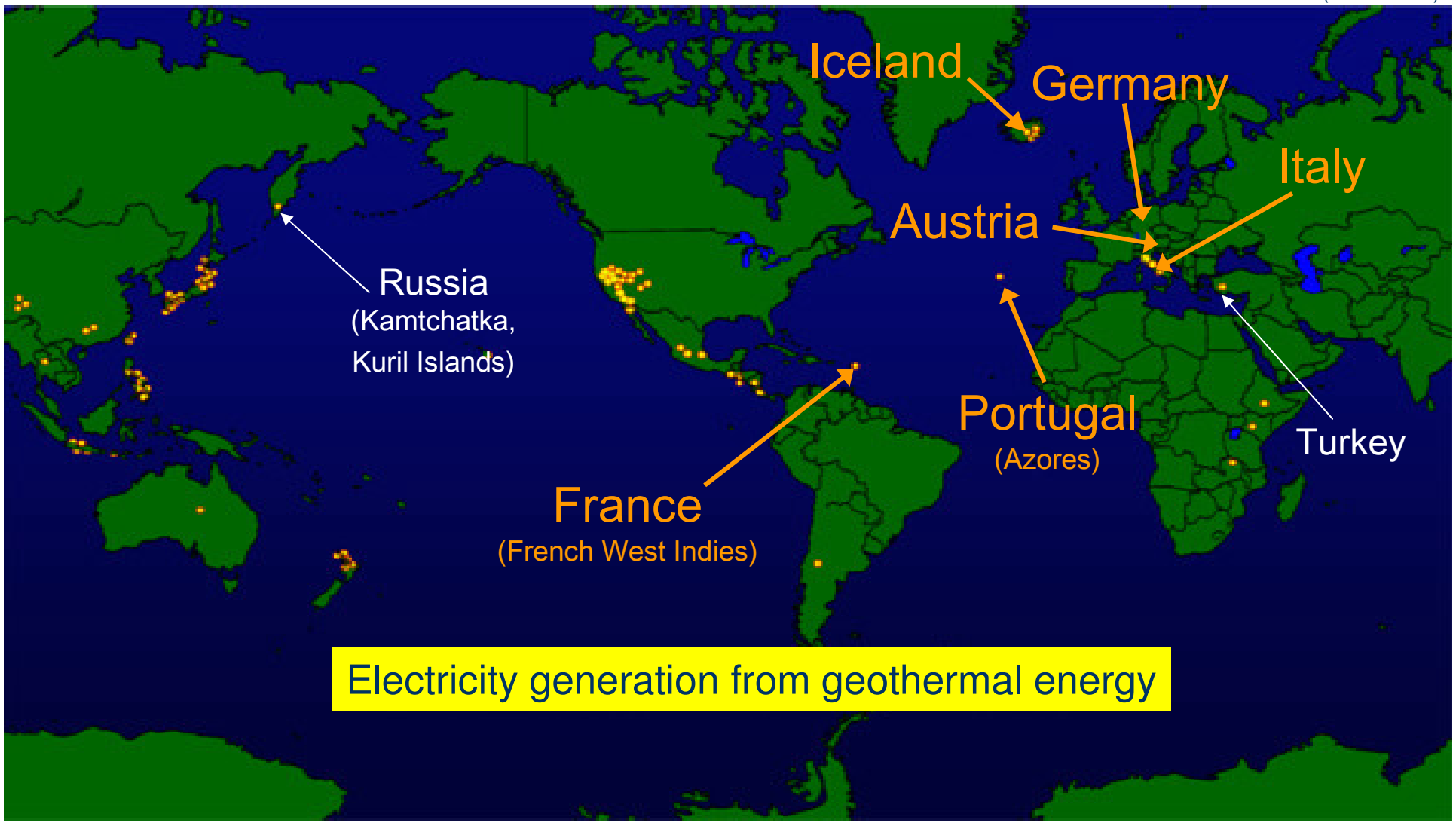
- 8,863 MW_{el} worldwide installed geothermal capacity
- 57 TWh/a produced electricity
- 6,400 full load hours in average

