Le Prospettive della Geotermia

Adele Manzella
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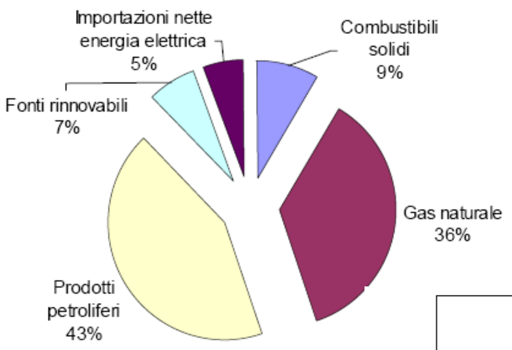
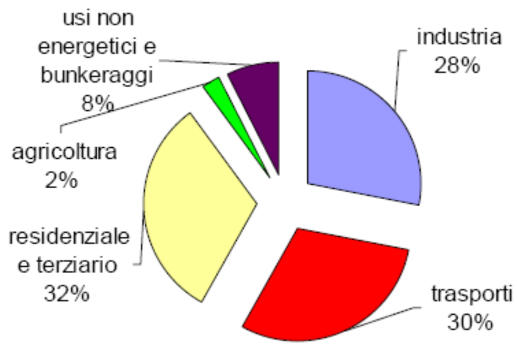
Figura 11 - Consumi di energia per fonte, anno 2005



Fonte: elaborazione su dati MS

Quote per settore di uso finale dei consumi di energia, anno 2005 (Mtep)



Fonte: elaborazione su dati MSE

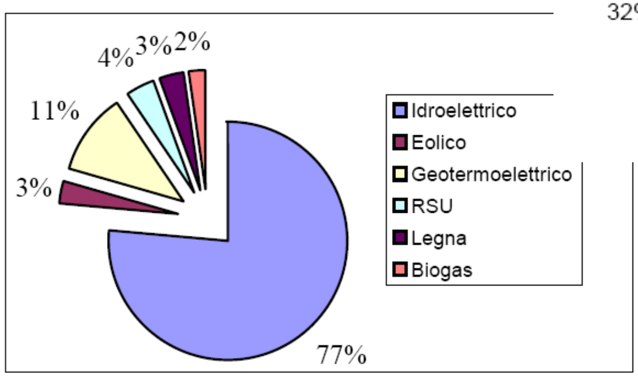


Figura 1.1 : Ripartizione della quota di energia elettrica prodotta da fonti rinnovabili

Tabella 1 - Emissioni di gas climalteranti in Italia: dati storici, scenario di riferimento al 201 e obiettivo di Kyoto (Mt CO_2 eq.)

Emissioni 1990	519,5
Emissioni 2000	554,6
Emissioni 2004	580,7
Scenario Riferimento 2010	587,3
Obiettivo Kyoto	485,7
Distanza Obiettivo (Emissioni 2004 – Obiettivo)	95,0

