The main outcomes from ENGINE

Géosciences pour une Terre durable
brgm

Why a co-ordination action about Enhanced Geothermal Systems ?

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Engine Launching Conference
12-15 February 2006
Orléans, France
Opening Session

Géosciences pour une Terre durable
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An intitiative 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

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

ENGINE breakdown structure

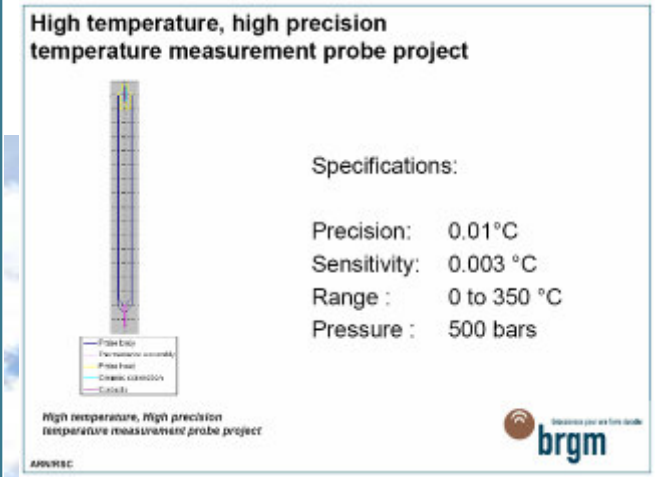
A scientific and technical European Reference Manual for the development of Enhanced Geothermal Systems

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

Enhanced Geothermal Systems: the concept

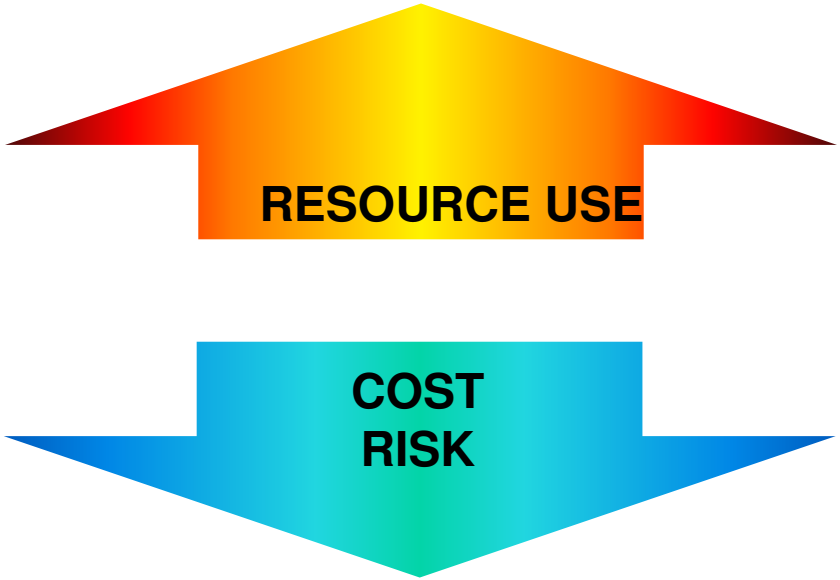


> Enhancing and broadening geothermal energy reserves

- stimulating reservoirs in Hot Dry Rock systems and enlarging the extent of productive geothermal fields
- 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

Development of Unconventional Geothermal Resources

1. An EGS is defined by artificial improvement of the hydraulic performance of a reservoir whose criteria are a minimum temperature (85-100°C) taking into account the current technical limitations in conversion of heat into electric energy
2. The Enhancement challenge: based on several non-conventional methods for exploring, developing and exploiting geothermal resources that are not economically viable by conventional methods
3. Enhanced vs Engineered



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

After two years, 7 workshops and 2 conferences…

- ENGINE, a R&D task force for defining research projects
  - A network
  - Identification of bottlenecks and prioritisation of research needs
- ENGINE, along with other coordinating initiatives can
  - contribute to the construction of an international strategy
  - consolidate the available information systems
- Economic and environmental constrains have changed
  - increase of the energy price, threats of global warming (greenhouse gas concentration in the atmosphere)
  - new EU objectives: 20% Renewable Energy in 2020
- Several major geothermal projects have been developed (Germany, Iceland), renewed interest for unconventional geothermal energy worldwide (Australia, US)

Enhanced Geothermal Systems: what are the next moves?

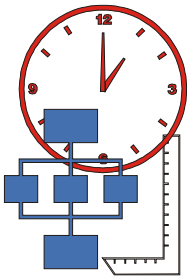
> A R&D strategy

Investigation of UGR and EGS

Drilling stimulation and reservoir assessment

Exploitation, economic, environmental and social impacts

Concept

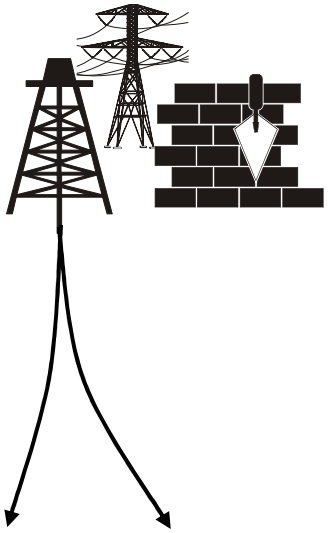


General planning and geological screening
- conceptual
- technical
- political and environmental
- financial