Electricity generation from geothermal energy



Geothermal power plants in European countries

Source: IGG (A. Manzella)



Austria

Source: Proceedings World Geothermal Congress 2005, J. Goldbrunner

Reservoir

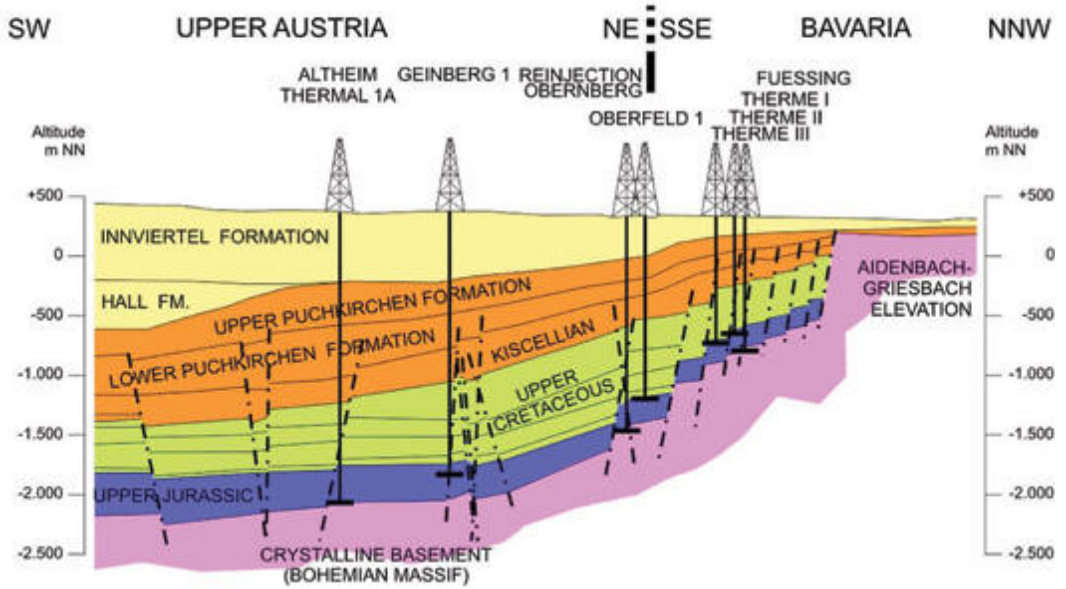
- No high enthalpy resources
- Favourable conditions to exploit low enthalpy resources existing in Alpine-Carpathian intramontane basins and the Molasse Basin

Status of Electricity Generation

- Since 2001 ORC-plant in Bad Blumau with 0.2 MW_{el}
- Since 2002 ORC-plant in Altheim with 1.2 MW_{el}

Future Development

- Expansion to a total capacity of 6 MW_{el} planned by 2010



France

Source: IGG (A. Manzella), Géothermie Soultz, Proceedings World Geothermal Congress 2005

Reservoir

- Low enthalpy resources in 2 major sedimentary basins (Paris Basin, Aquitaine Basin) at depths between 600 and 2,000 m; other low enthalpy resources have a more complex structure and are of more local nature
- French Overseas Departments comprise high enthalpy resources: French West Indies with temperatures up to 260 °C at 300 to 1,000 m depth

Status of Electricity Generation

- Since 1995 4 MW_{el} plant in Bouillante (Guadeloupe); extension with a second unit to 15 MW_{el} in 2004

Future Development

- In Bouillante a third unit is in the pre-feasibility phase
- Martinique and La Réunion are in exploration
- In 2002 Soultz-sous-Fôrets, 3-well-system drilled through granite, 5,000 m, > 200 °C, 5 to 6 MW_{el} planned

Germany

Source: IE, ErdwärmeKraft GbR

Reservoir

- No high enthalpy resources
- Promising reservoirs are located in the North German Basin, the Molasse Basin and the Upper Rhine Graben
- Most promising is the Upper Rhine Graben; 100 to 170 °C at depths of 3,000 m can be expected; problematic might be the productivity of such systems

