



ENhanced Geothermal Innovative Network for Europe: The State-of-the-Art

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A paradox in Europe in 2005

- > Europe is a pioneer 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



An initiative for building an innovative research network for Europe

- > An expression of interest from the EC FP6 for a coordination action for developing Unconventional Geothermal Resources
- > to motivate the scientific community to face up to the scientific and technological challenges
- > to capitalise the know-how
 - EGS Soultz experiment, Italy, Bouillante and Iceland...
- > to define new integrated projects that will federate the scientific community, in partnership with industry, in order to achieve the strategic objectives of the European Community

**ENhanced Geothermal Innovative Network for Europe
(ENGINE, <http://engine.brgm.fr>)**



ENGINE breakdown structure

A scientific and technical European Reference Manual for the development of Enhanced Geothermal Systems

An updated framework of activities concerning Enhanced Geothermal Systems in Europe

Best Practice Handbook and innovative concepts

- > A major scope is the identification of gaps that hamper the development of geothermal energy and definition of research targets for the future
- > Start 1 November 2005, 30 months, 2,3 M€, 31 European partners + 4 from Third Countries, 20 countries involved in Geothermal R&D





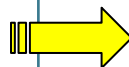
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LaGeo
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EL SALVADOR

<http://engine.brgm.fr/>

Unconventional Geothermal Resources

What between end-members?

GÉOTHERMIE TRÈS BASSE ÉNERGIE

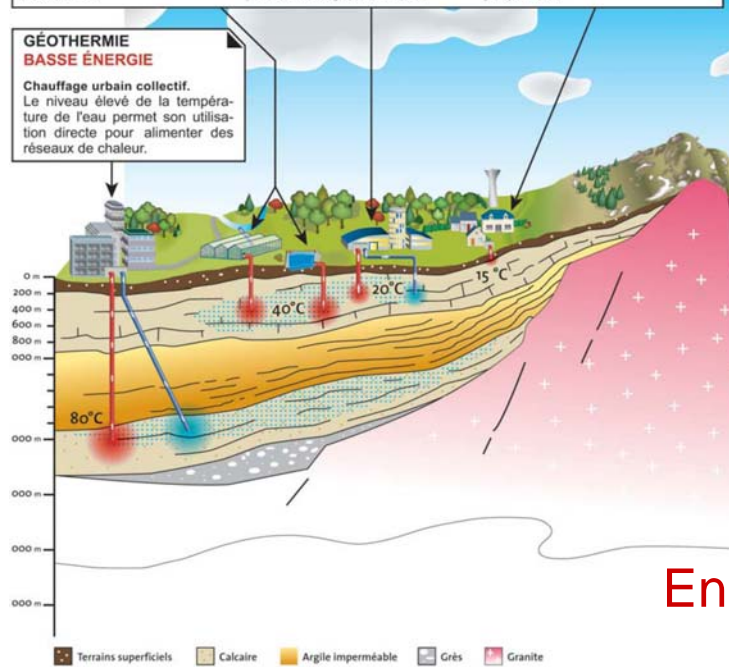
Chauffage de piscines, de serres... Bien qu'elle présente une faible température, l'eau peut directement être utilisée pour le chauffage de piscines, serres ou bassins de pisciculture.

Chauffage par pompe à chaleur. La température de l'eau insuffisante pour le chauffage direct de locaux, nécessite de recourir à des pompes à chaleur sur eau souterraine ou à des sondes géothermiques.

Chauffage de maisons individuelles. Les calories nécessaires au chauffage sont prélevées par un dispositif associant une pompe à chaleur à un capteur enterré dans le sous-sol superficiel.

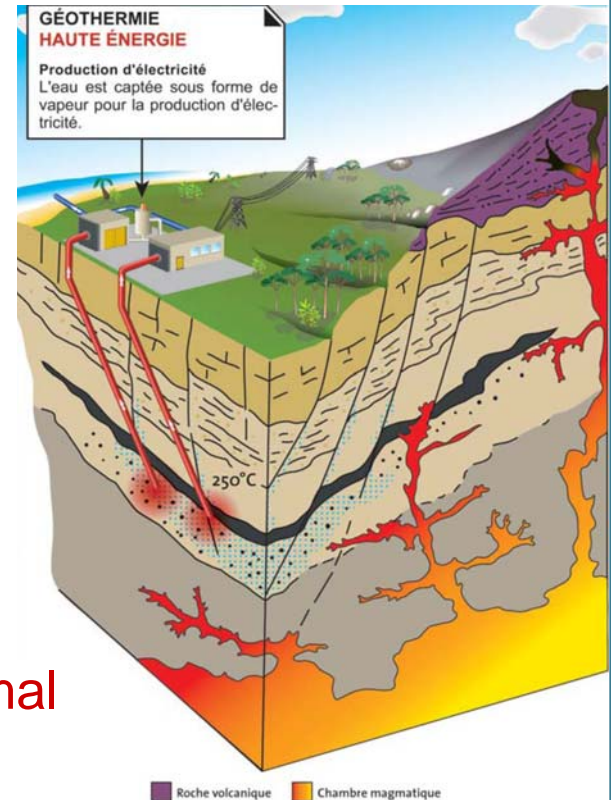
GÉOTHERMIE BASSE ÉNERGIE

Chauffage urbain collectif. Le niveau élevé de la température de l'eau permet son utilisation directe pour alimenter des réseaux de chaleur.



GÉOTHERMIE HAUTE ÉNERGIE

Production d'électricité. L'eau est captée sous forme de vapeur pour la production d'électricité.



?