Site exploration

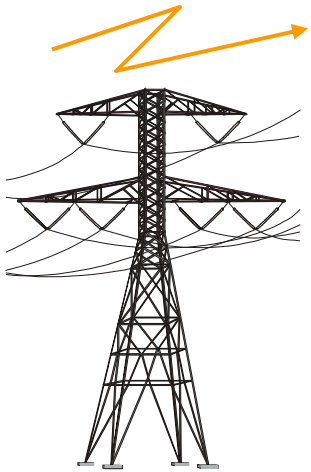
- Site screening
- Pilot borehole
- Stimulation tests
- Production modelling

Site development



- Inj./Prod boreholes
- Intensive stimulation
- Production tests
- Surface installations

Production



- Power/Heat production
- Maintenance

Abandonment

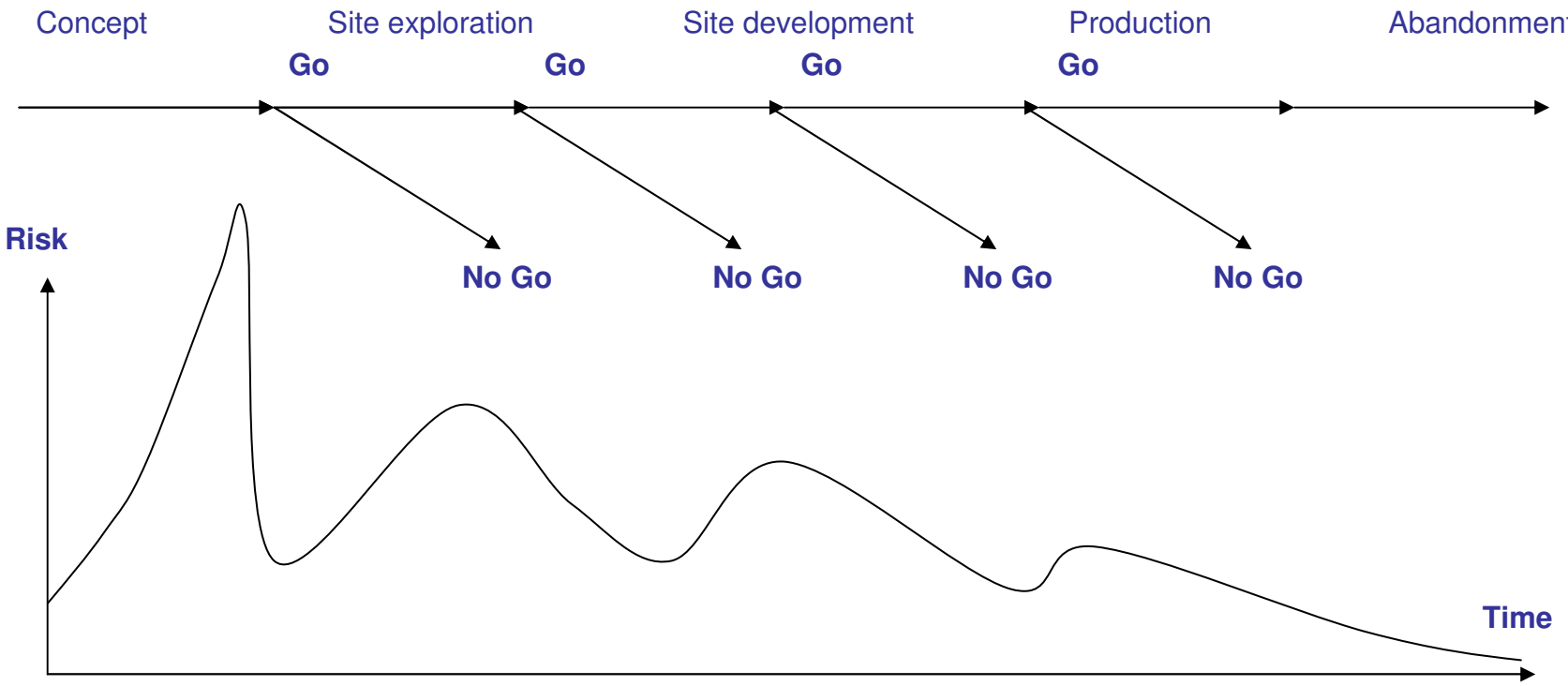
If no re-investment for this site: Deconstruction

Milestones

- Site selected
- Feasibility of EGS at site demonstrated
- Installations and reservoir ready for production
- Production lifetime reached