Status of Electricity Generation

- 2003 “coldest” power plant (98 °C brine temperature) worldwide started its power generation with 230 kW_{el} at the plant in Neustadt-Glewe

Future Development

- Possible total capacity of more than 25 MW_{el} by 2008
- Promising geological regions are already almost totally legally subdivided
- Possible total capacity for the future of more than 400 MW_{el} by 2020

Iceland

Source: IGG (A. Manzella), Proceedings World Geothermal Congress 2005

Reservoir

- Iceland, as a geologically young country, is located on the Mid-Atlantic Ridge; therefore Island has tectonically very active places with numerous volcanoes, hot springs and other post volcanic activities
- 26 high enthalpy resources within active volcanic zones with temperatures of more than 300 °C at 2,500 m depth are known; additionally 250 separate low-temperature areas exists

Status of Electricity Generation

- First geothermal power plant operates since 1969 in Bjarnarflag with 3 MW_{el}
- Since 77 Krafla power plant works; since 1997 total capacity of 60 MW_{el}
- Since 77 CHP-plant Svartsengi (Reykjanes peninsula) works (now 45 MW_{el})
- Since 2000 first plant with 2 MW_{el} based on a Kaline cycle is in operation

Future Development

- 2 new plants in 2007; expansion of existing capacity; total additional capacity 210 MW_{el}; 370 MW_{el} in the future with 7 further production fields
- Unconventional Geothermal Systems; at depths to 5,000 m within volcanic systems supercritical fluids are expected

Italy

Source: IGG (A. Manzella), Proceedings World Geothermal Congress 2005

Reservoir

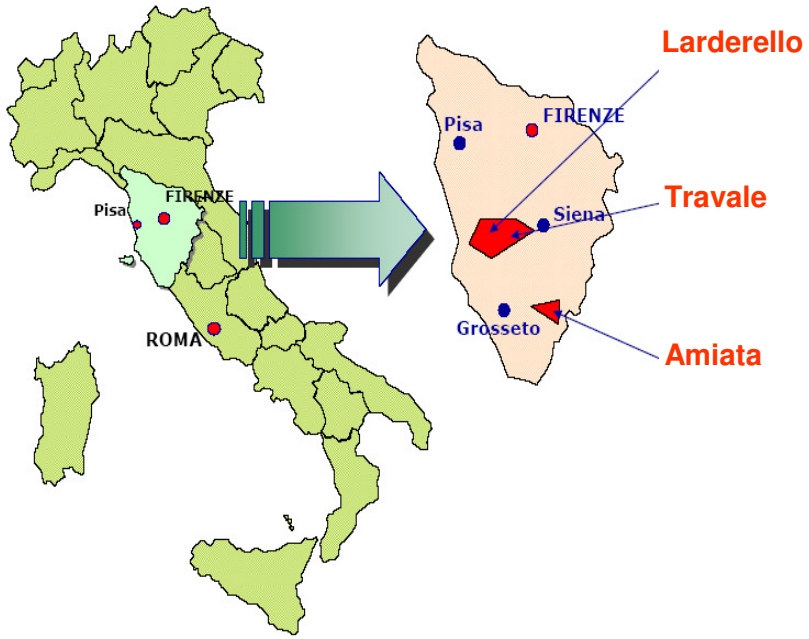
- Italy can be divided in two geothermal main zones: the Western (Tyrrhenian) high enthalpy zone and the Eastern (Adriatic) cold belt
- 2 exploited areas (Larderello-Travale/Radicondoli and Mt. Amiata, Latera decommisioned): a shallow reservoir in carbonatic and a deeper reservoir in metamorphic units; steam dominated in Larderello-T/R and water dominated in Mt. Amiata (extinct volcano); 300 to 350 °C at 3,000 m

Status of Electricity Generation

- 1904 first experiment world-wide, first production in 1913
- Larderello-T/R in 400 km^2, 202 wells, 27 units, 702 MW_{el} installed capacity
- Mt. Amiata 5 units, 88 MW_{el}

Future Development

- Increase of 100 MW_{el} to a total installed capacity of 882 MW_{el} foreseen in 5 years



