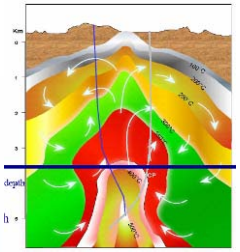
ENhanced Geothermal Innovative Network for Europe

Ledru P.

Géosciences pour une Terre durable
brgm

Geothermal activity in Europe

Iceland



Icelandic Deep Drilling project

Guadalupe

Alvsby

Açores

Klapeida

Podhale, Mszczonów, Pyrzyce, Uniejów Slomniki

Groß Schönebeck

Landau

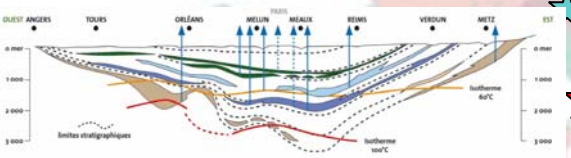
Neustadt-Glewe

Paris Basin

Soultz-sous-forêt EGS

Basel EGS

Altheim



Cozia-Calciulata

Larderello

Ferrara

Bansko, Kocani, Gevgelia

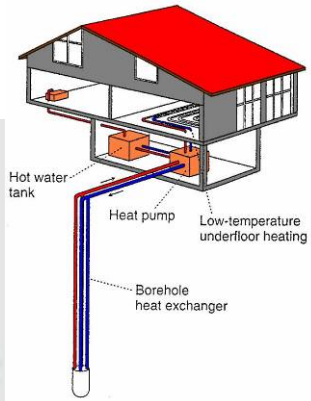
Izmir

Heat Pumps

District heating

Enhanced Geothermal Systems test sites

Electricity production, co generation



Geothermal Heat Pumps

Pyrzyce

Groß Schönebeck

Soultz

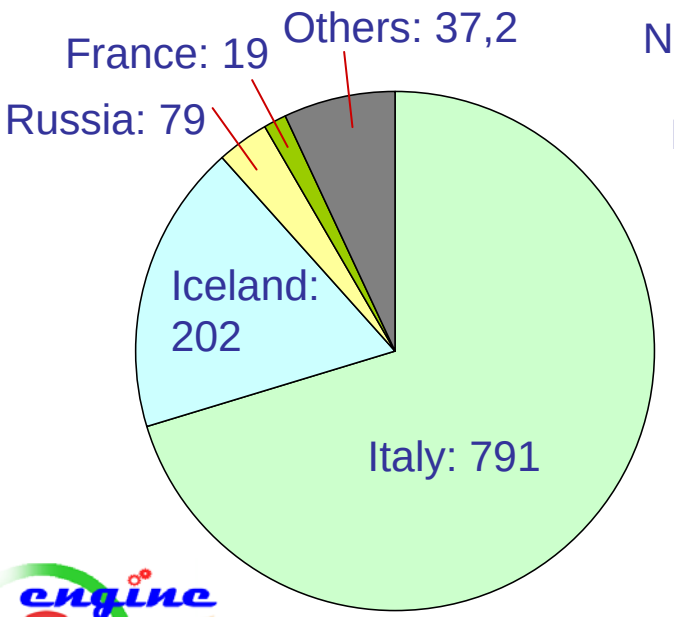
Neustdat-Glewe

Altheim

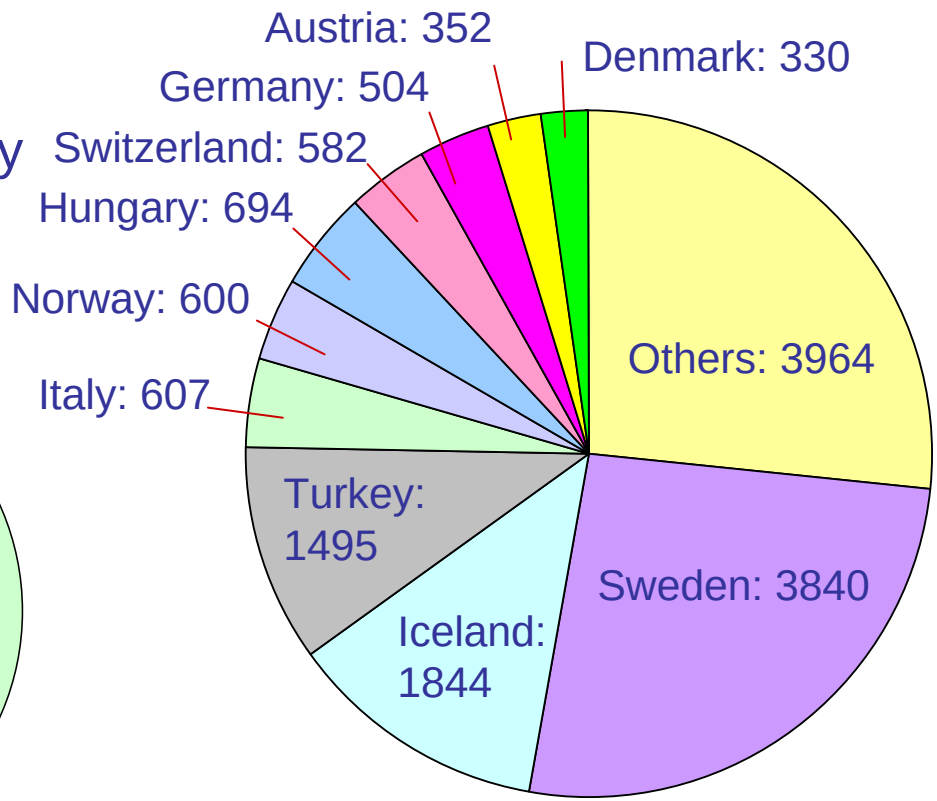
Larderello, 1904-2006

Geothermal power and direct use production

Geothermal power capacity 2004, 1179 MWE



Geothermal direct use capacity 2005 13626 MWt



Compilation, L. Rybach, GRC 2006

The strategy of the European commission and the R&D programs

- Directive 2001/77/EC : doubling the contribution of renewable energy from 6 to 12% of total energy consumption by 2010.
- The White Paper (Community Strategy and Action Plan, 1997) : doubling (500 to 1000 MW) of electricity production capacity, increase from 750 to 25000 MW for heat production capacity of geothermal origin by 2010
- To be compared with in 2004: electricity production capacity: 1179 MWE, and in 2005: heat production capacity 13626 MWt

A paradox in 2005

- Europe is a pionneer for the development of geothermal energy
  - Larderello
  - Iceland
  - Paris basin
  - GHP in Scandinavia
  - R&D in Soultz-sous-Forêts
  - Power generation by binary plants
  - …
- but there is no major ambition for the development of geothermal energy at the scale of Europe because:
  - a lack of political support
  - no coordination of communication compared to other lobbies
  - no major companies involved
  - the division of the scientific community

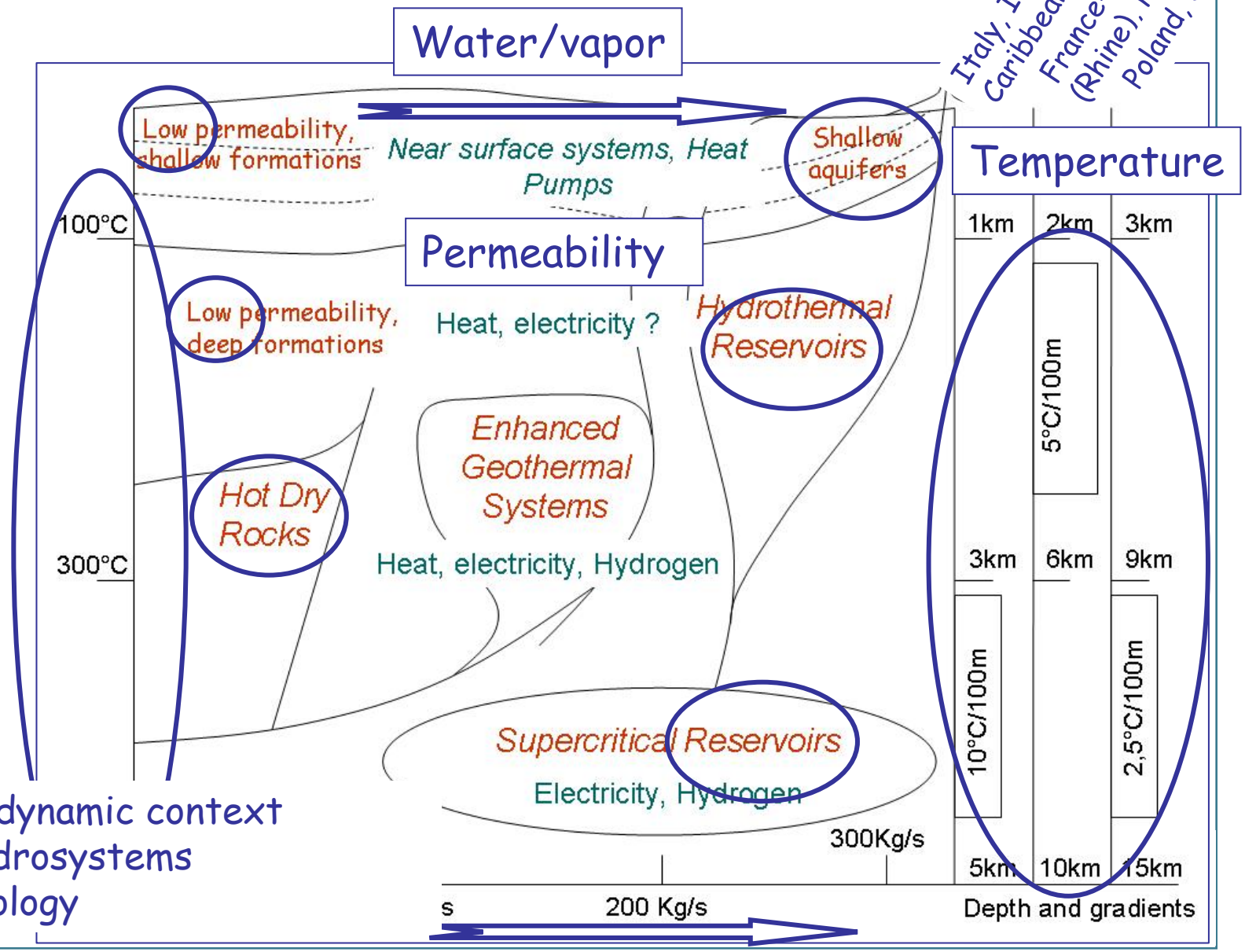
A need for a co-ordination action about R&D in Enhanced Geothermal Systems