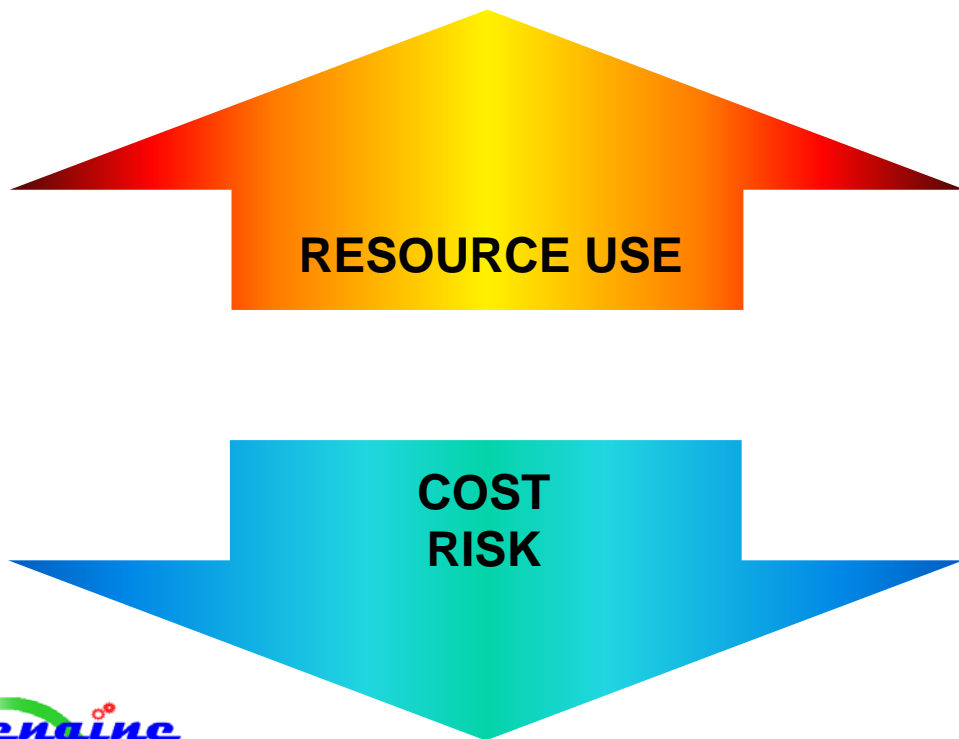
Enhanced Geothermal systems



Development of Unconventional Geothermal Resources

The Enhancement challenge

How to use non-conventional methods for exploring, developing and exploiting geothermal resources that are not economically viable by conventional methods?

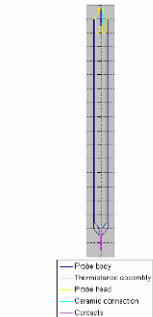


- exploration
- resource assessment
- resource management
- advanced drilling
- advanced stimulation
- efficient power cycles
- environmental impact



Unconventional Geothermal Resources

High temperature, high precision temperature measurement probe project



Specifications:

Precision: 0.01°C
Sensitivity: 0.003 °C
Range : 0 to 350 °C
Pressure : 500 bars

High temperature, High precision temperature measurement probe project



ARN/RSC

> Enhancing and broadening geothermal energy reserves

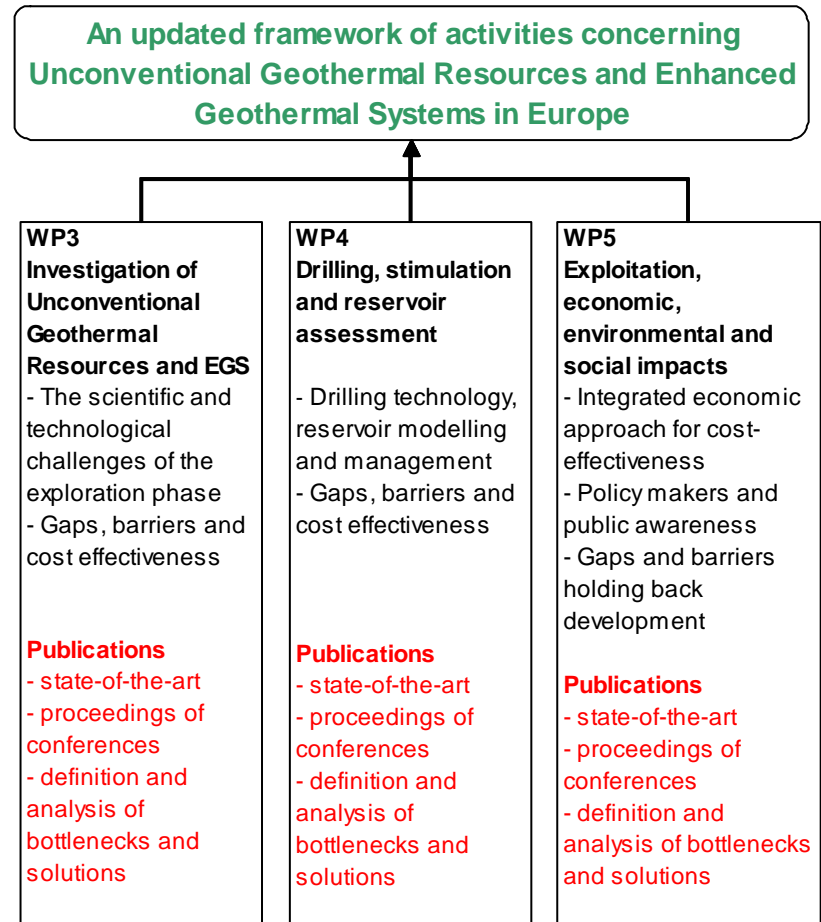
- stimulating reservoirs in Low Permeability Systems
- enlarging the extent of productive geothermal fields by enhancing/stimulating permeability in the vicinity of naturally permeable rocks and improving thermodynamic cycles
- improving exploration methods for deep geothermal resources
- improving drilling and reservoir assessment technology
- defining new targets and new tools for reaching supercritical fluid systems, especially high-temperature down-hole tools and instruments

Husavik power plant: the first Kalina cycle geothermal plant in the world



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

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

WP3
Investigation of Unconventional Geothermal Resources and EGS
- The scientific and technological challenges of the exploration phase
- Gaps, barriers and cost effectiveness

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

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 and the use of Geophysical methods