Portugal

Source: IGG (A. Manzella), Proceedings World Geothermal Congress 2005

Reservoir

- On Portugal's mainland exist hydrothermal low-temperature resources, e.g. 27 springs with temperatures between 25 and 75 °C
- High enthalpy fields are located in the volcanic Azores Archipelago; e.g. the Ribeira Grand Geothermal Field (São Miguel Island) with temperatures of 250 °C in approx. 1,000 m depth

Status of Electricity generation

- Since 1980 pilot plant in Pico Vermelho (São Miguel) with 3 MW_{el} installed and 1 MW_{el} running capacity
- Since 1994 ORC power plant in Ribeira (São Miguel); today two 2,5 MW_{el} and two 4 MW_{el} power units are under operation

Future Development

- Replacement of the pilot plant in Pico Vermelho in 2006 by a new total capacity of 10 MW_{el}
- 12 MW_{el} power plant in Terceira by 2008

Russia

Source: IGG (A. Manzella), JSC (O. Povarov), Proceedings World Geothermal Congress 2005

Reservoir

- Huge areas with active volcanism, Kamchatka and Kuril Islands
- Vapour and water dominated fields, e.g. thermal field North Muthnosky, shallow vapour dominated reservoir at depths of 700 to 900 m; underneath liquid dominated reservoir with 250 to 310 °C

Status of Electricity Generation

- 1967 Pauzhetska (Kamchatka), today with a total capacity of 11 MW_{el}
- 2 plants in Verkhne/Mutnovka (Kamchatka) with a total capacity of 62 MW_{el}
- On Kuril Islands (Kunashir and Iturup) 6 MW_{el} installed

Future Development

- In Kamchatka an expansion of 107 MW_{el} is under development
- Planned increase on Kuril Islands of overall 11 MW_{el}

Switzerland

Source: Deep Heat Mining Project, Basel Proceedings World Geothermal Congress 2005