- A need for building an innovative research network for Europe (An expression of interest from the EC FP6)
- A renewed interest for the geothermal energy from deep sources

Objectives of the coordination action

- to motivate the scientific community to face up to the above-mentioned challenges
- to capitalise the know-how acquired in the framework of the EGS Soultz experiment but also from the exploration and exploitation of Italy, Bouillante and Iceland geothermal fields
- to define new integrated projects that will federate the scientific community working in the "geothermal field", in partnership with industry, in order to achieve the strategic objectives of the European Community

Strategy for defining targets for Geothermal energy



the geodynamic context
- the hydrosystems
- the geology

FP6 projects: a significant R&D investment

CAMELIA: Multigeneration Energy Systems with Locally Integrated Applications

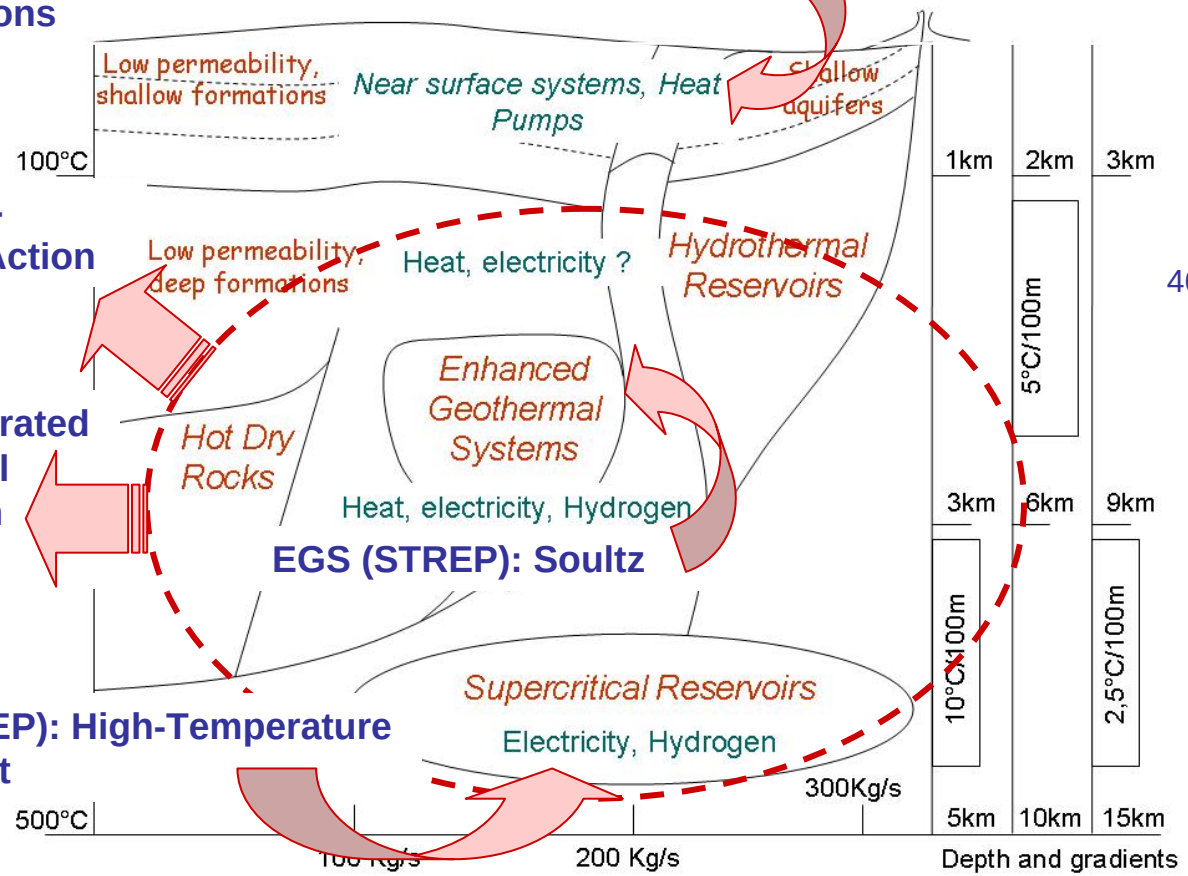
GroundHit: Ground Coupled Heat Pumps of High Technology

Low Bin: Binary systems

ENGINE Co-ordination Action

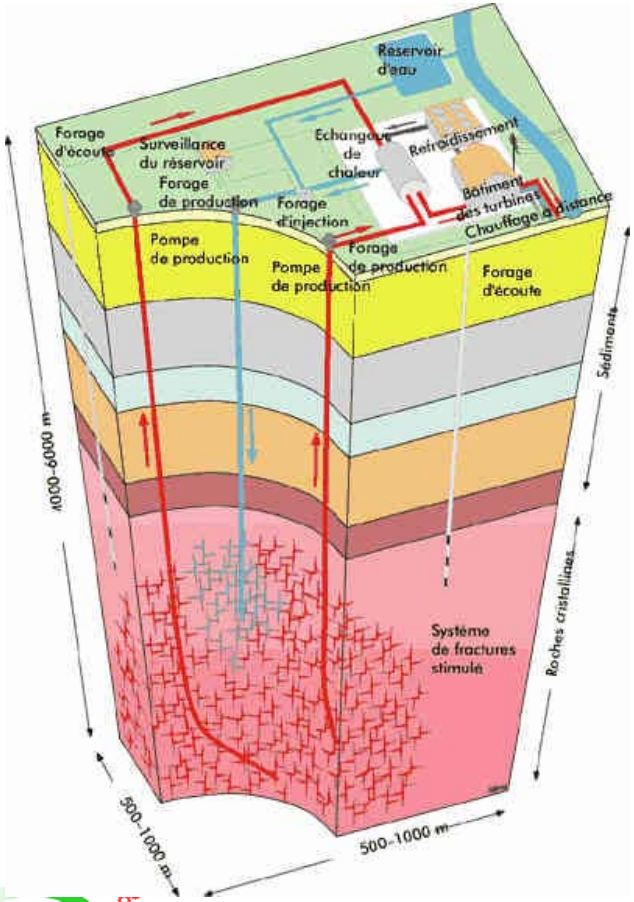
I-GET: Integrated Geophysical Exploration Technology

HITI (STREP): High-Temperature Equipment



>A total budget of 46,6M€ over 4 years and a support of 17,6M€ from EU dedicated to geothermal energy

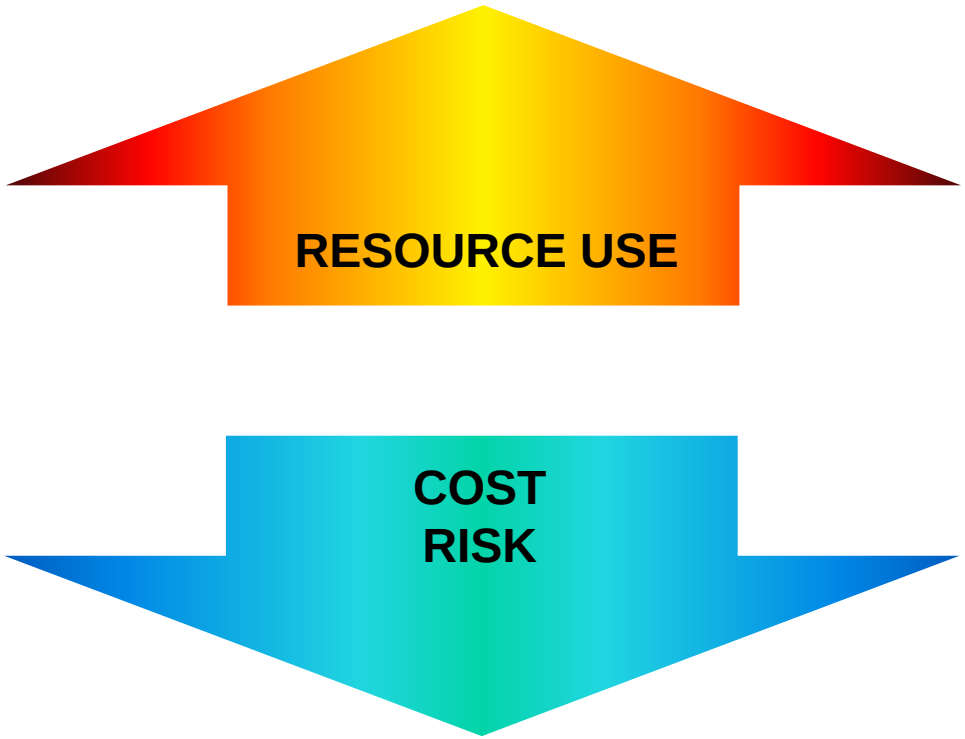
Enhanced Geothermal Systems: the concept



> Enhancing and broadening geothermal energy reserves

- stimulating reservoirs in Hot Dry Rock systems,
- enlarging the extent of productive geothermal fields by enhancing/stimulating permeability in the vicinity of naturally permeable rocks
- enhancing the viability of current and potential hydrothermal areas by stimulation technology and improving thermodynamic cycles,
- improving drilling and reservoir assessment technology,
- improving exploration methods for deep geothermal resources
- defining new targets and new tools for reaching supercritical fluid systems, especially high-temperature down-hole tools and instruments

The EGS challenge



- exploration
- resource assessment
- resource management
- advanced drilling
- advanced stimulation
- efficient power cycles
- environmental impact