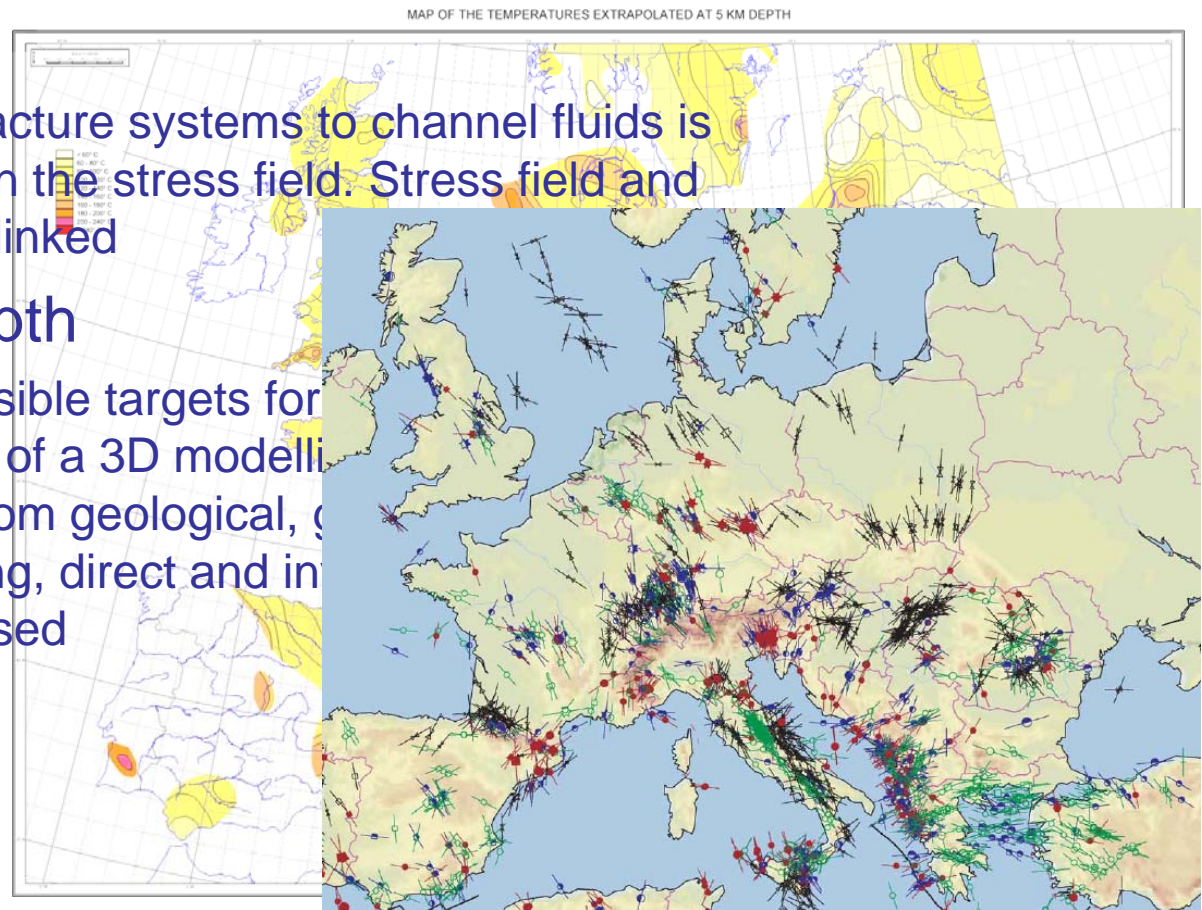
- An global approach at the scale of Europe

> Stress field

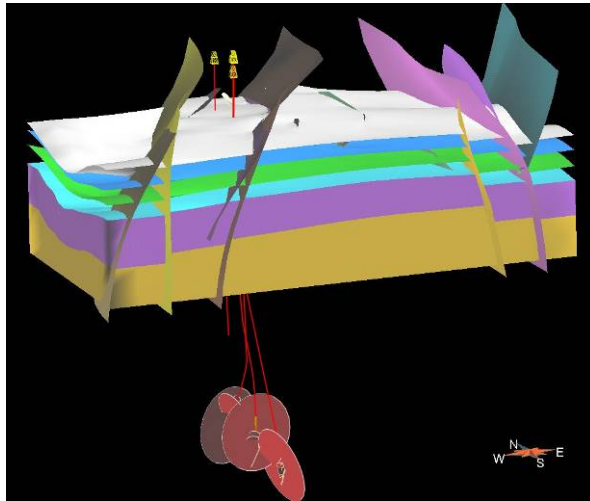
- Ability of fault and fracture systems to channel fluids is directly dependant on the stress field. Stress field and hydro-fracturing are linked

> Finding heat at depth

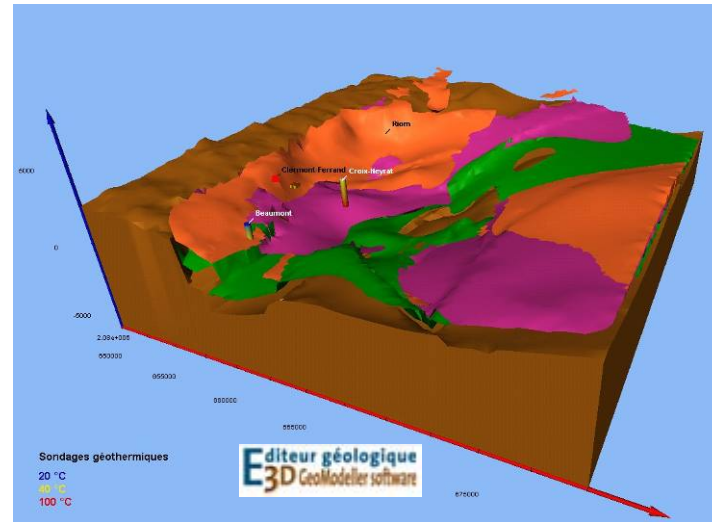
- The definition of possible targets for improved by the use of a 3D modelling which all solutions from geological, geophysical modelling, direct and indirect combined and analysed



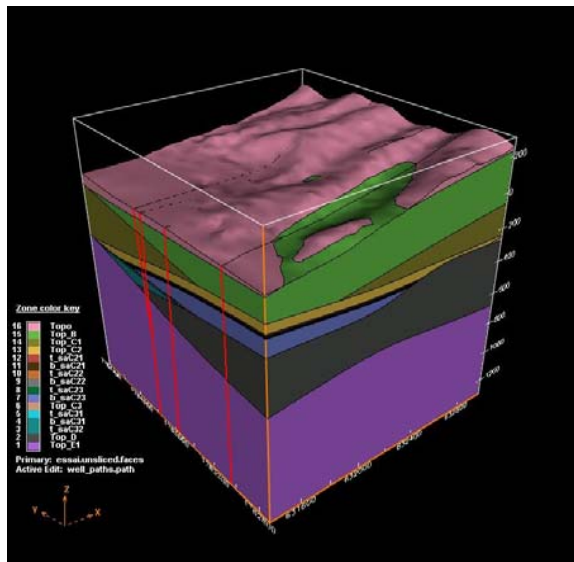
a 3D modelling platform



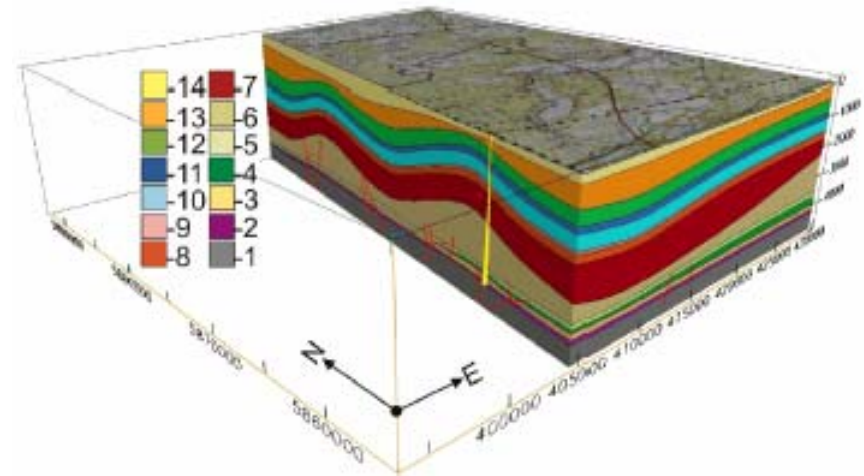
Soutz fault model, GOcad



Limagne clastic reservoir, 3D Geomodeller, BRGM



Bouillante volcanic reservoir, EarthVision, BRGM



Gross Schönebeck model, EarthVision, GFZ



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](#)