The main milestones

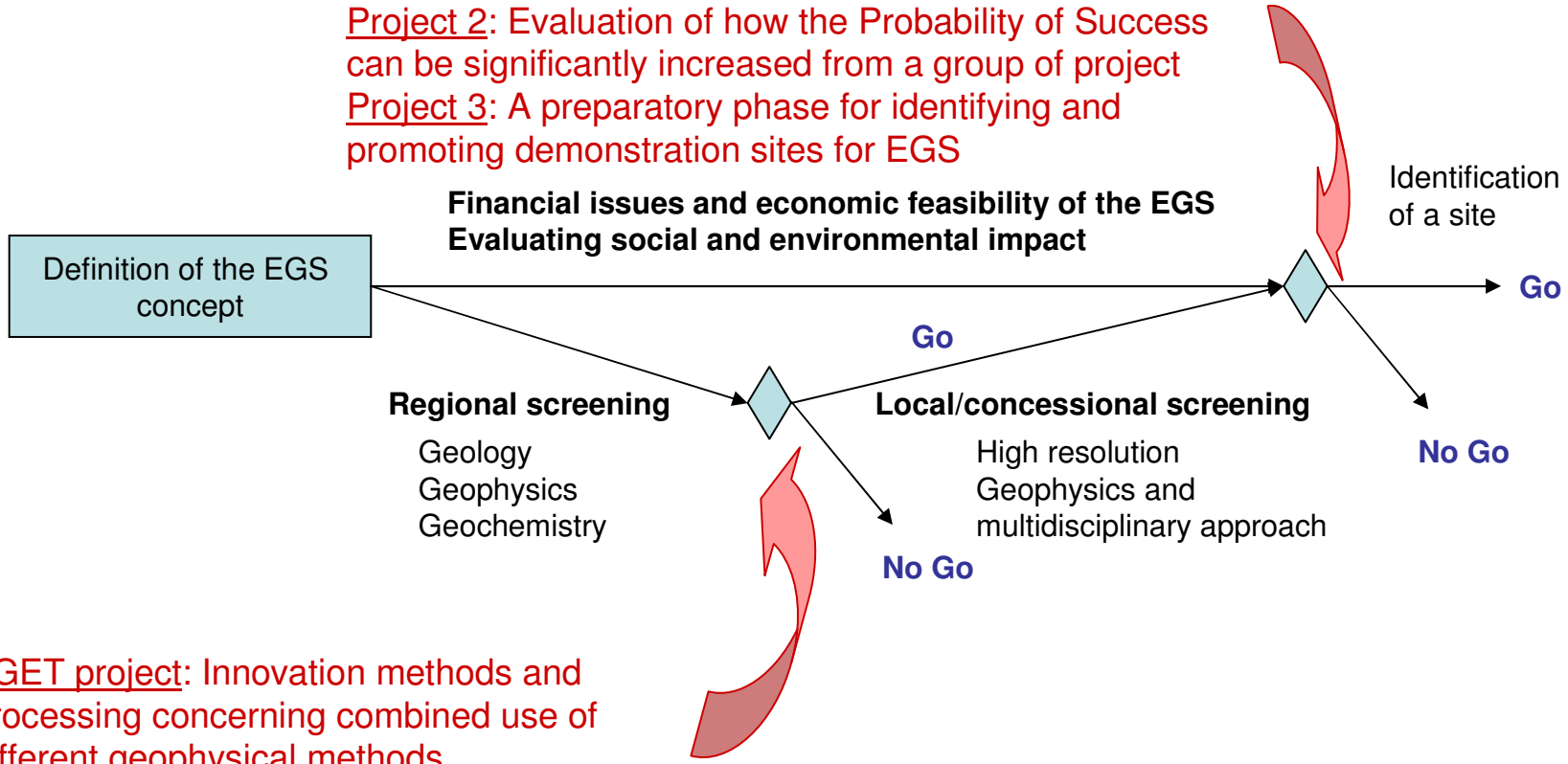
Investigation of UGR and EGS | Drilling stimulation and reservoir assessment | Exploitation, economic, environmental and social impacts



Some critical steps on the way to EGS development, that requires R&D for improving Probability of Success

Investigation of UGR and EGS: R&D contribution for increasing Probability of Success at critical steps of EGS development

Project 2: Evaluation of how the Probability of Success can be significantly increased from a group of project
Project 3: A preparatory phase for identifying and promoting demonstration sites for EGS



I-GET project: Innovation methods and processing concerning combined use of different geophysical methods
Project 1: Evaluation of the stored geothermal energy, i.e. the thermal potential available of the first tenth kilometres of the European continental crust

Project 1. Distribution of heat at depth to define targets with limited risks: a priority issue for all type of resources

> Evaluation of the stored geothermal energy

- the thermal potential available within the first tenth kilometres of the European continental crust
- from very sparse in situ measurement of temperature in wells at depth, how can we extrapolate the distribution of heat at a continental scale and calculate temperature at depth maps based on an appropriate geological model?
- The main barrier to achieve such modelling is in fact our limited knowledge of the structure and properties of the underground

Calculation of temperature at depth

Input values: Measured Heat Flow (Q_0), Mantle Heat Flow (Q_m), Thermal Conductivity (K), Temperature: surface (T_0) or at depth (T), Radioactive Heat Generation (A), Radioactive depth variable constant (r), Layer Thickness (X), Subscript "b"- basement and "s"- sediment.