Reservoir

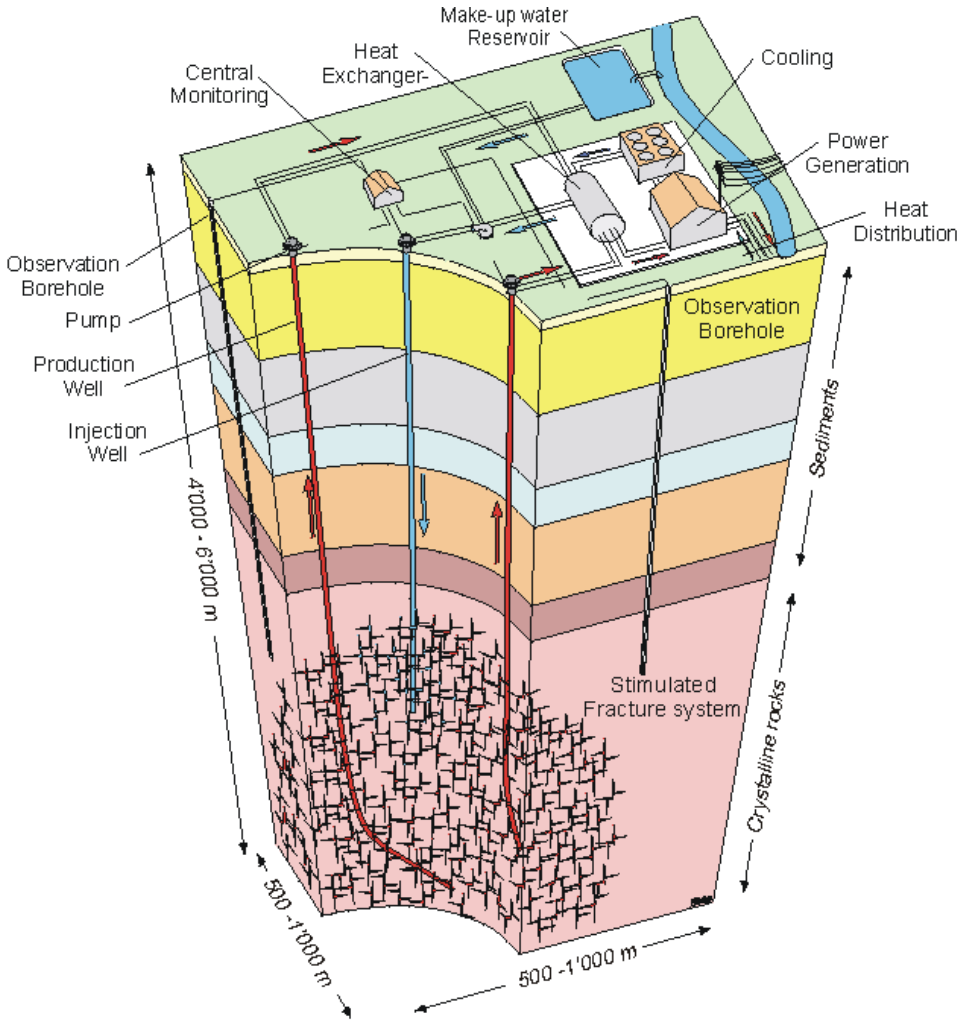
- No high enthalpy resources

Status of Electricity Generation

- So far no geothermal electricity generation

Future Development

- HDR-CHP-project in Basel (Deep Heat Mining Project); installation of 3 MW_{el} and 20 MW_{th} by 2010



Turkey

Source: IGG (A. Manzella), ORME (T. Kaya), Proceedings World Geothermal Congress 2005

Reservoir

- Most of the country is located on the Alpine-Hymalayan orogenic belt; therefore Turkey has high geothermal potential
- More than 170 geothermal fields exist; 10 of them are high enthalpy fields with temperatures from 142 to 242 °C
- Denizli-Kizildere geothermal field as an example is located on an active tectonic setting; a shallow reservoir lies in limestones and marble (195 to 205 °C at 600 to 800 m) and a deep reservoir in gneiss (242 °C at 1,500 m)

Status of Electricity generation

- First pilot plant 1974 in Kizildere geothermal field with 0.5 MW_{el}
- First power plant since 1984 with 20.4 MW_{el} installed capacity, 12 to 15 MW_{el} running capacity

Future Development

- A 25 MW_{el} power plant under construction in Aydin-Germencik-Omerbeyli field
- In the future a total of 500 MW_{el} is estimated

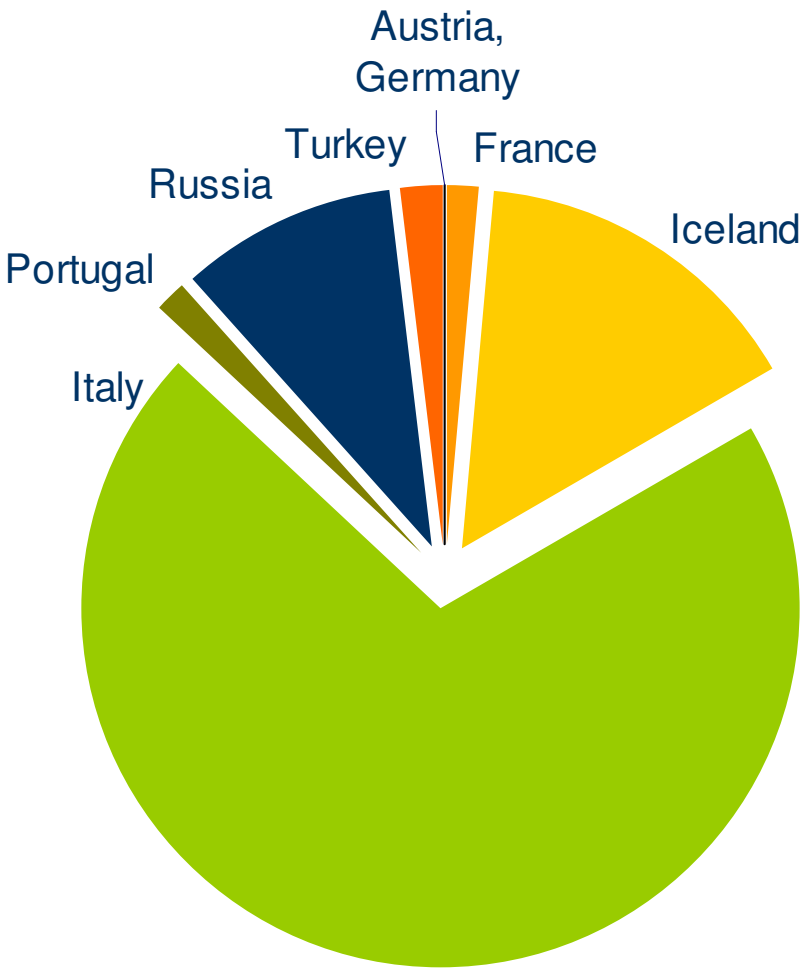
Geothermal electricity generation in Europe