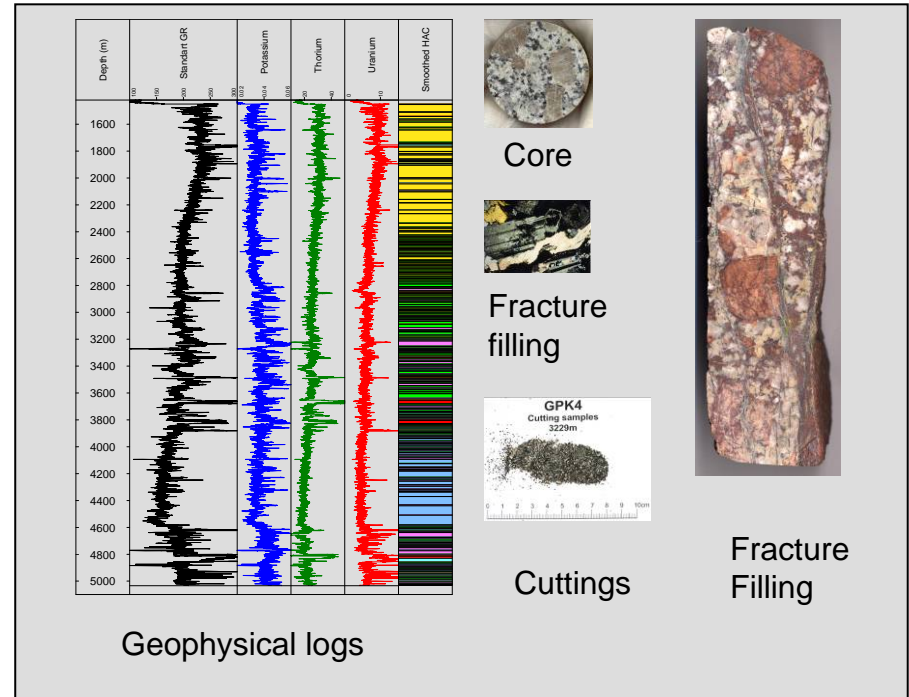
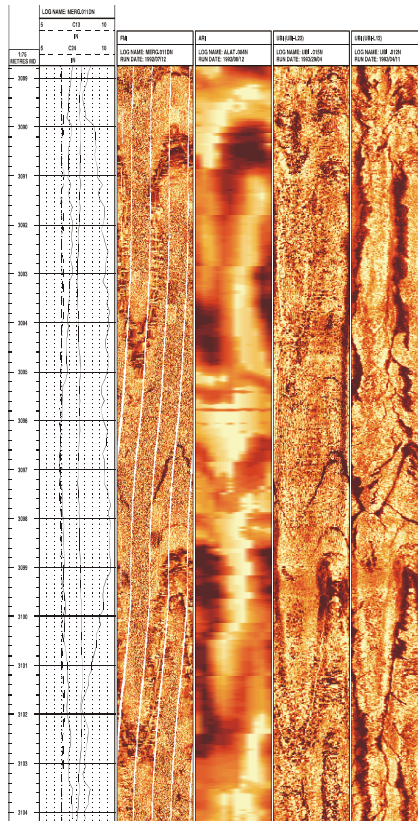
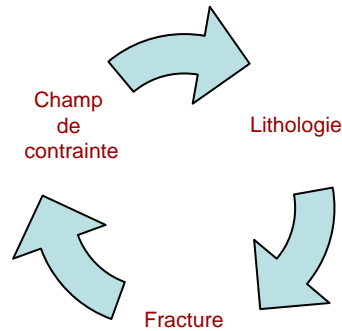
Drilling, stimulation and reservoir assessment

- > Enhancing or engineering the reservoir, through 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

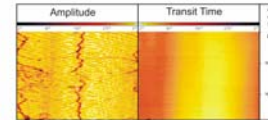


Complex interaction between lithologies, fractures and stress field

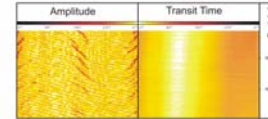
- Visualisation of fractured zones
- In situ measurement of their properties
- Measurement of the stress field
- Evaluation of interaction between lithologies and fluid circulation
- Understanding the history
- Modelling the fractured reservoir



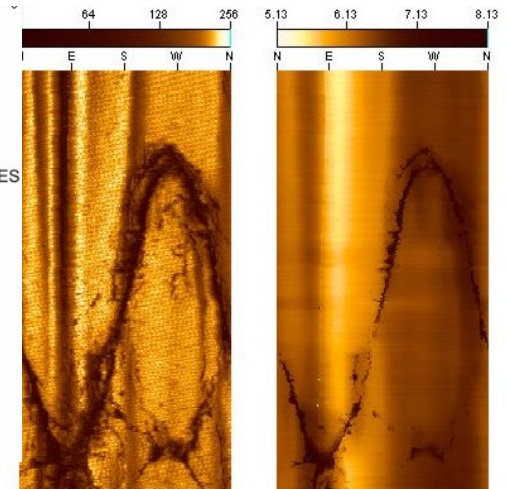
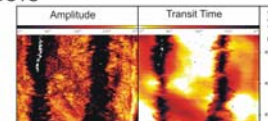
AXIAL DRILLING INDUCED TENSION FRACTURES