Sediment Contribution

$$T_S = \frac{Q_0 X_S}{K_S} - A_S \frac{X_S^2}{K_S}$$

Where A_s=1 μW/m^3

Basement Contribution

$$T_b = \frac{Q_m X_b}{K_b} - A_b r^2 \left[\frac{1 - e^{-\frac{x_b}{r}}}{K_b}\right]$$

Where A_b=($Q_{below\_sediments}$-Q_m)/r

Temperature at depth

$$T = T_s + T_b$$

Correct for surface temperature

$$T_{final} = T + T_0$$

2-12

The Future of Geothermal Energy

Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century

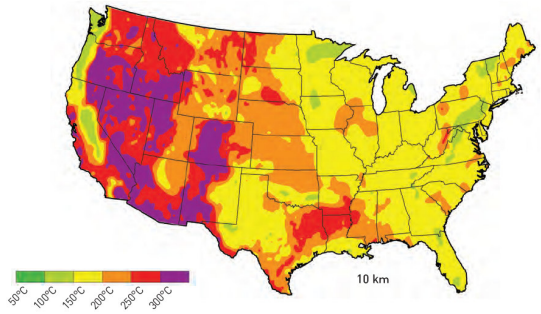


Figure 2.7f Average temperature at 10.0 km.

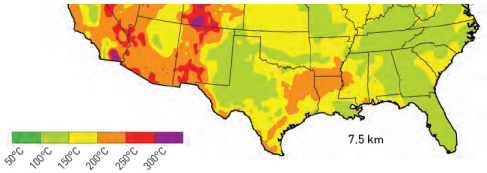


Figure 2.7e Average temperature at 7.5 km.

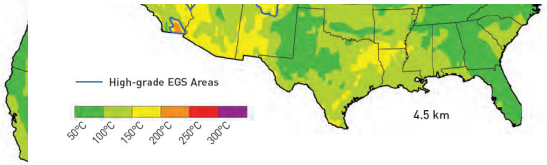


Figure 2.7b Average temperature at 4.5 km. Includes areas of special EGS interest outlined in blue and identified in Table 2.2.

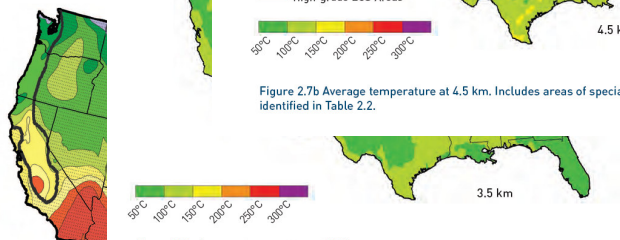


Figure 2.7a Average temperature at 3.5 km.

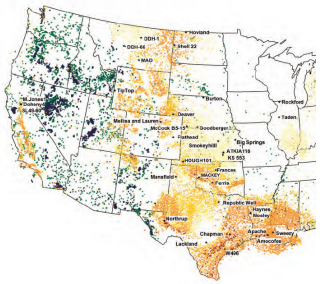


Figure 2.2 All BHT sites in the conterminous United States in the AAPG dat based on depth and temperature (heat flow is not available for all of the sit preparation of the Geothermal Map of North America). The named wells are the calibration points. The regional heat flow and geothermal database sites are also shown.

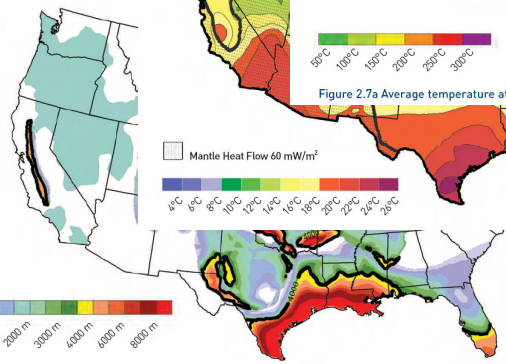
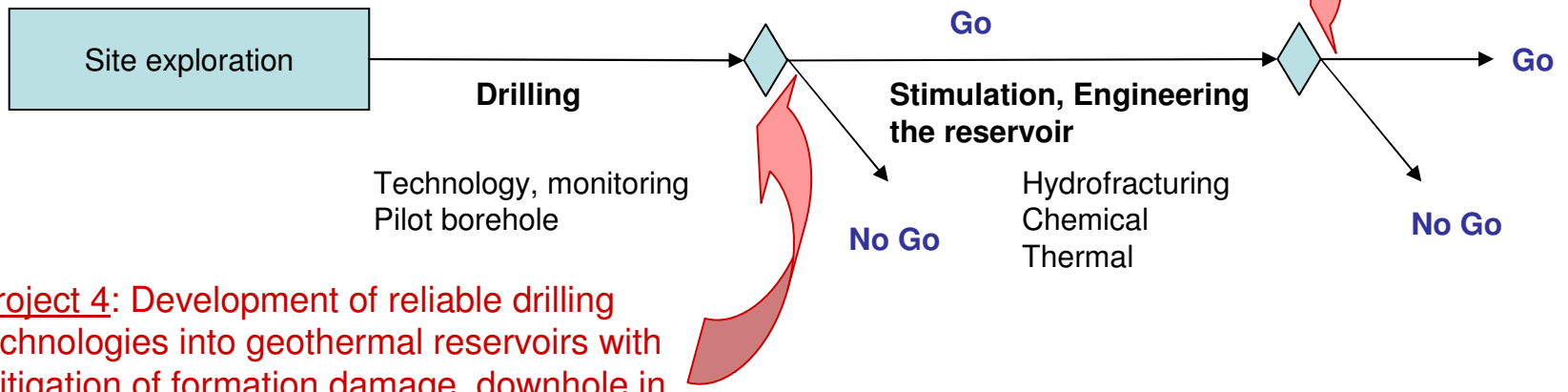


Figure 2.5 Sediment thickness map (in meters, modified from AAPG Basement Map of North America, 1978). The 4 km depth contour is outlined with a bold black line. The low-conductivity regions in the western United States are in blue/green.