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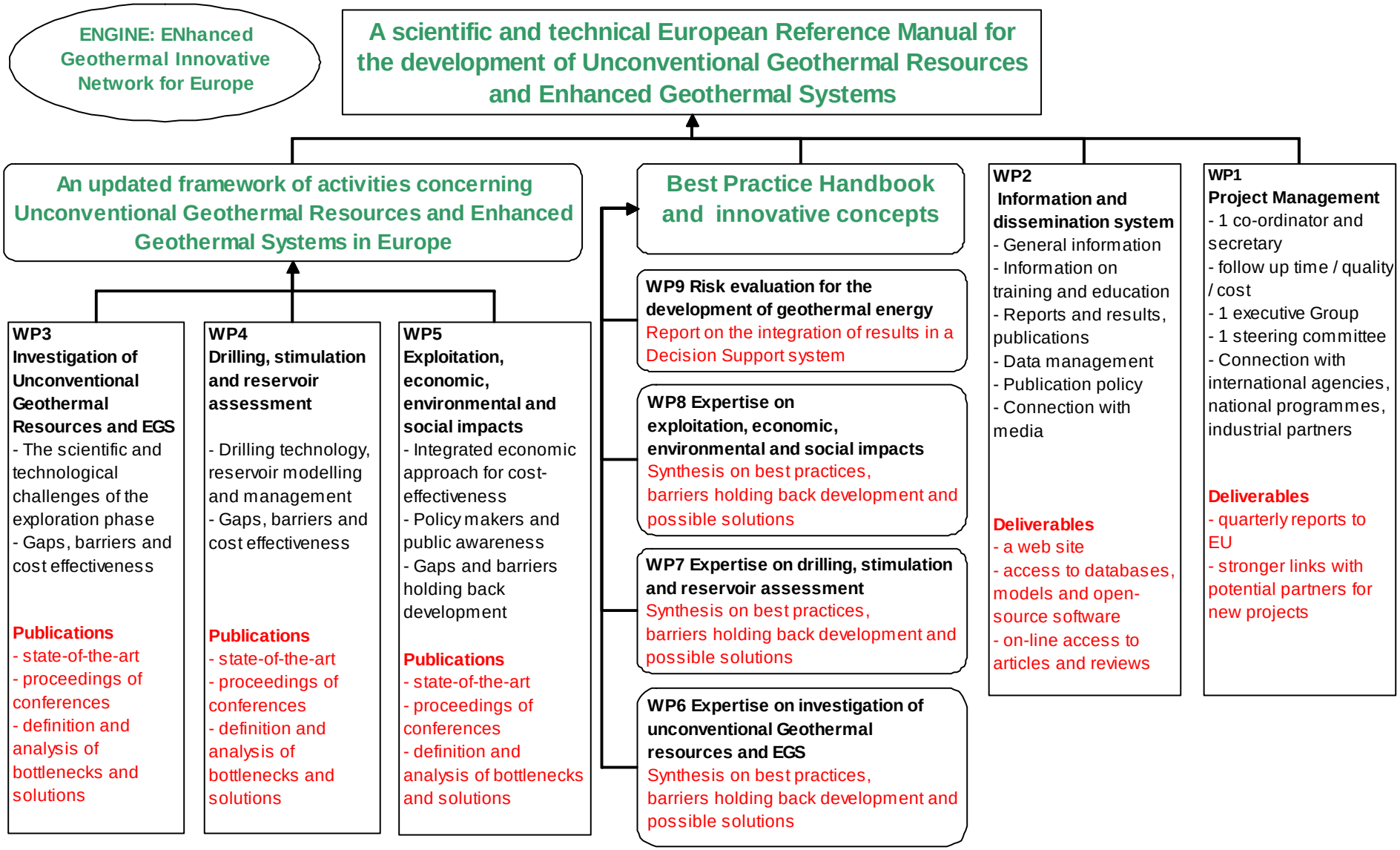
LaGeo
Col Utila Santa Tecla
EL SALVADOR

http://engine.brgm.fr/

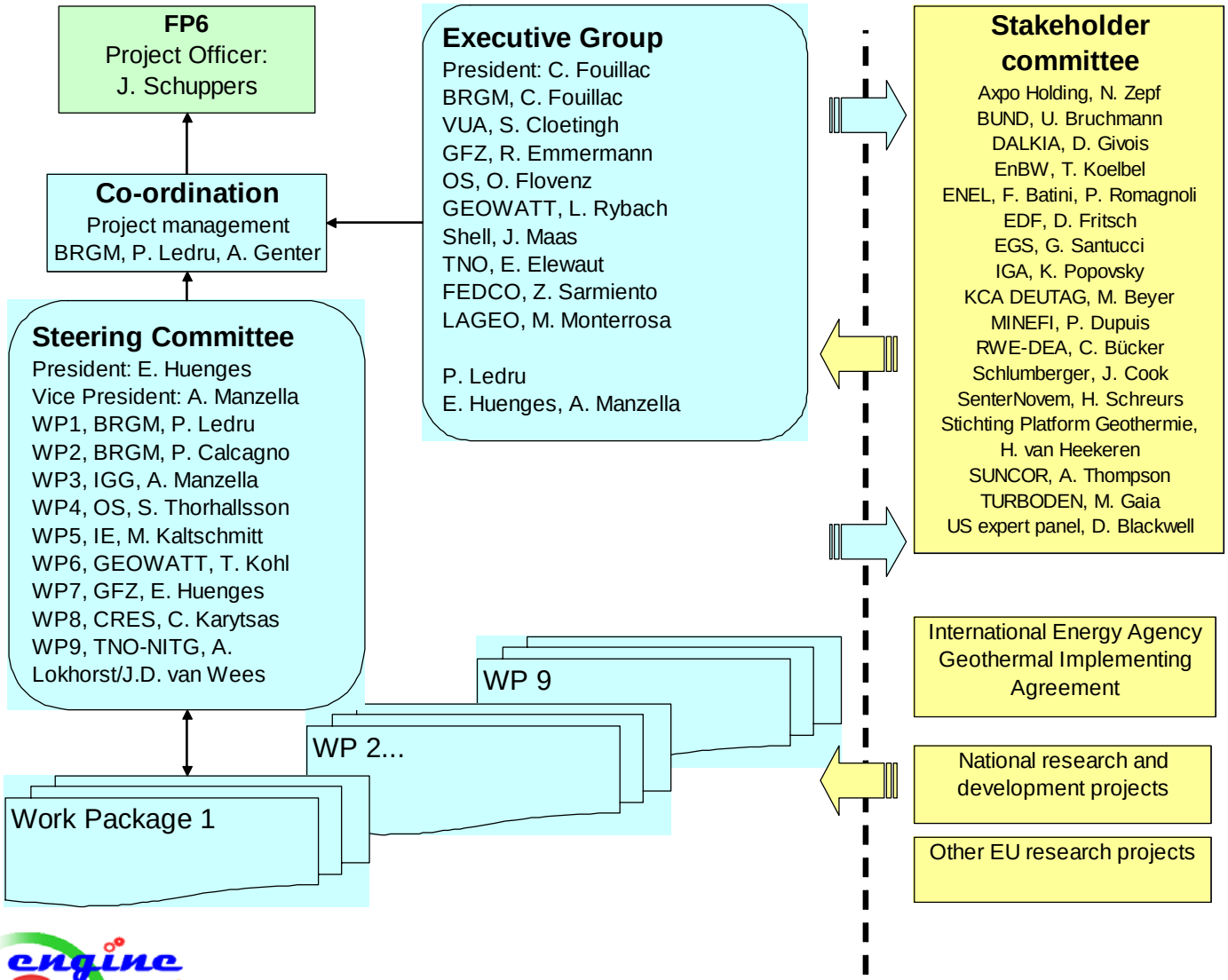
Coordination action breakdown structure: http://engine.brgm.fr/

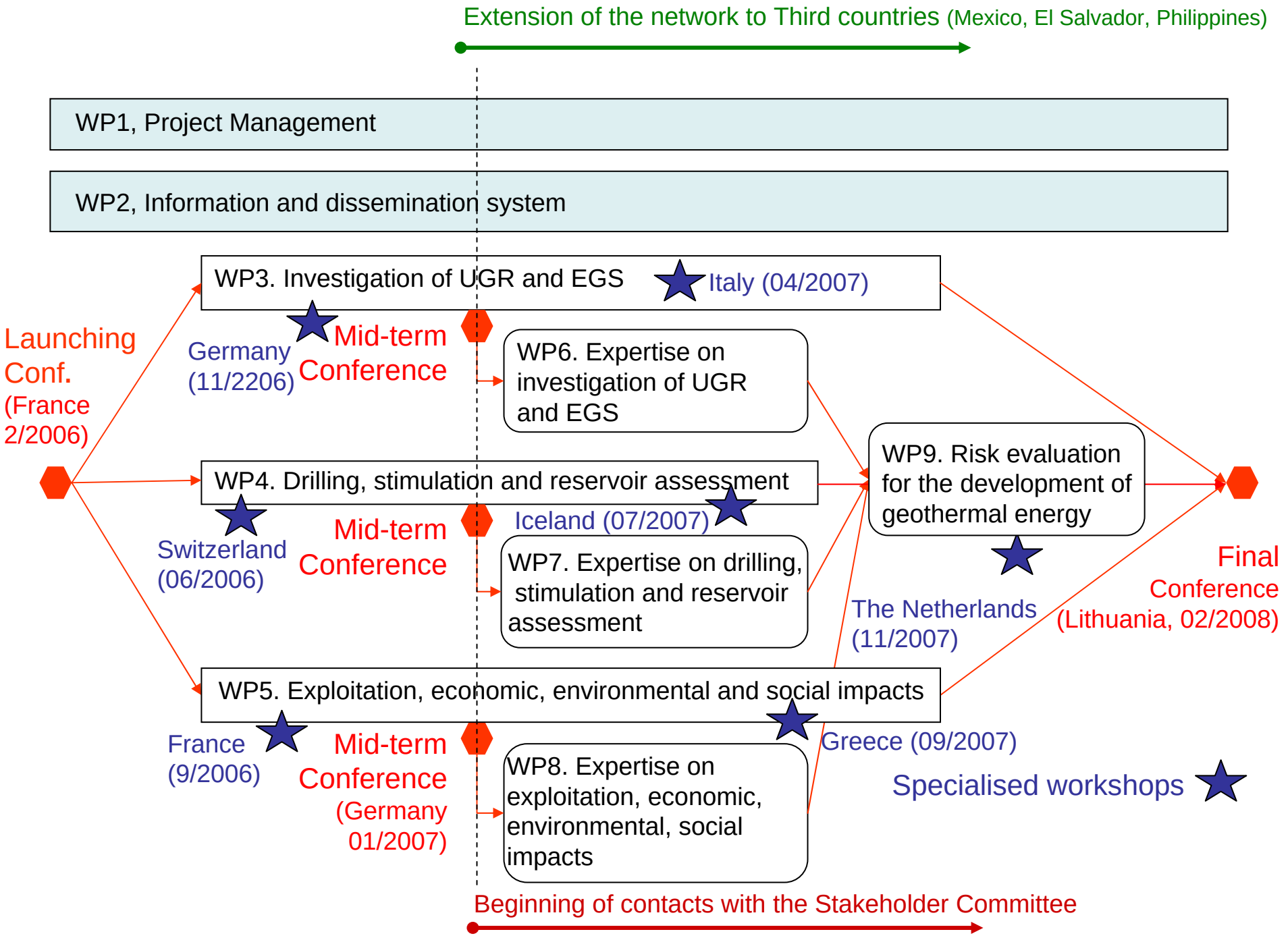


One major target: How to prioritise R&D needs?