EN ECHELON DRILLING INDUCED TENSION FRACTURES



BREAKOUTS



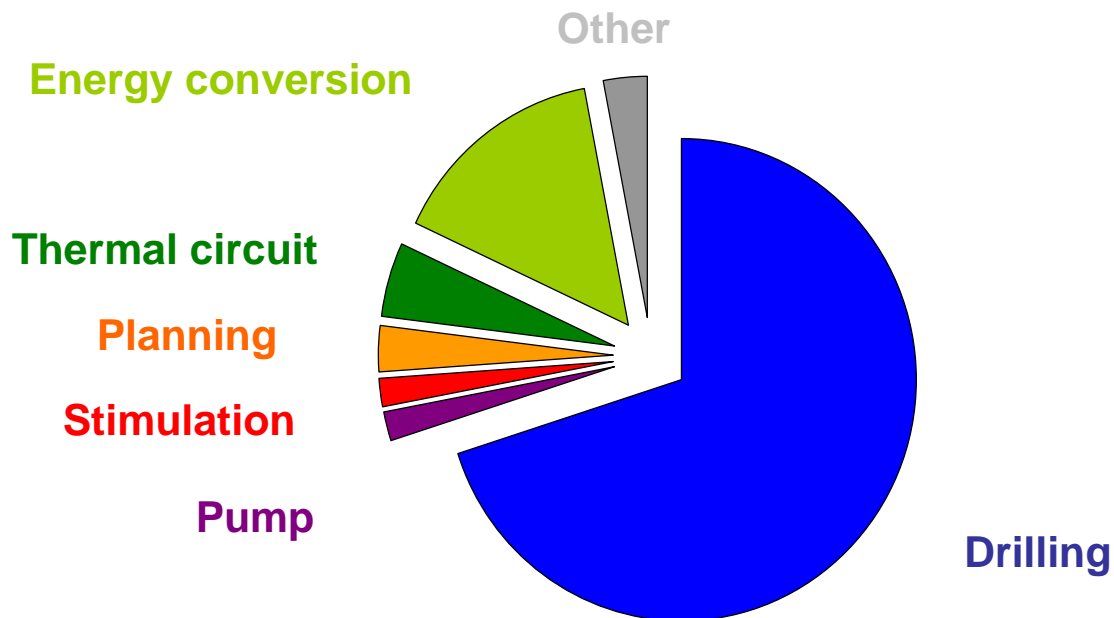
Imagery of fractures par by geophysical logging

The Soultz case history

Drilling, stimulation and reservoir assessment

RELIABLE TECHNOLOGY

ECONOMIC VIABILITY



EGS – invest cost structure



Drilling, stimulation and reservoir assessment

How to increase cost effectiveness?

- ✓ Reliability of geothermal drilling
- ✓ Standardization of geothermal drilling and stimulation operations
- ✓ System studies with focus on operational issues
- ✓ Drilling instruments and tools and completion components
- ✓ Improve 3D seismic geothermal exploration technology

EUROPEAN
GEOHERMAL
DRILLING
PROGRAMM



INNOVARIG – an instrument for a European geothermal drilling program

- > to have an opportunity for applying various drilling processes within the frame of usual industry safety standards,
- > specific equipment for sample recovery (cores, cuttings, mud, gas),
- > reliable installations to support various stimulation procedures (chemical, mechanical, and thermal),
- > installations to make logging easier respectively to reduce its preparing time,
- > support for comprehensive data acquisition from drilling, logging, testing, and monitoring



GeoForschungsZentrum Potsdam



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 [Electricity generation from Enhanced Geothermal Systems - Strasbourg, France, Workshop 5](#)

13-14 September 2007 [Increasing policy makers' awareness and public acceptance - Athens, Greece, Workshop 6](#)



Economic, environmental and social impacts

- > Improvement of the efficiency of a power plant cycle 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

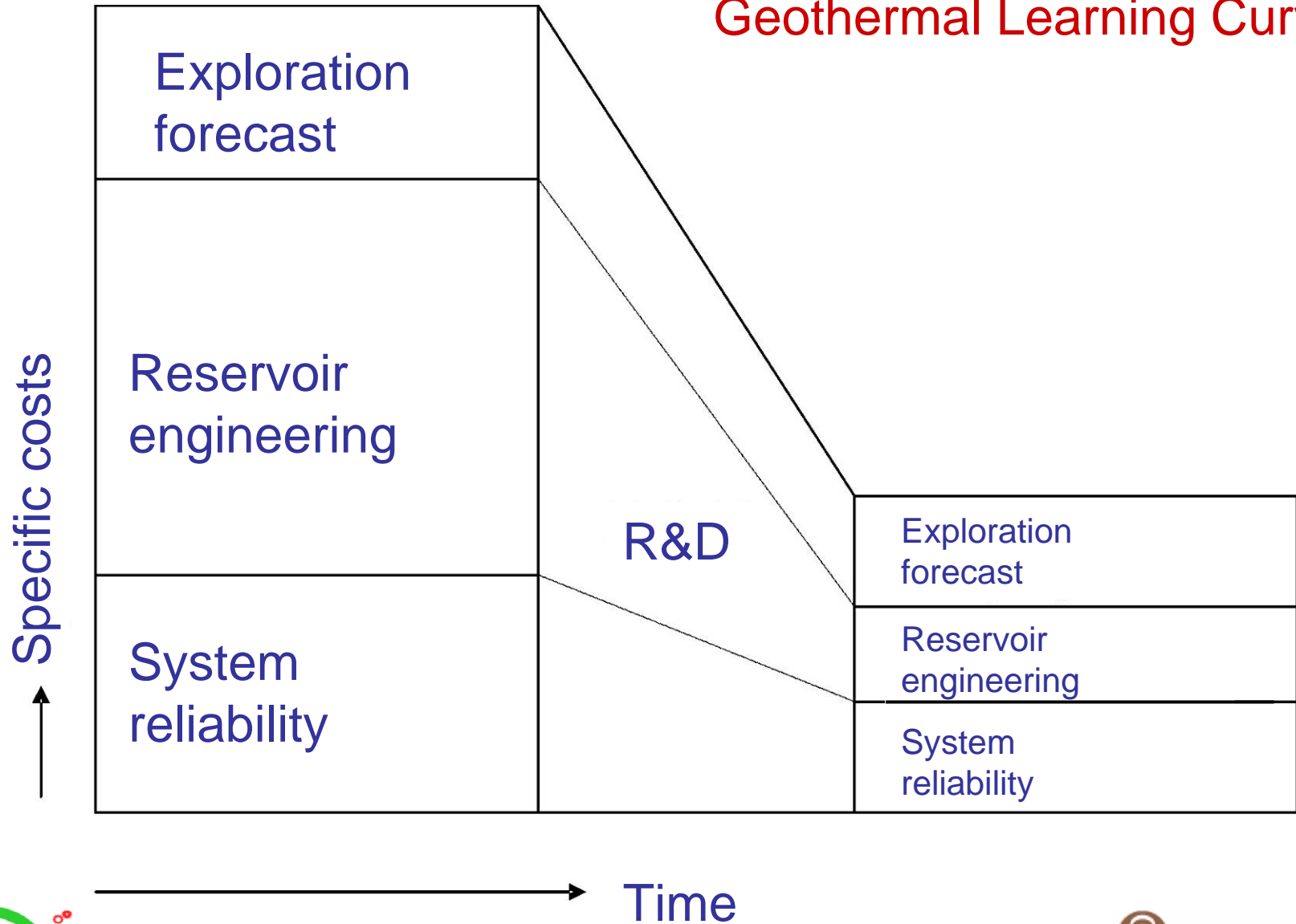


The Enhanced Geothermal Systems: the adult age?