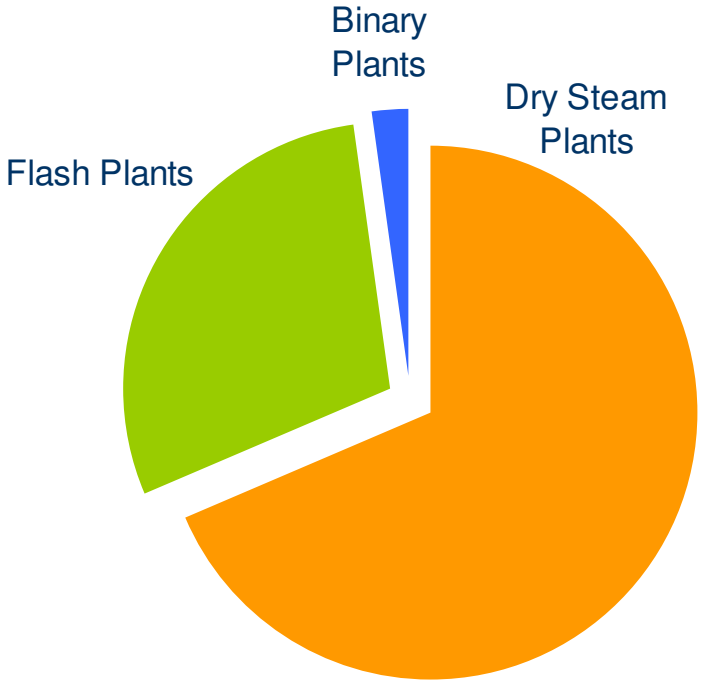
Source: Proceedings World Geothermal Congress 2005

	Dry Steam Plants in MW_{el}	Flash Plants in MW_{el}	Binary Plants in MW_{el}	Total Capacity in MW_{el}	Capacity by 2010 in MW_{el}
Austria			1.4	1.4	7.4
France		14.7[a]		14.7	20.7
Germany			0.2	0.2	25.2
Iceland		161.7	10.4	172.1	392.1
Italy	770.5	20		790.5	890.5
Portugal		3.0	13.0[b]	16	35
Russia		110[c]		110	228
Switzerland					6
Turkey		20.4		20.4	
Europe	770,5	329.8	24.3	1,125.3	1,650.3