EGS technology	Priority A	Impact of innovation	Priority B	Impact of innovation	Priority n	Impact of innovation
Resource investigation	Topic 1	x%	Topic 2	y%	Topic n	z%
Drilling, stimulation and reservoir assessment	…		…		…	
Exploitation, reservoir management and monitoring	…		…		…	
Economic, environmental and social impacts	…	high	…	medium	…	low
…						

An efficient network: http://engine.brgm.fr/




Extension of the network to Third countries (Mexico, El Salvador, Philippines)
WP1, Project Management
WP2, Information and dissemination system
WP3. Investigation of UGR and EGS
Italy (04/2007)
Launching Conf. (France 2/2006)
Germany (11/2206)
Mid-term Conference
WP6. Expertise on investigation of UGR and EGS
WP4. Drilling, stimulation and reservoir assessment
Iceland (07/2007)
Switzerland (06/2006)
Mid-term Conference
WP7. Expertise on drilling, stimulation and reservoir assessment
WP9. Risk evaluation for the development of geothermal energy
The Netherlands (11/2007)
Final Conference (Lithuania, 02/2008)
WP5. Exploitation, economic, environmental and social impacts
Greece (09/2007)
France (9/2006)
Mid-term Conference (Germany 01/2007)
WP8. Expertise on exploitation, economic, environmental, social impacts
Specialised workshops
Beginning of contacts with the Stakeholder Committee

Publication policy and Meeting management

> **Launching Conference**
> **Orléans, France**

> **Workshop 3**
> **Zurich, Switzerland**

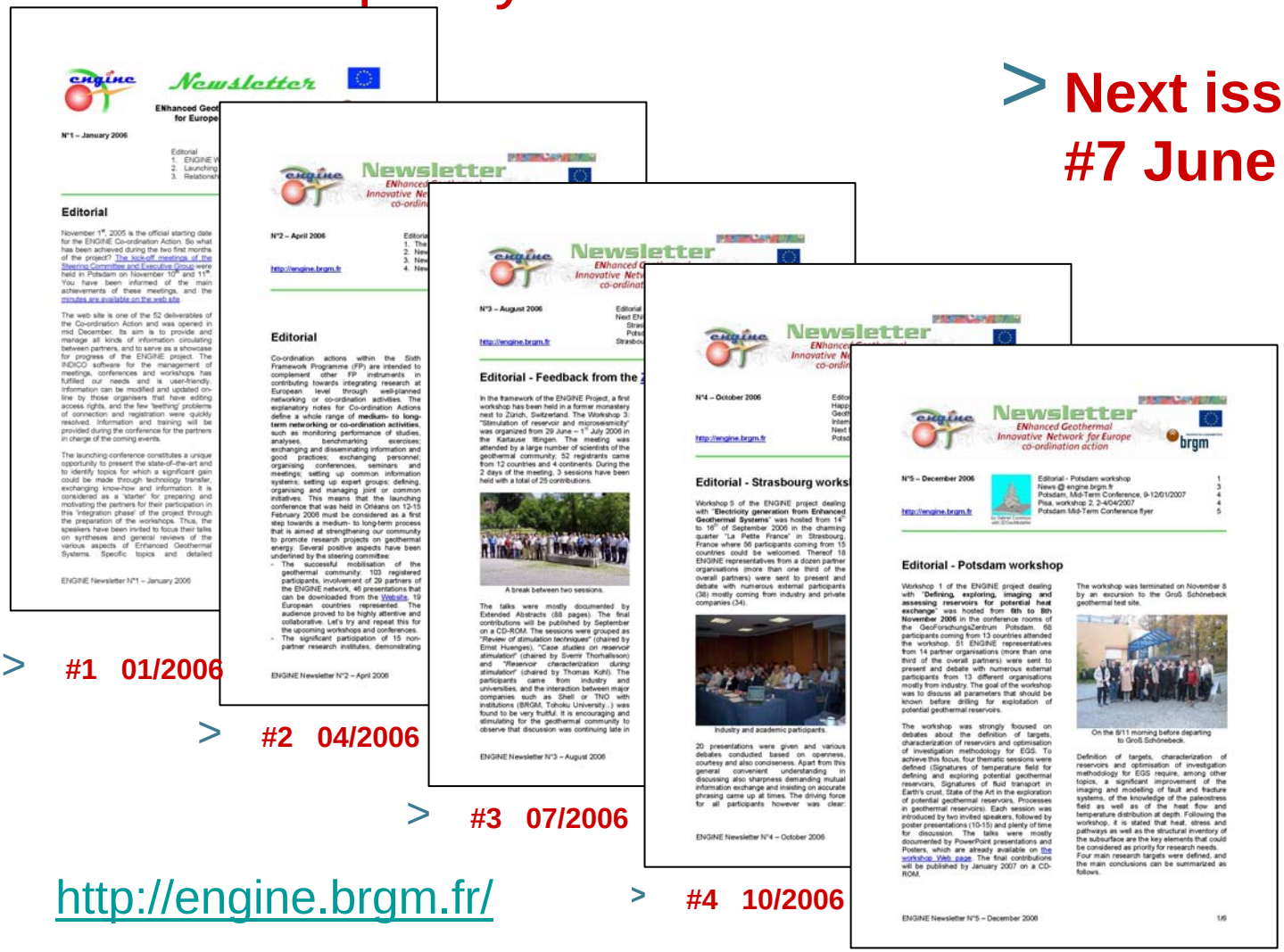
> **Workshop 5**
> **Strasbourg, France**