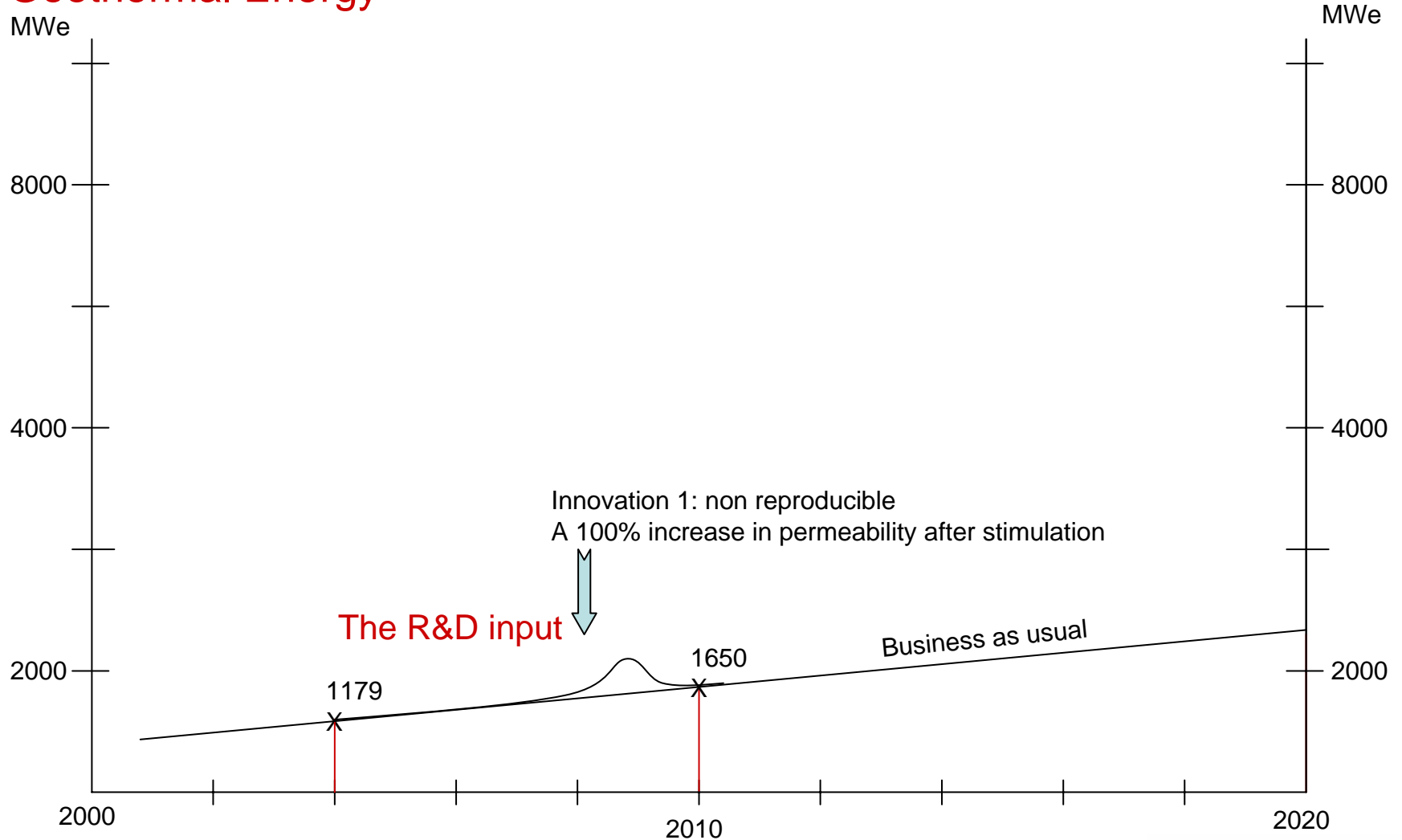
- The R&D contribution to the learning curve of Geothermal Energy
- Economic impact visible on power production projection
- 2008 EU commission Call for proposal for EGS Demonstration projects
- An international renewed interest for geothermal resources of deep origin
 - The « heat rush » in Nevada, Australia and Germany
 - A new priority on renewable energies in USA
 - A rising force for investing in exploration in Europe
 - A favorable context for preparing new ambitious projects within an European geothermal drilling program