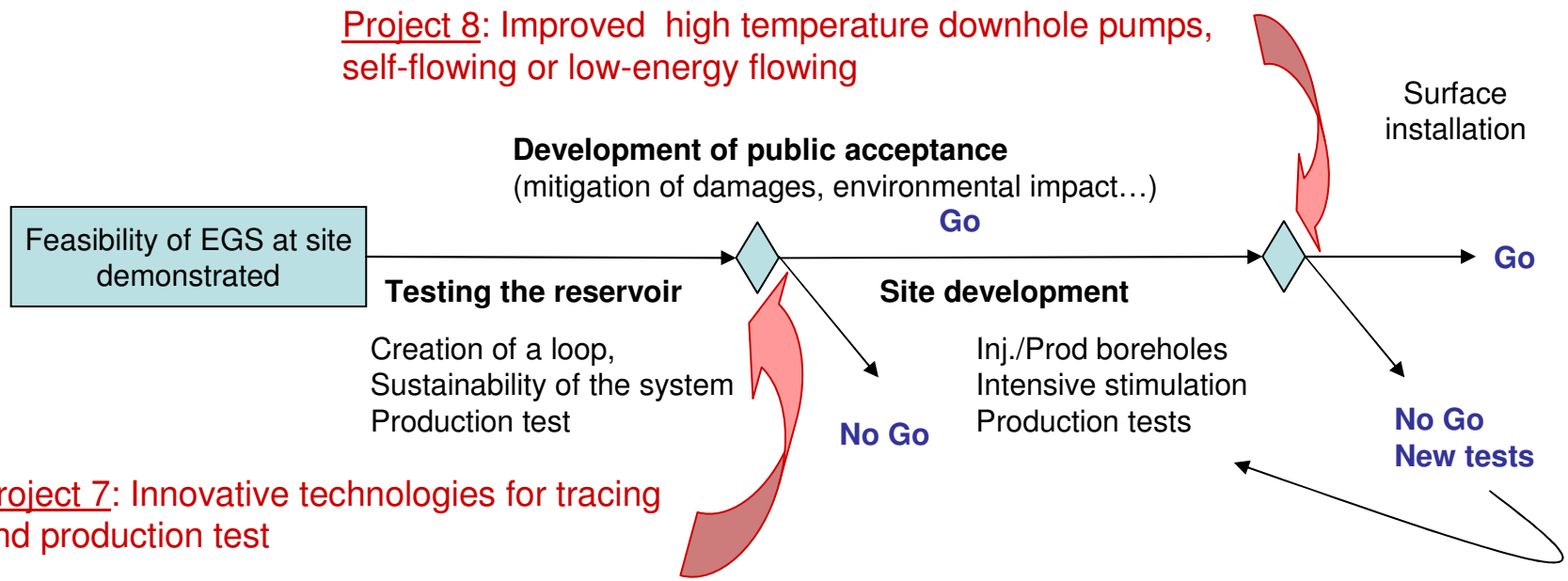
Drilling, stimulation: R&D contribution for increasing Probability of Success at critical steps of EGS development

Project 5: understanding of active processes during stimulation, whether thermal, mechanical or chemical
Project 6: breakthrough stimulation and rock fracturing technology with zero or minimal induced micro-seismicity



Project 4: Development of reliable drilling technologies into geothermal reservoirs with mitigation of formation damage, downhole in situ monitoring, testing stimulation, operating thermal water loop

Reservoir assessment: R&D contribution for increasing Probability of Success at critical steps of EGS development



Enhanced Geothermal Systems: what are the next moves?