> **Workshop 1**
> **Potsdam, Germany**

> **Mid-Term Conference**
> **Potsdam, Germany**

http://engine.brgm.fr/

Publication policy



> **Next issue**
> **#7 June 2007**

> #1 01/2006

> #2 04/2006

> #3 07/2006

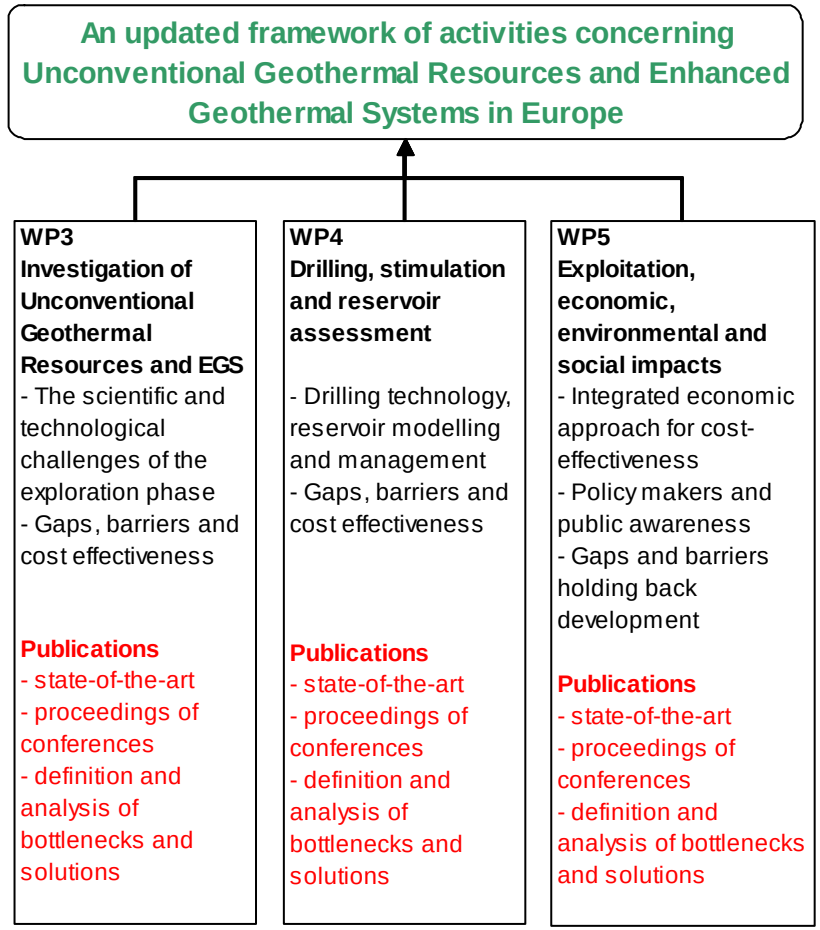
> #4 10/2006

> #5 12/2006

http://engine.brgm.fr/

A framework for some of the R&D issues that will result from the ENGINE project

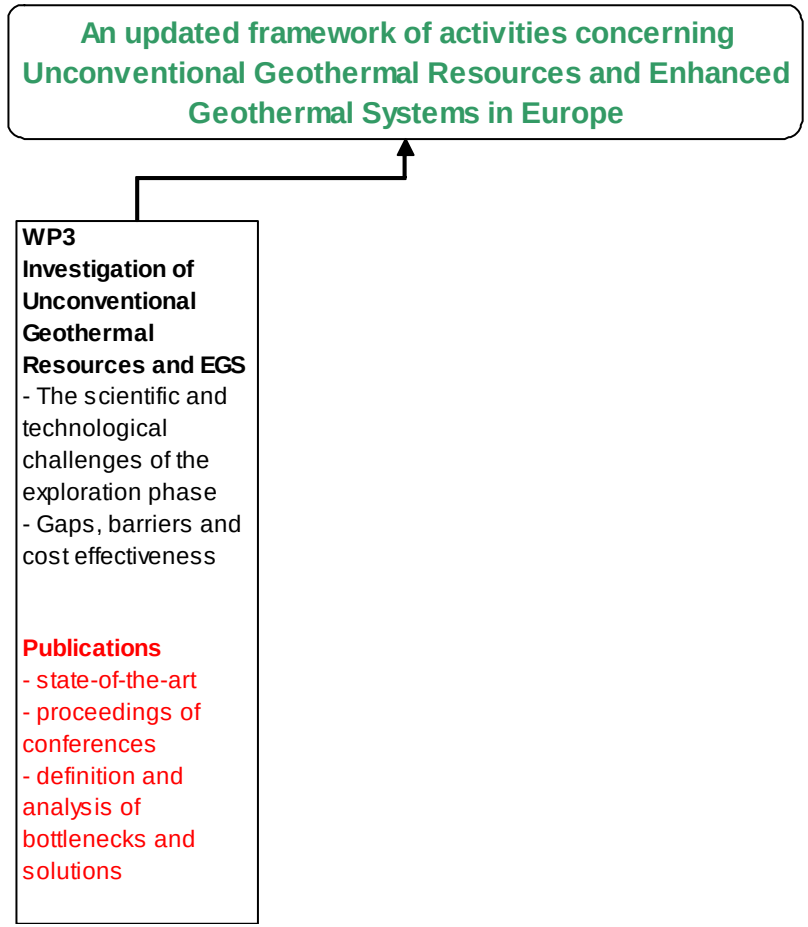
- An illustration of the bottom-up approach
- to capitalise the know-how and to define new integrated projects
  - Investigation of Unconventional Geothermal Resources and Enhanced Geothermal Systems
  - Drilling, stimulation and reservoir assessment
  - Economic, environmental and social impacts



A framework for some of the R&D issues that will result from the ENGINE project

> to capitalise the know-how and to define new integrated projects

- Investigation Enhanced Geothermal Systems
- Drilling, stimulation and reservoir assessment
- Economic, environmental and social impacts



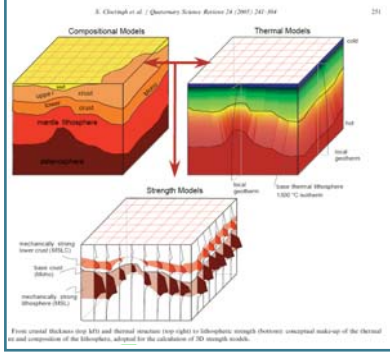
6-8 November 2007 Defining, Exploring, imaging and assessing reservoirs for potential heat exchange - Potsdam, Germany, Workshop1

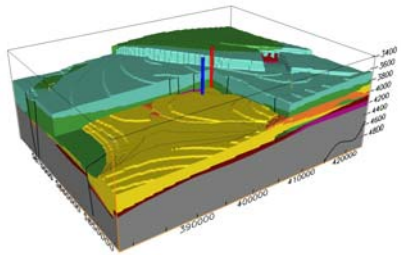
1-4 April 2007 Exploring high temperature reservoirs: new challenges for geothermal energy, Volterra, Italy, Workshop2

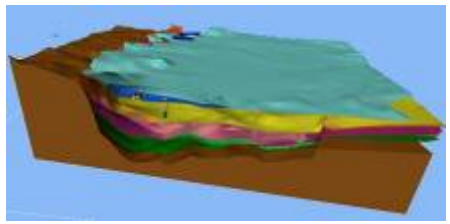
Investigation of Unconventional Geothermal Resources and Enhanced Geothermal Systems

> Geological knowledge

- Architecture, geometry and nature of the target deduced from geological context and structural analysis: a 3D model
- Geophysical methods are suitable but existing methods must be improved and used in combination with different, highly sensitive techniques in order to meet the specific requirements of modern geophysical exploration for geothermal purposes: links with IGET







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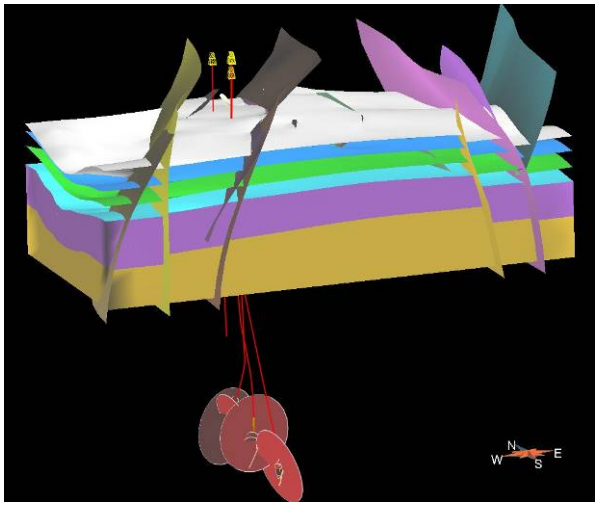
Investigation of Unconventional Geothermal Resources and Enhanced Geothermal Systems

> Geological knowledge

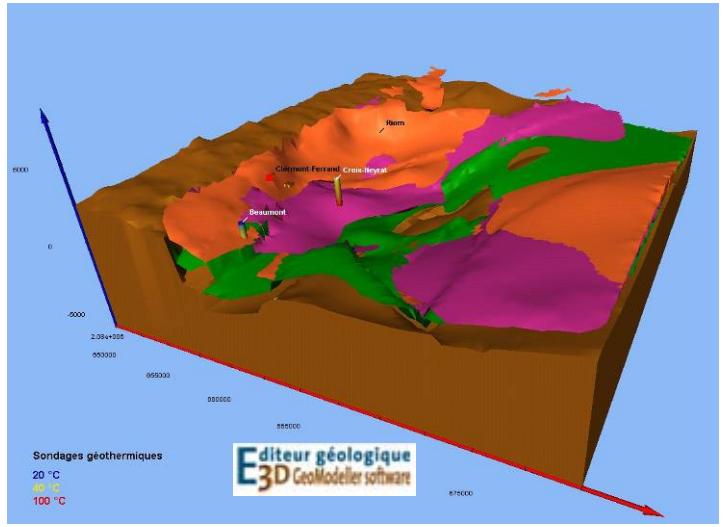
> Finding heat at depth

- Extension of large-wavelength heat-flow anomalies at depth is often inaccurate (insufficient knowledge of the causes of heat-flow anomaly and of thermal properties of the main lithologies)
- Several physical parameters are coupled with temperature and can be imaged by different geological, geophysical and geochemical methods
- The definition of possible targets for EGS could be improved by the use of a 3D modelling platform, in which all solutions from geological, geochemical and geophysical modelling, direct and inverse, could be combined and analysed

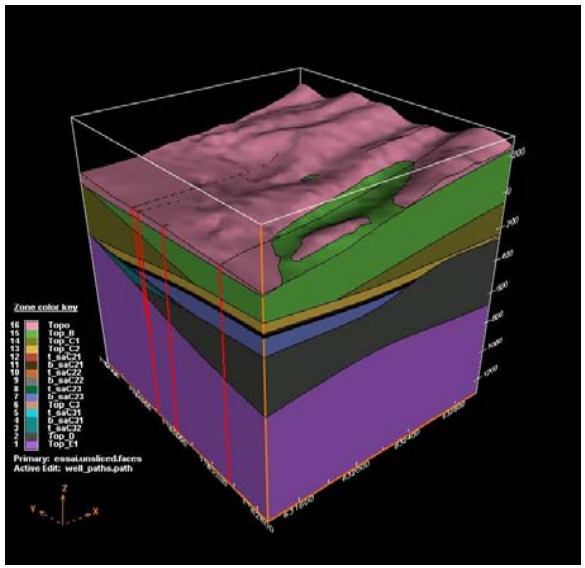
a 3D modelling platform



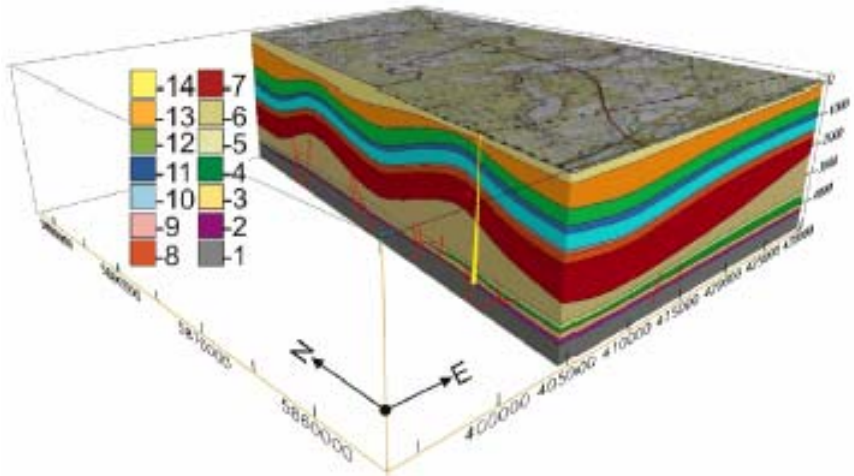
Soultz fault model, GOcad



Limagne clastic reservoir,
3D Geomodeller, BRGM



Bouillante volcanic reservoir,
EarthVision, BRGM



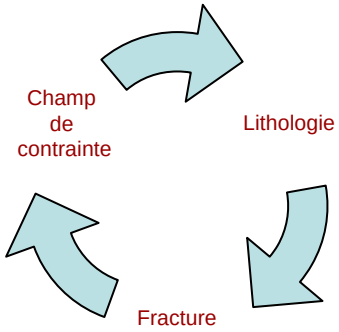
Gross Schönebeck model,
EarthVision, GFZ