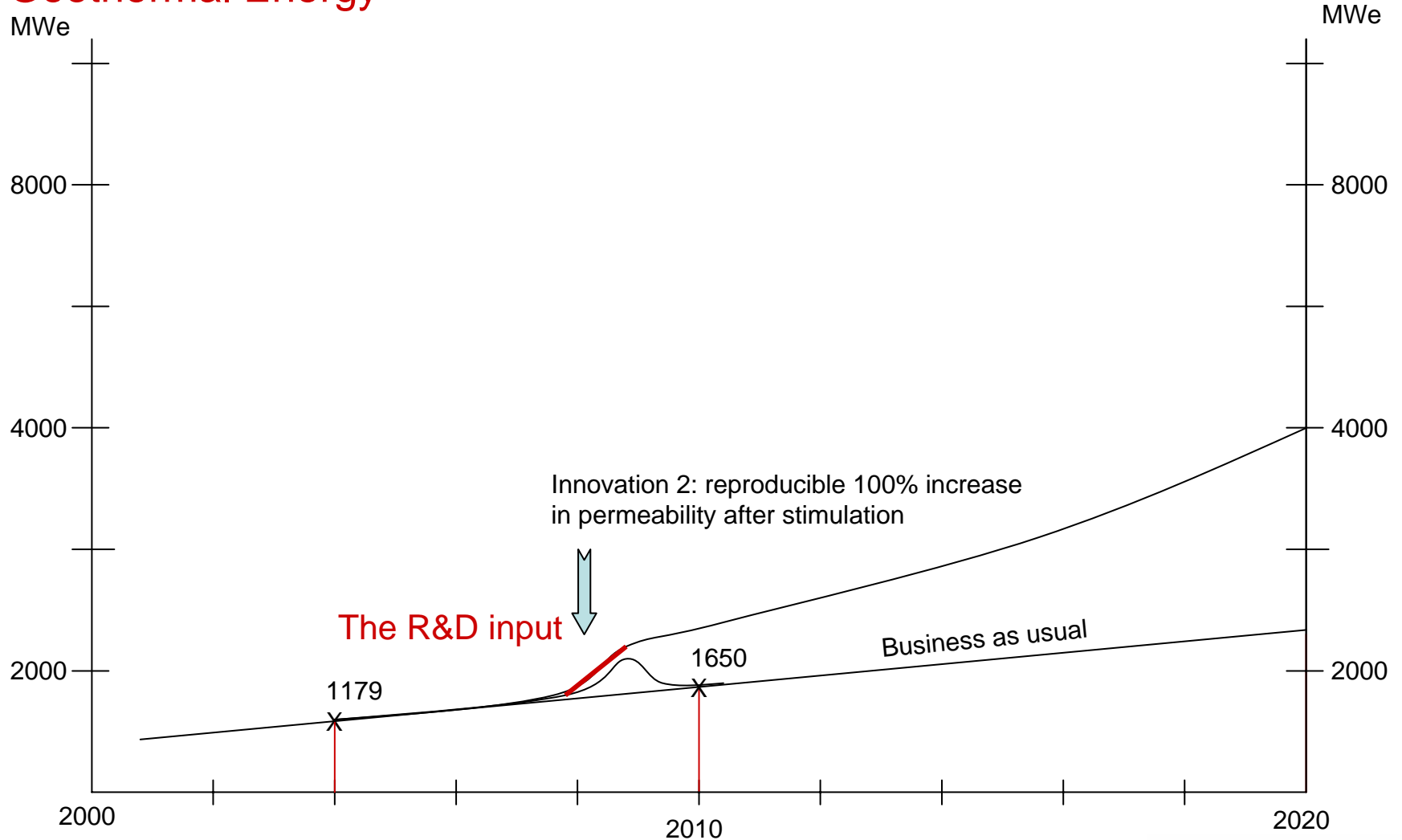
Geothermal Learning Curve



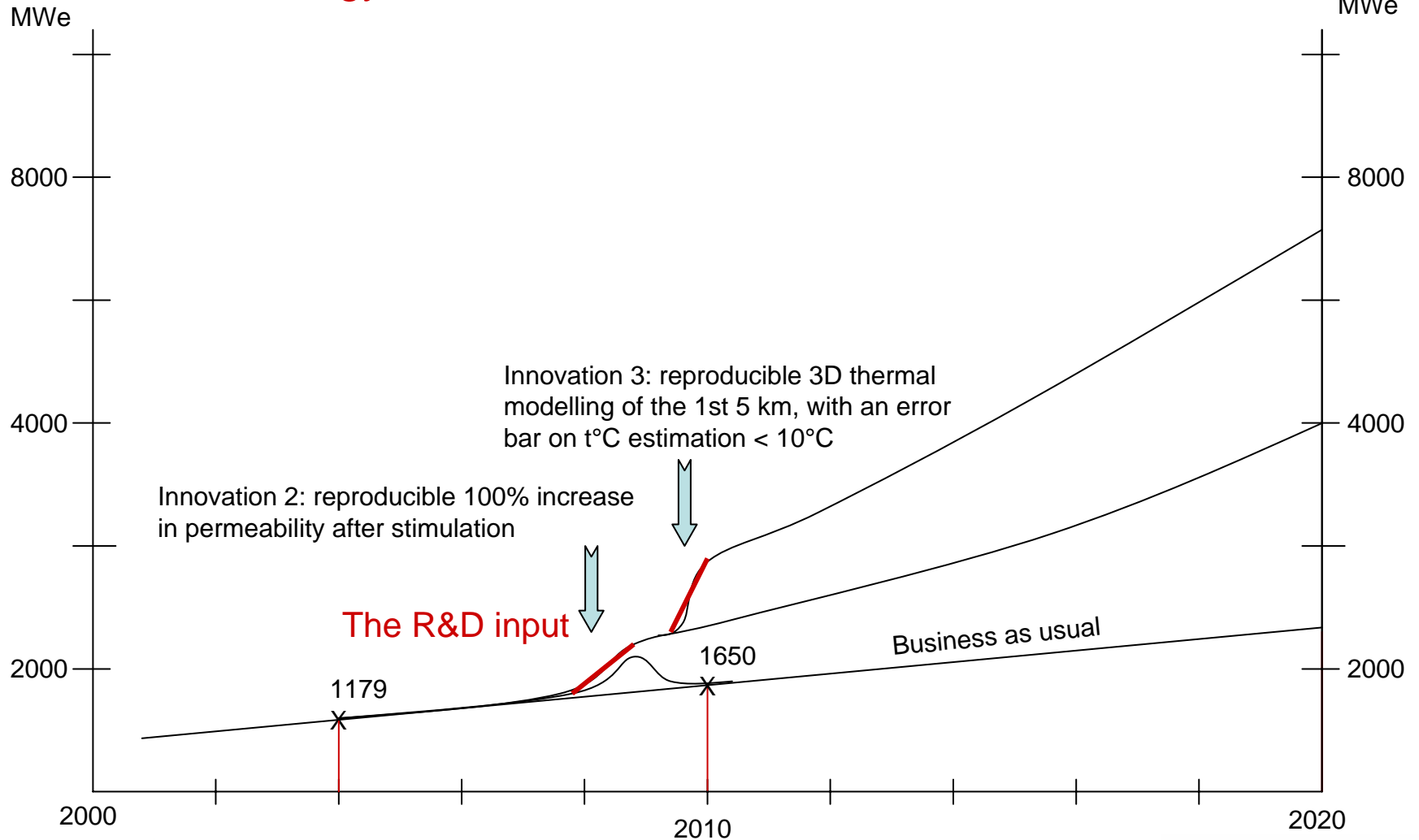
The R&D contribution to the learning curve of Geothermal Energy