> A R&D strategy

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

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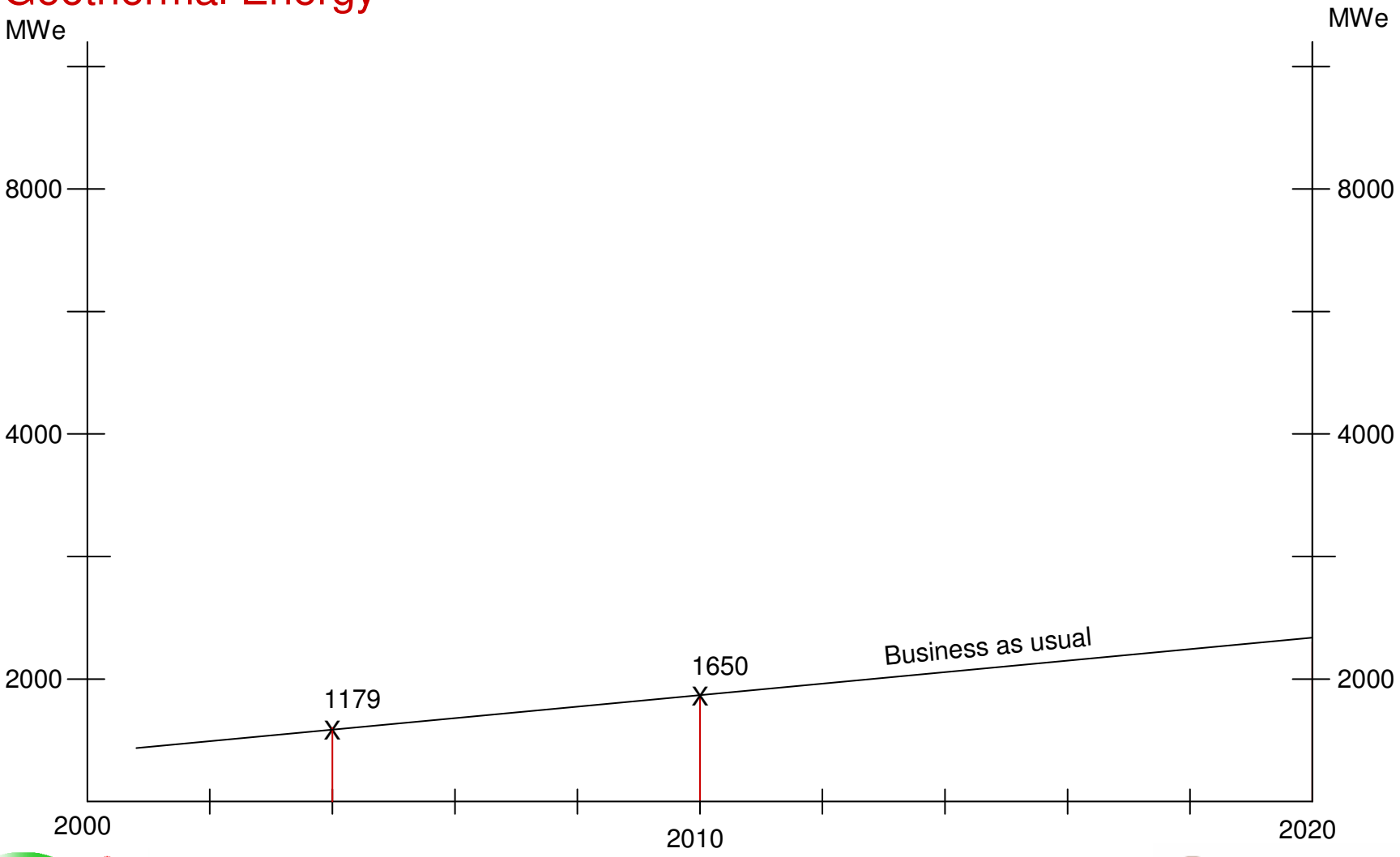
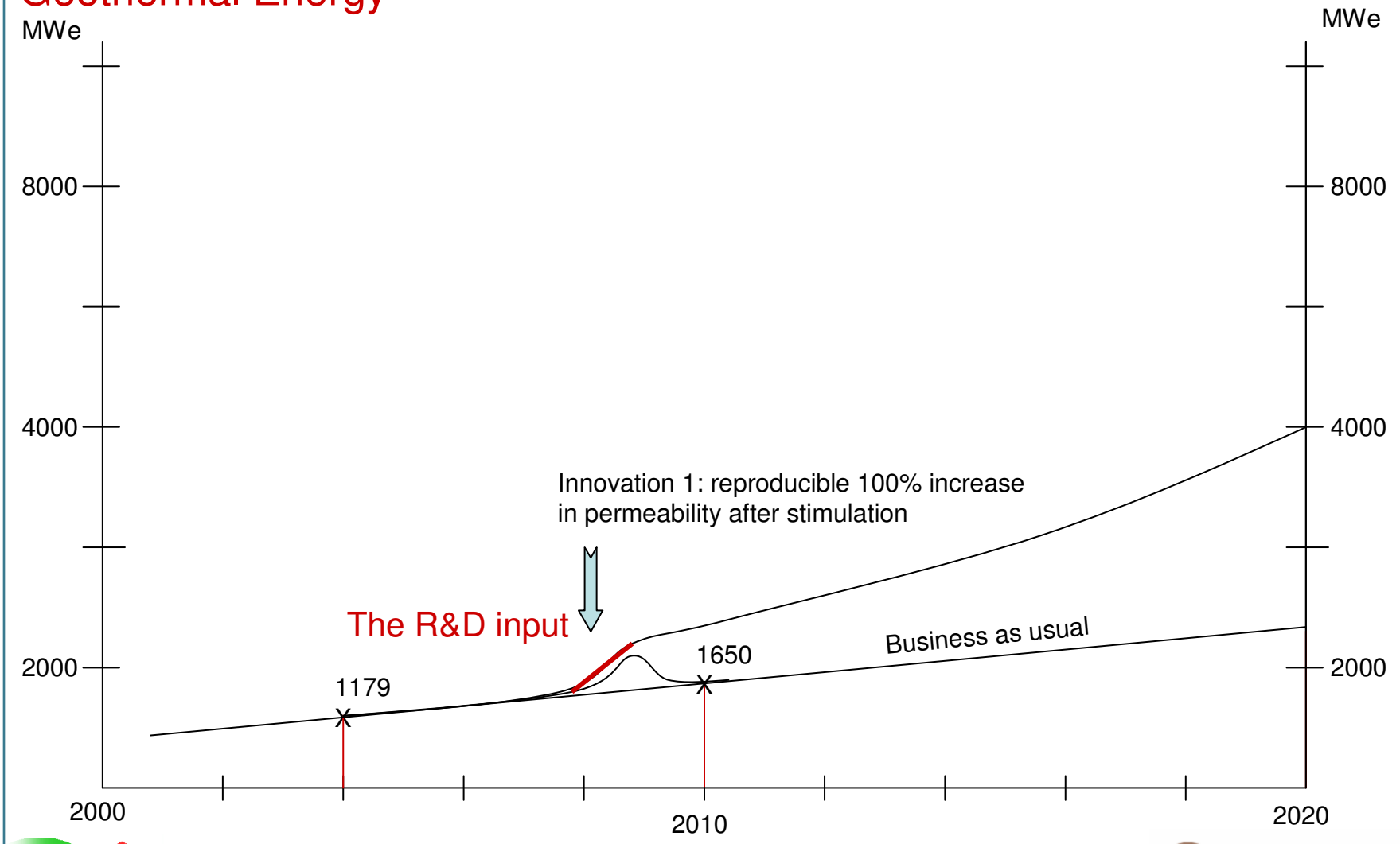