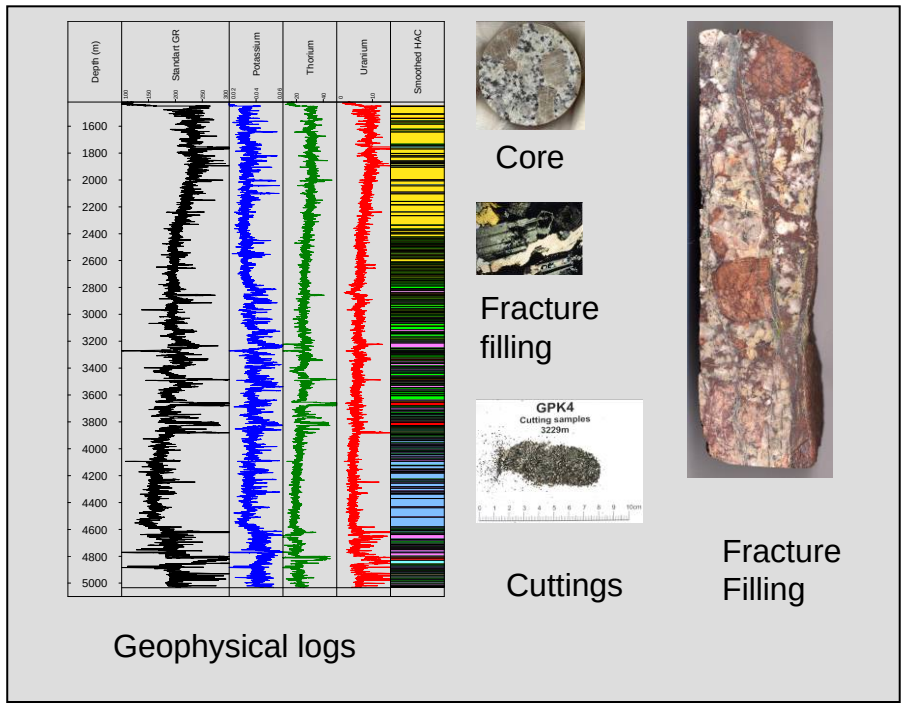
Investigation of Unconventional Geothermal Resources and Enhanced Geothermal Systems

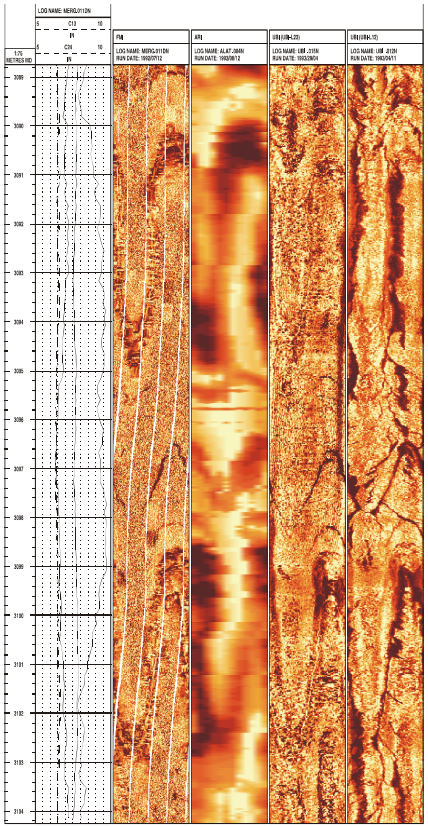
- Geological knowledge
- Finding heat at depth
- Stress field
  - Ability of fault and fracture systems to channel fluids is directly dependant on the stress field. Stress field and hydro-fracturing are linked
  - Mechanisms of rupture and propagation of an existing fault system and related displacement remain debated as well as the permeability associated with
  - Favourable and unfavourable stress field conditions must be evaluated, depending of the different stimulation methods

Complex interaction between lithologies, fractures and stress field

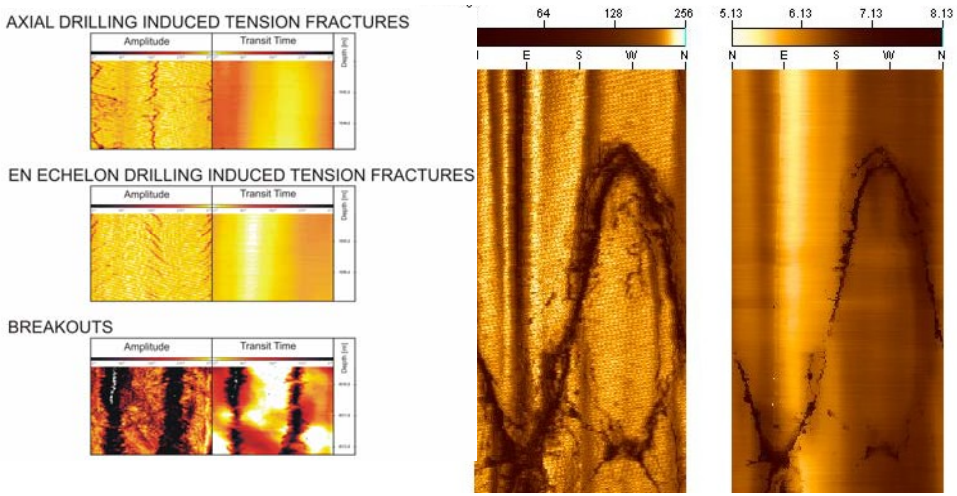
- Visualisation of fractured zones
- In situ measurement of their properties
- Measurement of the stress field
- Evaluation of interaction between lithologies and fluid circulation
- Understanding the history
- Modelling the fractured reservoir







The Soultz case history



Imagery of fractures par by geophysical logging

A framework for some of the R&D issues that will result from the ENGINE project

- to capitalise the know-how and to define new integrated projects
  - Investigation of Unconventional Geothermal Resources and Enhanced Geothermal Systems
  - **Drilling, stimulation and reservoir assessment**
  - Economic, environmental and social impacts

An updated framework of activities concerning Unconventional Geothermal Resources and Enhanced Geothermal Systems in Europe

WP4
Drilling, stimulation and reservoir assessment

- Drilling technology, reservoir modelling and management
- Gaps, barriers and cost effectiveness

Publications
- state-of-the-art
- proceedings of conferences
- definition and analysis of bottlenecks and solutions

29 Jun - 01 Jul 2006 Stimulation of reservoir and induced microseismicity - Zurich, Switzerland, Workshop3
1-05 July 2007 Drilling cost effectiveness and feasibility of high-temperature drilling - Reykjavik, Iceland, Workshop4

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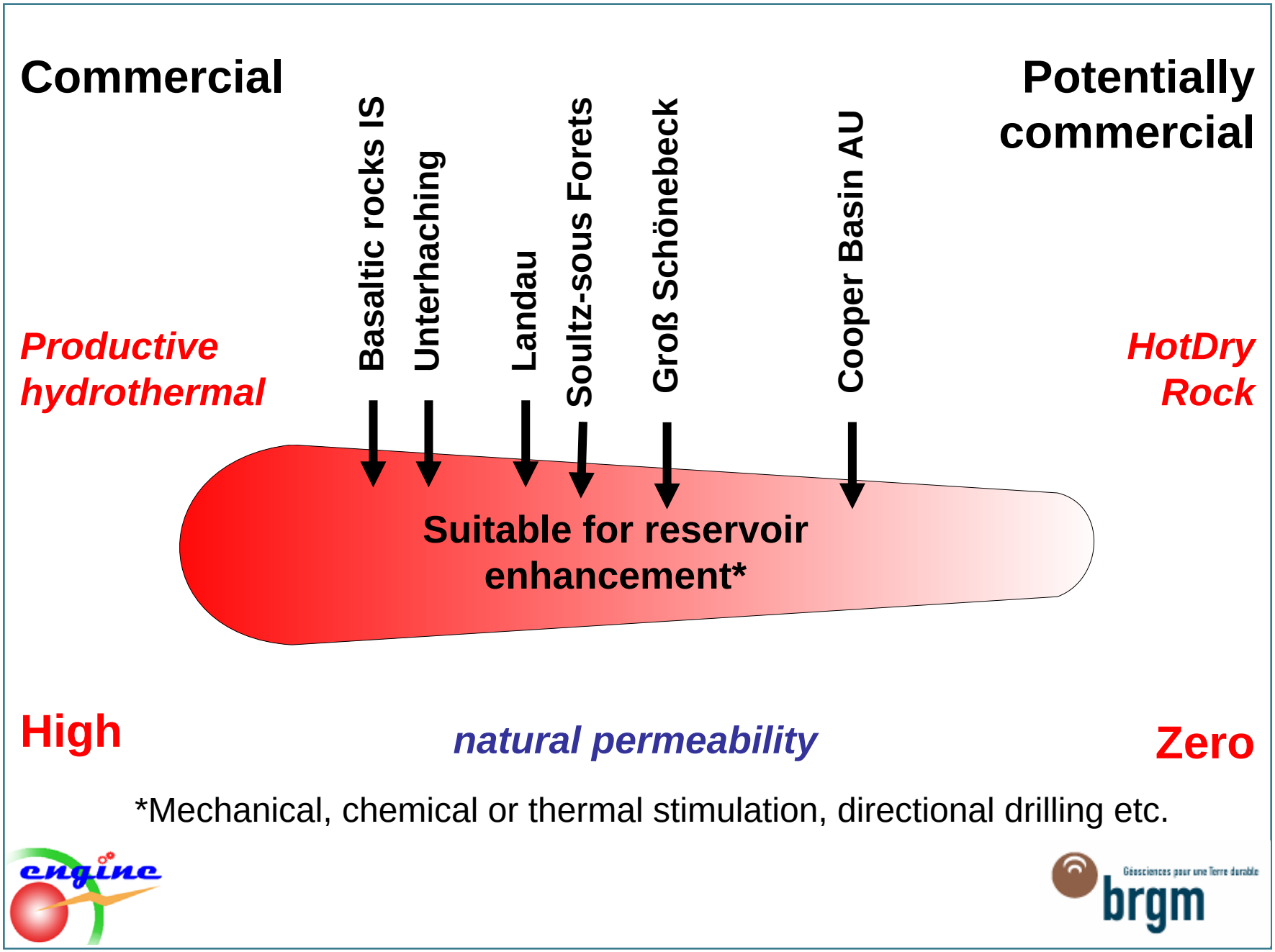

mod.from USGS

Drilling, stimulation and reservoir assessment

- Enhancing or engineering the reservoir is a key issue for EGS
- Mechanical and chemical stimulations are commonly used to enhance their hydraulic properties.
- Induced microseismicity, geochemical tracing and thermal evolution of the system is an exceptional opportunity to characterize the reservoir and its dynamics
- The success of these experiences is still a matter of trial and error, depending on the variety of geological contexts and site conditions. More detailed reviews are needed about some stimulation methods, and exchanges with hydrocarbon industry and underground nuclear waste and CO2 storage platforms are likely