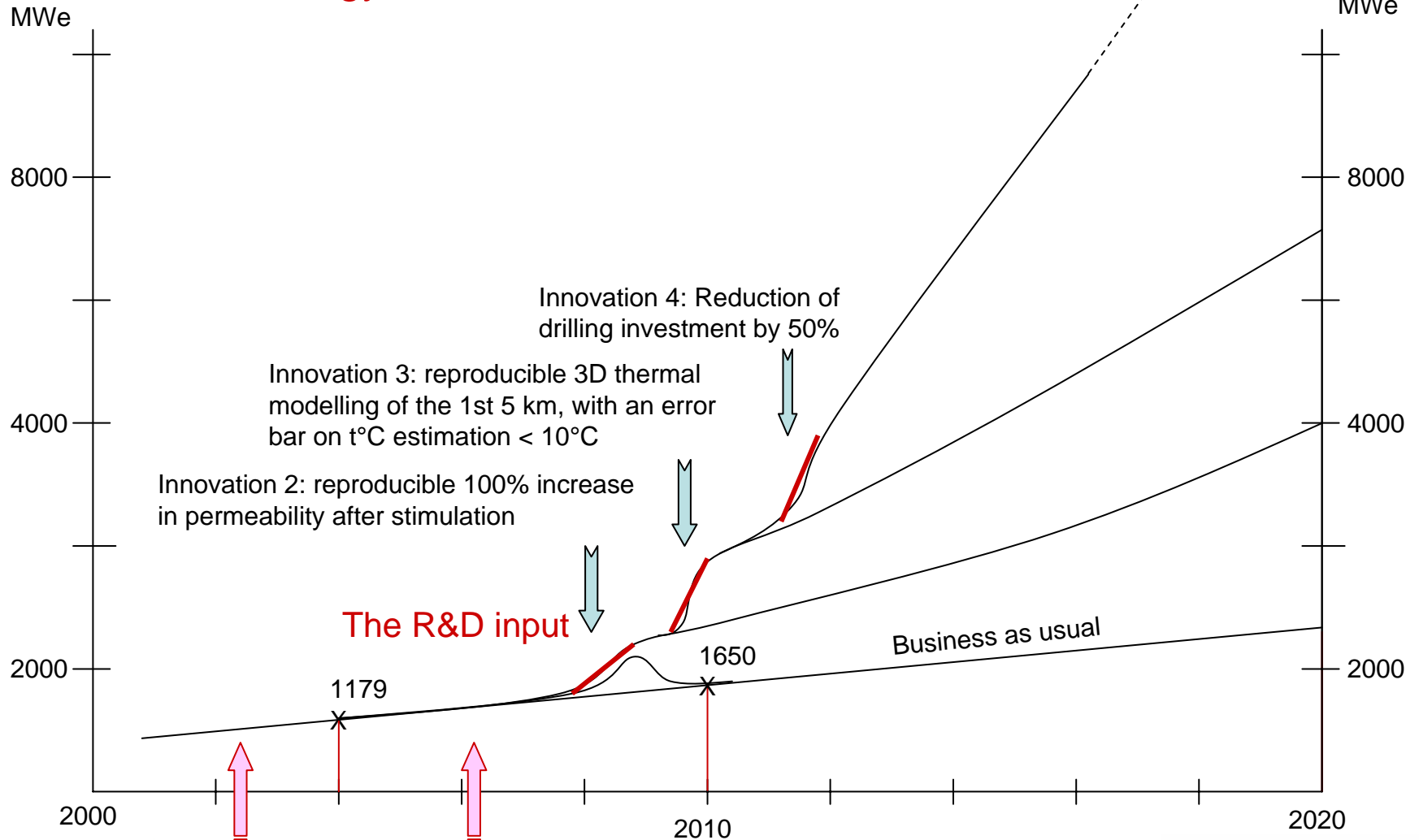
The R&D contribution to the learning curve of Geothermal Energy



The R&D contribution to the learning curve of Geothermal Energy



The R&D contribution to the learning curve of Geothermal Energy



The Soultz Innovation: non connectivity at depth between wells

The Gross schönebeck Innovation: non reversible increase in permeability in sedimentary basin, sustainability of t°C



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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	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



The Enhanced Geothermal Systems: the adult age?

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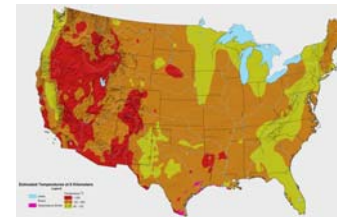
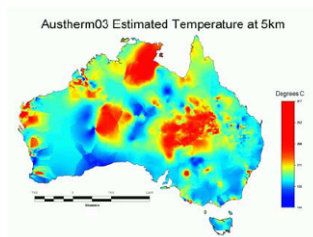
Our proposals are expected within the FP7 of the European Commission

- > Topic ENERGY.2008.2.4.1: Increased electricity production from Enhanced Geothermal Systems (EGS), including Hot Dry Rock
- > Expected impact: Demonstration of efficient and sustainable electricity production from EGS; reduced costs; better understanding of plant operation
- > Topic ENERGY.2008.2.4.2: Innovative cycles for low/medium temperature geothermal power
- > Expected impact: Increase the range of potentially interesting geothermal sites for exploitation, with reduced capital costs and higher energy conversion efficiency
- > Topic ENERGY.2008.4.3.1: Innovative components and subsystems for geothermal district heating/cooling
- > Expected impact: Increased market penetration of geothermal heat supply, facilitated by affordable and easy-to-use off-the-shelf components tailored to the market needs



The Enhanced Geothermal Systems: the adult age?

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 - A rising force for investing in exploration in Europe
 - A favorable context for preparing new ambitious projects
- European geothermal drilling program



August 31, 2005



Conclusion: An international strategy to be built up?

- > ENGINE, along with other **coordinating 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.
- > A need for a scientific exchange platform: **a R&D task force for defining research projects**
 - A result from the identification of bottlenecks and prioritisation of research needs
 - The need of ambitious projects
- > A need for a political exchange platform: **an appropriate consortium joining R&D institutes and private investors** (an Economic Interest Group?)
 - A pre-competitive project generation to develop a common expertise and share the risk
 - A promotion of past and on-going experiences by making them visible and reproducible
 - A lobby to promote supported market access for geothermal innovative technologies



In the case of Europe, from an ENhanced Geothermal Innovative Network for Europe to an European geothermal drilling program?

- An European geothermal drilling program for demonstrating that EGS can provide continuous base load-power for Europe: 30 EGS projects for the next 15 years?
 - A required convergence between the scientific and political exchange platforms, i.e. a common approach of both scientist and stakeholders
 - Reference to the Soultz experiment and to all specific target research projects for promoting new EGS projects: highly radiogenic reservoirs at depth, extension of existing geothermal fields, geothermal recovery from existing oil and gas operations...