The R&D contribution to the learning curve of Geothermal Energy



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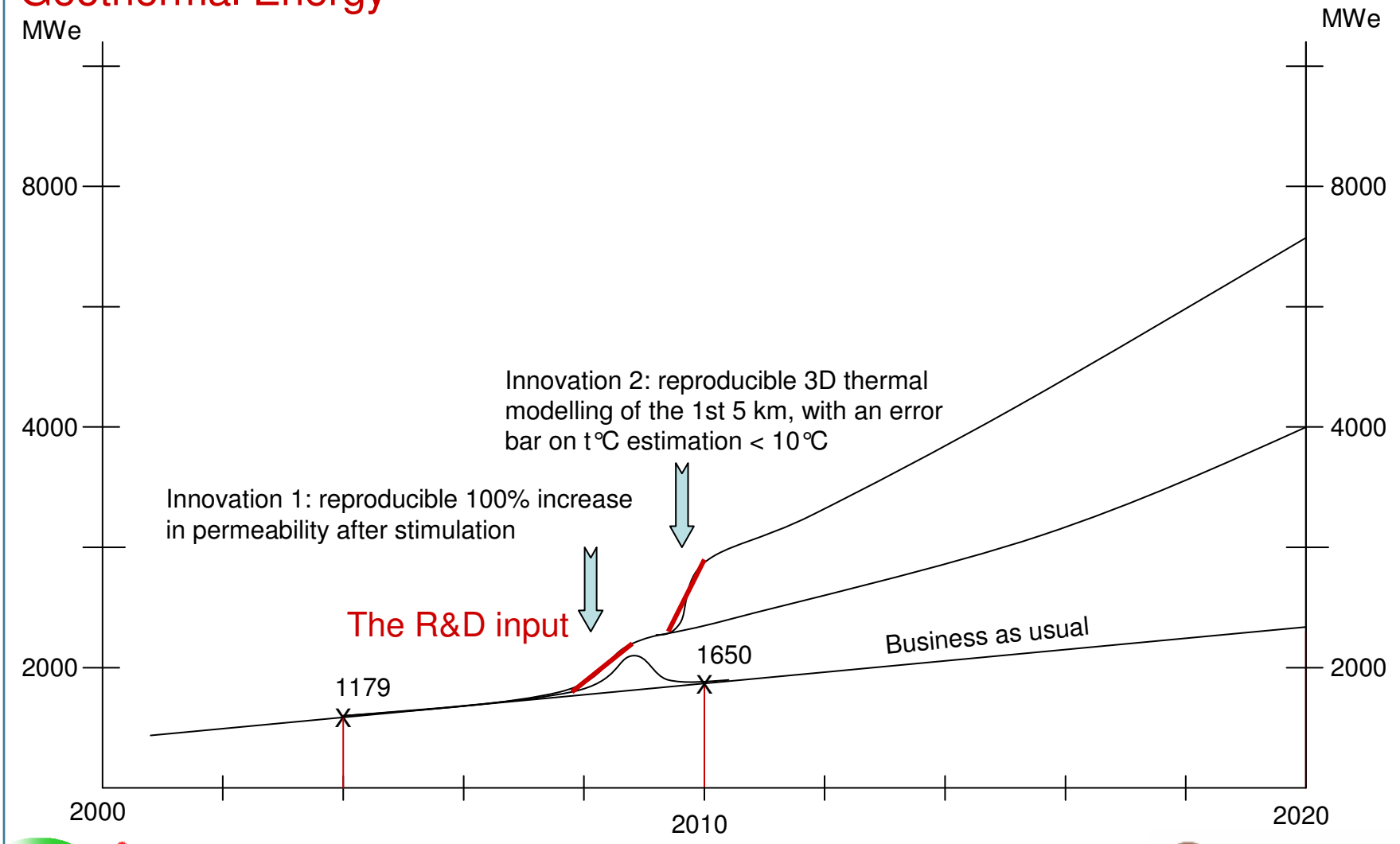
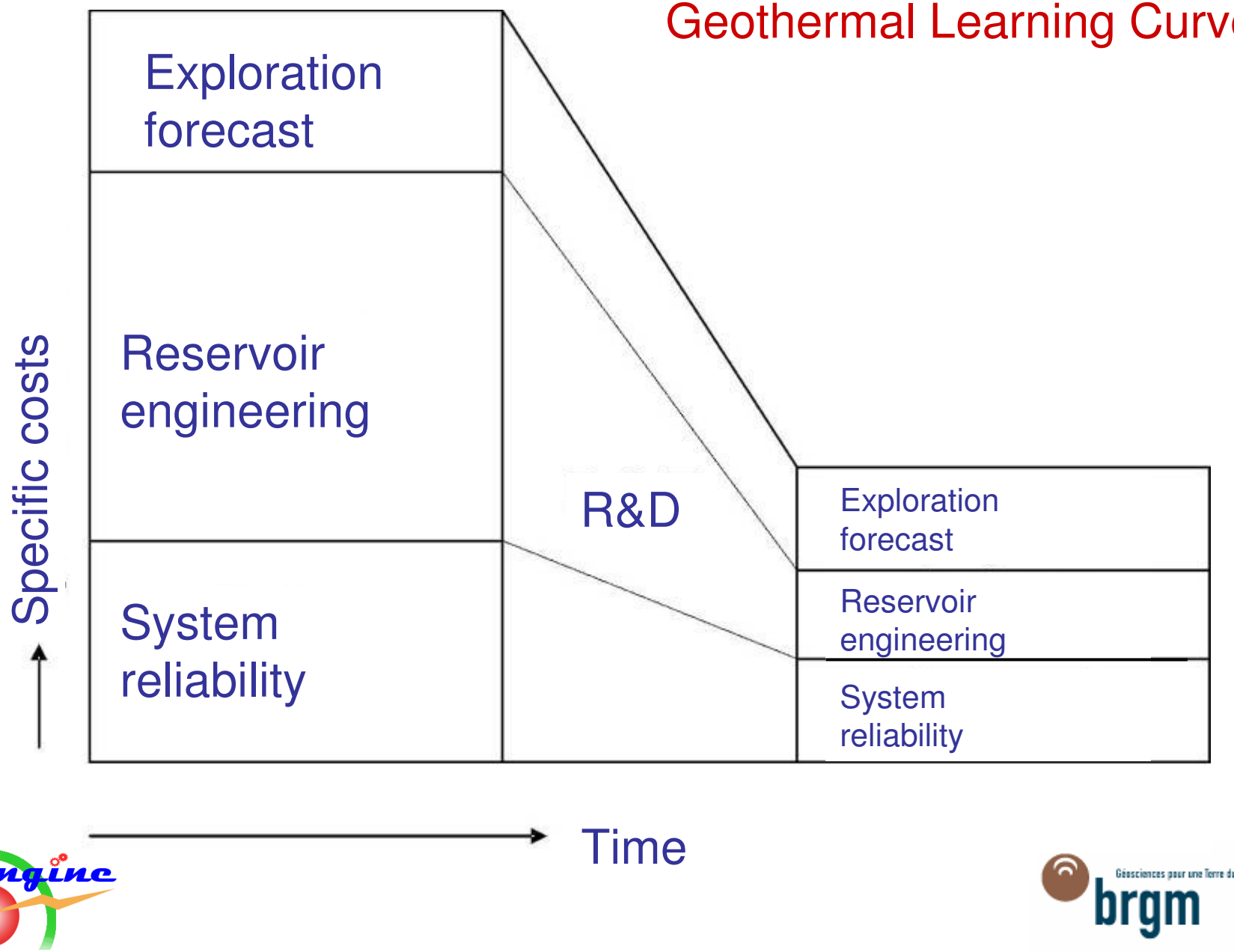