Drilling, stimulation and reservoir assessment

- As it is already partly expressed in the FP7 work program, researches should
  - define conceptual models for irreversible enhancement of permeability of the reservoirs
  - analyse the distribution in time and space of the magnitude of seismic events in order to improve the 3D imaging of the fracture system and stress field
  - set requirements for seismic monitoring and recommend management strategies for prolonged field operation,
  - provide a methodology for the estimation of site-specific seismic hazard prior to development of potential sites for EGS.
- The induced earthquake in Basel on the 8th December 2006 reveals the urgent necessity to fill the gap in knowledge about this matter

A framework for some of the R&D issues that will result from the ENGINE project

> to capitalise the know-how and to define new integrated projects

- Investigation of Unconventional Geothermal Resources and Enhanced Geothermal Systems
- Drilling, stimulation and reservoir assessment
- Economic, environmental and social impacts

An updated framework of activities concerning Unconventional Geothermal Resources and Enhanced Geothermal Systems in Europe

WP5
Exploitation, economic, environmental and social impacts
- Integrated economic approach for cost-effectiveness
- Policy makers and public awareness
- Gaps and barriers holding back development

Publications
- state-of-the-art
- proceedings of conferences
- definition and analysis of bottlenecks and solutions

14 - 16 September 2006 Electriicty generation from Enhanced Geothermal Systems - Strasbourg, France, Workshop 5
13-14 September 2007 Increasing policy makers‘ awareness and public acceptance - Athens, Greece, Workshop 6

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Geothermal electricity generation in Europe

	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

Compiled by Kaltschmitt & Frick, 2006 from WGC05

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

Economic, environmental and social impacts

- Electricity production from low enthalpy resources in Europe: a fairly young technology which lacks wide experience, both for the development of geothermal resources and power plant systems
- Discussion about the pros and cons of
  - ORC vs. Kalina cycle,
  - air vs. water cooling
  - fancy vs. proven technology
  - power vs. Combined Heat Power

is of no interest in terms of a further development of geothermal energy use

- The main task of project developers is the optimisation potential in terms of the design of the working fluid, the cycle and turbine designs as well as the cooling systems

Economic, environmental and social impacts

- Efficiency of a power plant cycle can be improved with an increasing technical effort and innovative ideas. Before being able to break into the market these technologies need to be tested, which is generally not possible on a purely commercial basis as technical and financial risks are induced
- Governments, national agencies and Europe must support the market access of such new and innovative technologies
  - The Renewable Energy Source Act (EEG) was introduced in Germany to facilitate sustainable development of energy supply in the interest of managing global warming, conserving nature and protecting the environment
- The choice of a Turboden-Cryostar binary power plant for the Soultz-sous-Forêts : an application of optimisation potential and the choice of an innovative technology
- Combining different energy options supplying heat on different temperature levels can result in a higher overall efficiency, and thus profitability, and hence be decisive for realising geothermal based electricity production

EGS activity in the German part of the Upper Rhine graben

- The Renewable Energy Source Act (EEG) was introduced in Germany to facilitate sustainable development of energy supply in the interest of managing global warming, conserving nature and protecting the environment
- The EEG entered into force in 2000 and was amended on 1st of August 2004.
- Fees paid for electricity produced from geothermal energy:
  - At least 15 cents per KWh up to and including a capacity of 5 MW,
  - At least 14 cents per KWh up to and including a capacity of 10 MW,
  - At least 8.95 cents per KWh up to and including a capacity of 20 MW
  - At least 7.16 cents per KWh for a capacity of 20 MW and over
  - ***From Bestec, 2006***

EU-wide Feed-in tariffs for geothermal energy


Austria: 7,00 ct/kWh


Belgium: 2,50 ct/kWh


Czech Republic: 15,56 ct/kWh


Estonia: 5,10 ct/kWh


France: 10 ct/kWh (overseas: 12)


Germany: up to 15,00 ct/kWh


Greece: 7,31 ct/kWh


Slovakia: 9,04 ct/kWh

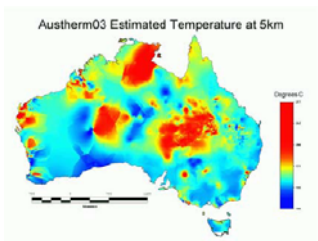

Slovenia: 5,85 + 2,52 ct/kWh

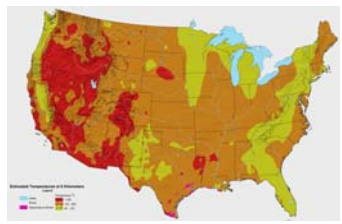

Spain: 6,49 + 2,94 ct/kWh

From Kaltschmitt, 2006

An international framework and a renewed interest for the geothermal energy from deep sources

- Development of geothermal energy requires the realisation of short term projects showing the use of cost-efficient geothermal energy and of medium to long term projects that concern Enhanced Geothermal Systems
- the Soultz experiment is considered as the international reference by the Australian investors and American scientists for whom EGS is one of the few renewable energy that can provide continuous base load-power
- The co-ordination of these short and long term projects requires a well organised scientific community at an international level, a restored political support and good links with industry and stakeholders