[a] Guadeloupe; [b] Azores; [c] thereof 9 MW_{el} flash-binary unit

Geothermal electricity generation in Europe

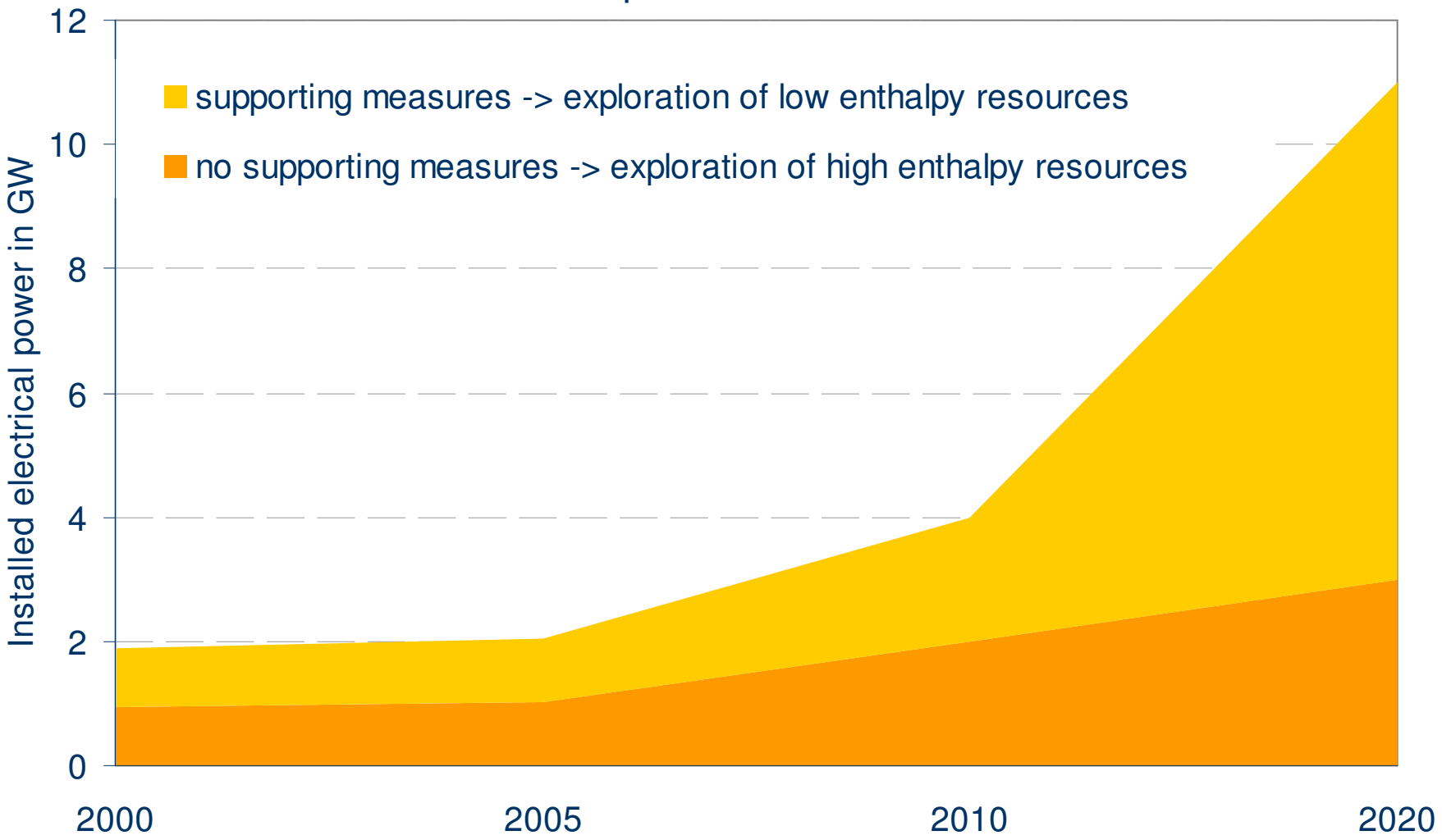




- 1,125 MW_{el} installed geothermal capacity in Europe
- 7.1 TWh/a produced electricity
- Approx. 6,300 full load hours

Future development of geothermal electricity generation

In dependence on the EGEC Ferrara Declaration, 1999



Summary & Outlook

- Electricity from geothermal energy contributes already to cover the given electricity demand in Europe and world wide.
- Most of the geothermal power plants are based on high enthalpy resources; however, the future expansion of geothermal electricity generation based on such plants is limited.
- Exploration of low enthalpy resources has started in the recent years; several projects are under development and there is still a high potential to discover; however, the thereby applied technology needs to be optimised.
- As an important part, low temperature power plant technology needs further development; demands on the technology are among others:
  - high efficiency for varying temperature levels
  - high full load hours
  - stable operation
  - cheap technology, low operation costs
  - low environmental effects
  - …
- A lot has to be done – let's sort things out!

Thank you very much for your attention!

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