Geothermal Learning Curve



Enhanced Geothermal Systems: what are the next moves?

- A R&D strategy
- The R&D contribution to the learning curve of Geothermal Energy
- Evaluation of the investment and the expected savings on cost operation at the 2020 horizon for each R&D initiative and industrial project
  - The European Strategic Energy Technology Plan defines a target of 20% renewable market penetration in 2020. However, if prospects for market penetration are presented for biofuels, photovoltaics or wind energy, reference to geothermal energy is still missing.
  - Definition of appropriate concepts for qualifying and quantifying geologic technical and environmental risks

Identification of bottlenecks and prioritisation of research needs for deep geothermal resources

Impact of innovation	Priority A	%	Priority B	%	Pric
Resource investigation	Distribution of heat at depth in order to define target with limited risk	100	Modelling and imaging potent permea (nature		ɜK grabben)
Drilling, stimulation and reservoir assessment	…				…
Exploitation, reservoir management and monitor			..		…
Ec			…		…

Definition of appropriate concepts for qualifying and quantifying geologic technical and environmental risks

Enhanced Geothermal Systems: what are the next moves?

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  - Definition of appropriate concepts for qualifying and quantifying geologic technical and environmental risks
- A new Coordination or Support Action promoting:
  - Past and on-going experiences by making them visible and reproducible
  - Specific projects to fill the gaps in knowledge
  - New EGS projects: highly radiogenic reservoirs at depth, extension of existing geothermal fields, geothermal recovery from existing oil and gas operations, supercritical fluid reservoirs…
  - Supported market access for geothermal innovative technologies