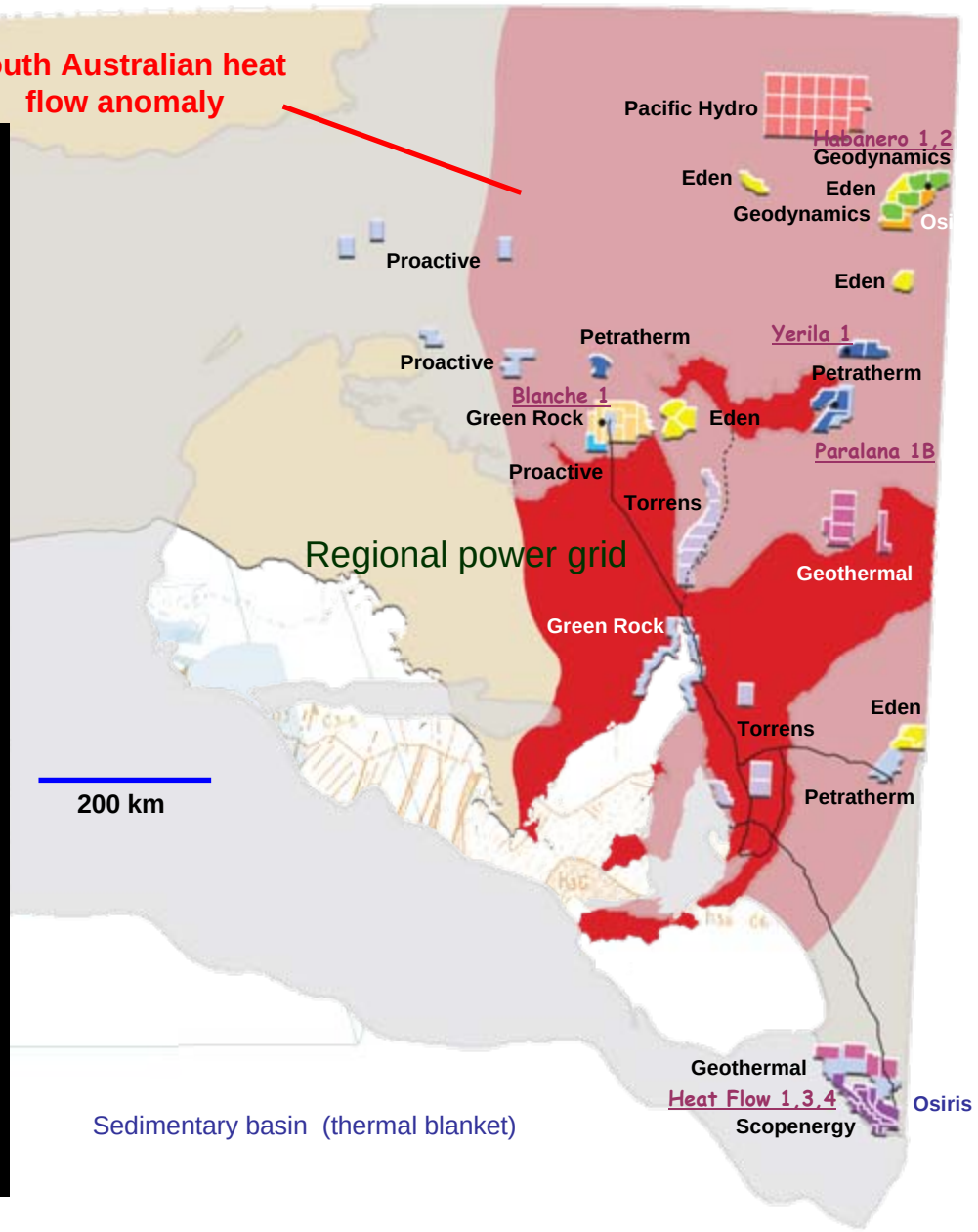


DOE Geothermal Technologies Program
Multi-Year Program Plan
2006 – 2011

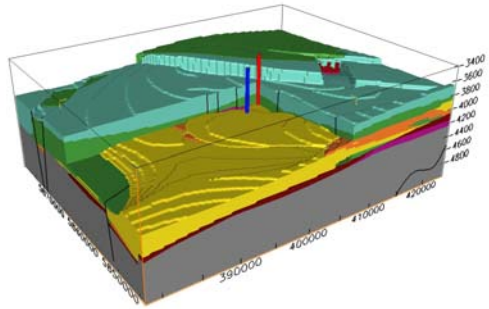
August 31, 2005

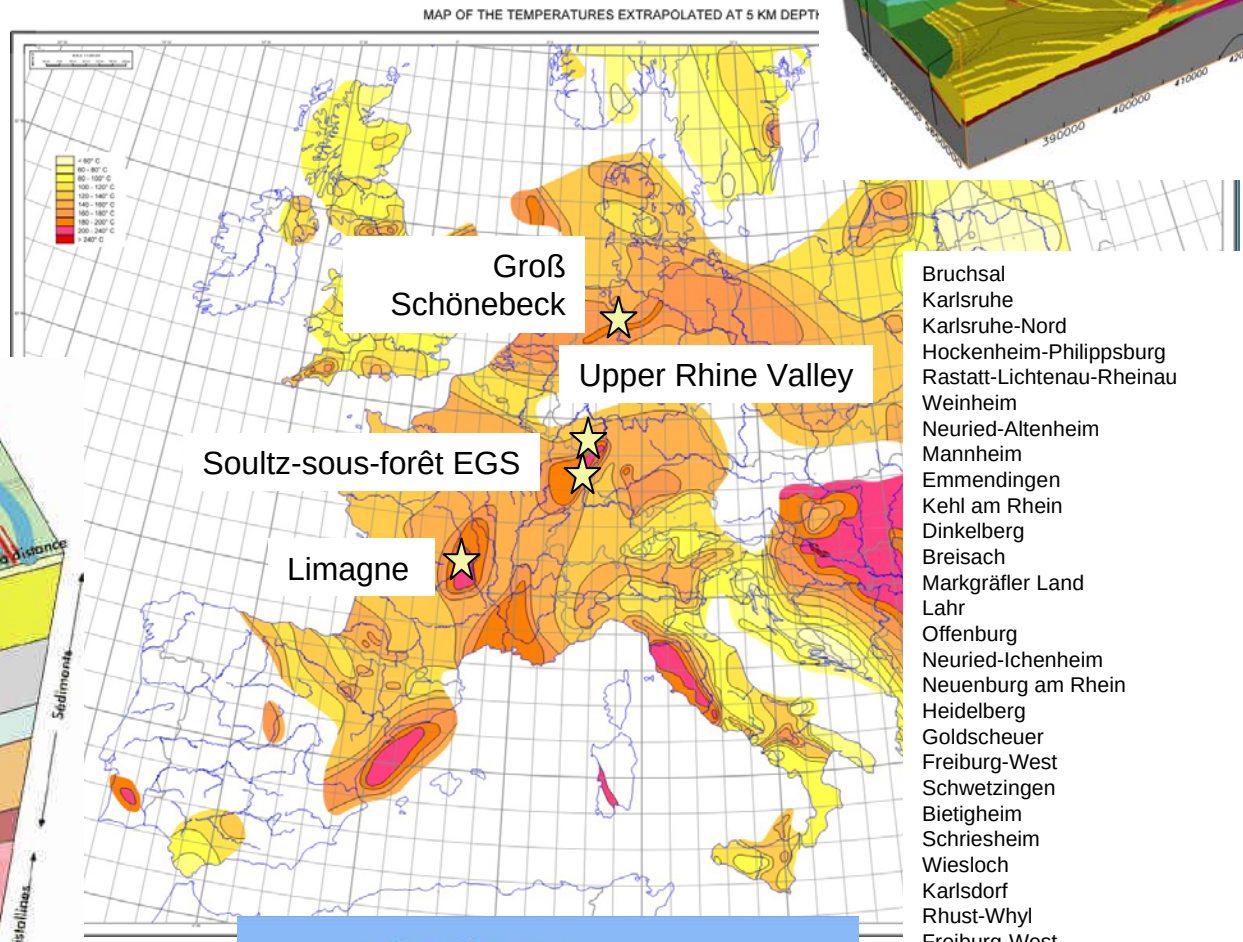
Hot Rock Projects in South Australia (from B. Goldstein)

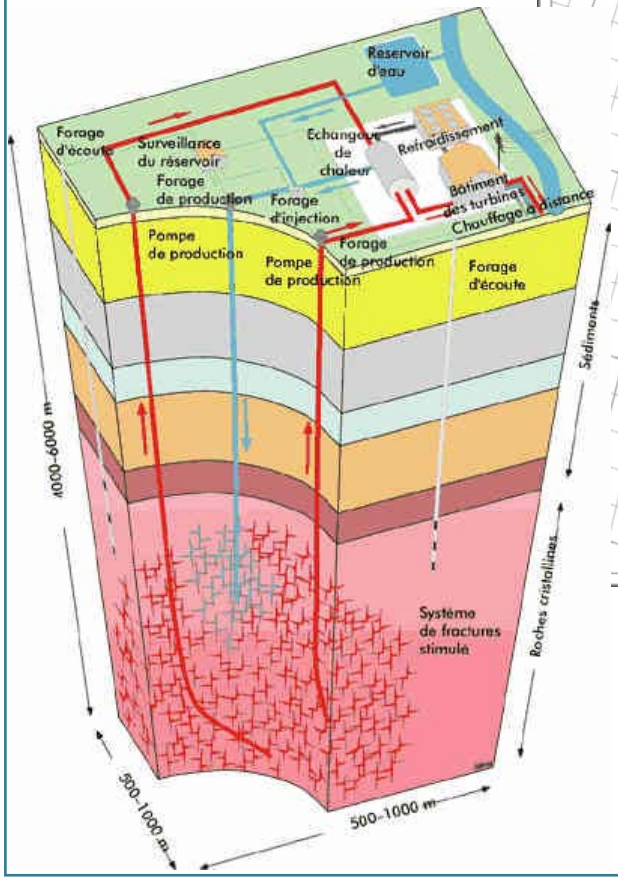
- 11 GEL / GELA Holders
  - ✓ Geodynamics
  - ✓ Petratherm =MNGI
  - ✓ Pacific Hydro
  - ✓ Osiris Energy
  - ✓ Geothermal Resources
  - ✓ Torrens Energy
  - ✓ Scopenergy
  - ✓ Green Rock
  - ✓ Eden (Tasman affiliate)
  - ✓ Proactive Energy
  - ✓ Origin Energy Resources
- 92 GELs / GELAs over 43,440 km²
- The 5-year GEL exploration and demonstration work programs correspond to $500+ million, and this excludes up-scaling and deployment projects
- Can benefit from Commonwealth renewable energy initiatives:
  1. Renewable Energy Certificates
  2. REDI Grants
  3. Circa $500 million in Federal grants to demonstrate low emissions technologies
- Just 1 GEL (500 km²) has hot rock emission-free energy potential to yield electricity equivalent to several Snowy Mountain Hydro Schemes (1 SM approx = 550 MWe)

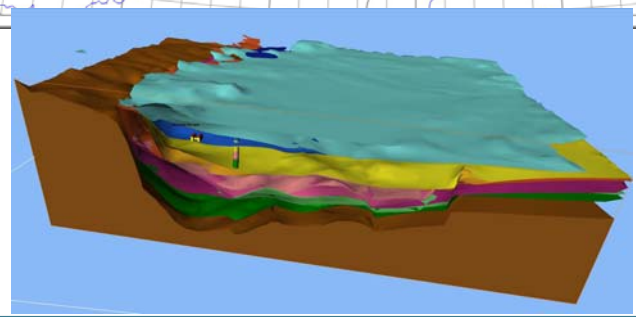


A continent to explore…







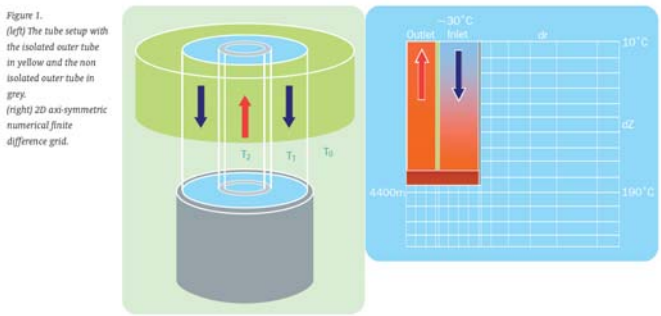


Bruchsal
Karlsruhe
Karlsruhe-Nord
Hockenheim-Philippsburg
Rastatt-Lichtenau-Rheinau
Weinheim
Neuried-Altenheim
Mannheim
Emmendingen
Kehl am Rhein
Dinkelberg
Breisach
Markgräfler Land
Lahr
Offenburg
Neuried-Ichenheim
Neuenburg am Rhein
Heidelberg
Goldscheuer
Freiburg-West
Schwetzingen
Bietigheim
Schriesheim
Wiesloch
Karlsdorf
Rhust-Whyl
Freiburg-West
Speyerdorf
Landau in der Pfalz
Offenbach an der Queich
Bellheim
Speyer
Riedstadt
Bad Bergzabern
Steinfeld
……

The use of Oil and Gas wells

Could we exploit the geothermal potential of North Sea oil fields as their oil runs out? Some have reservoir temperatures over 100º C and so electricity generation might be possible
(J. Busby, 2006, BGS)

Re-use of E&P-boreholes
for geothermal energy production



> Geothermal energy applications have gained renewed interest in recent years. One of the interesting applications is the re-use of deep boreholes drilled by oil and gas industry for a Deep Borehole Heat Exchanger (DBHE).

> (J. D. Van Wees, 2007, TNO)

From an ENhanced Geothermal Innovative Network for Europe to an European geothermal drilling program?

- an effort of communication to be done to promote the geothermal energy as a cost-efficient alternative source of energy
- a need of good synthesis of the knowledge and collection of existing datasets for modelling and assessment of the resources, prior to drilling
- a need for *a **scientific exchange platform*** for:
  - promoting past and on-going experiences by making them visible and reproducible
  - defining ***research projects*** that could be presented to the EU commission as a possible contribution for the future work programme of the FP7.
  - defining ***an ambitious research program at the scale of Europe*** that will federate the research capacity and limit the financial risk by sharing the investment. Such a program, that could be for example an ***European geothermal drilling program*** requires a common approach of both scientist and stakeholders

Conclusions

- A sound scientific and technical knowledge acquired in Europe during the 20th century
  - Conventional geothermal energy still benefits from ongoing improvements in conversion, heat distribution… and should become increasingly cost-effective (rise in energy prices, new environmental constraints, greenhouse gas reduction...)
- A need for long-term collaborative research on international projects to develop Enhanced Geothermal Systems
  - reference to the Soultz experiment for promoting new projects in Australia, Kamtchaka, Chile…, extension of existing geothermal fields, geothermal recovery from existing oil and gas operations…
- ENGINE, along with other initiatives (European Commission, IEA-GIA, MIT expert panel, IGA, EGEC…) can
  - contribute to the construction of an international strategy
  - consolidate the available information systems
  - propose spin-off projects that will receive the support of stakeholders, decision makers and private investors.