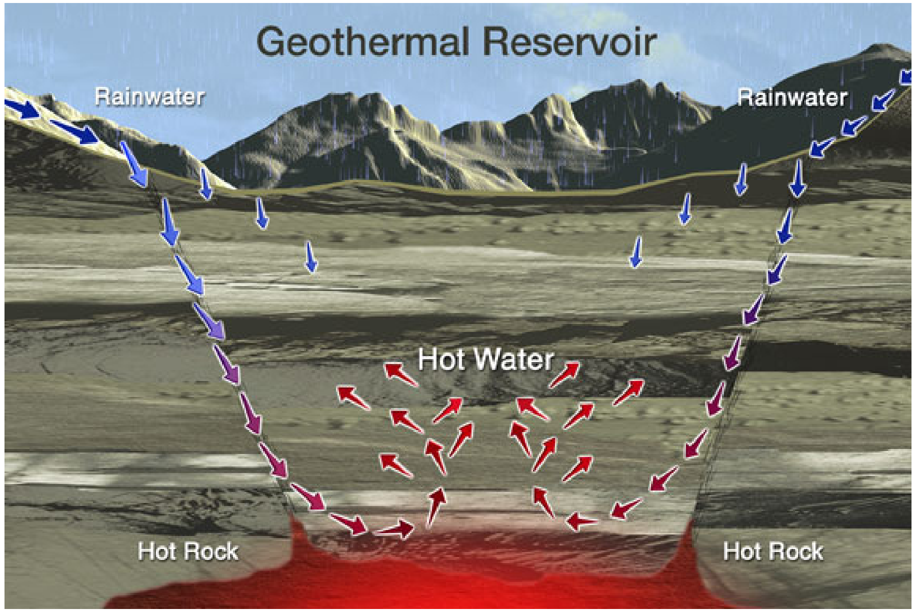
Fonte: MSE MATT PNA2 18 dicembre 2006

Da "Rapporto Energia Ambiente 2006", ENEA

CONVENTIONAL GEOTHERMAL SYSTEMS

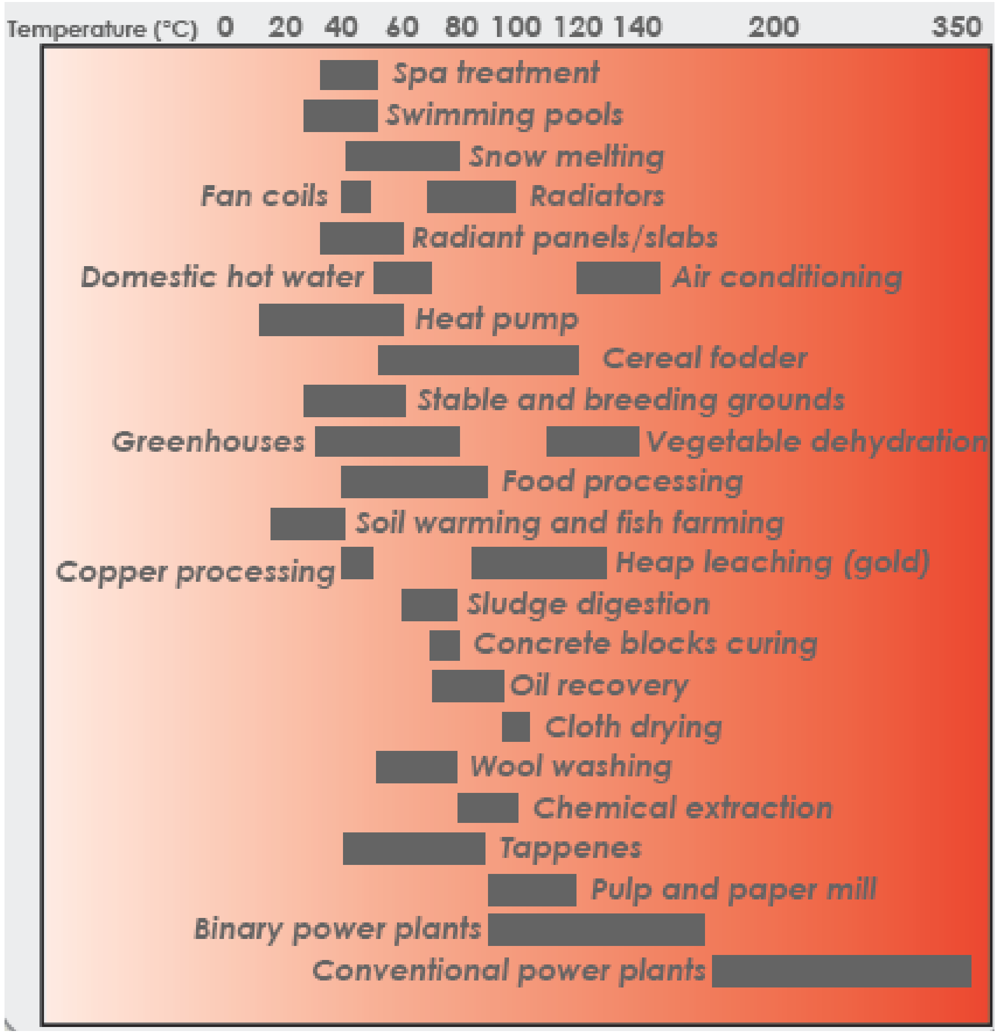
A Geothermal system can be described schematically as

"convecting water in the upper crust of the Earth, which, in a confined space, transfers heat from a heat source to a heat sink, usually the free surface".



UTILIZATION

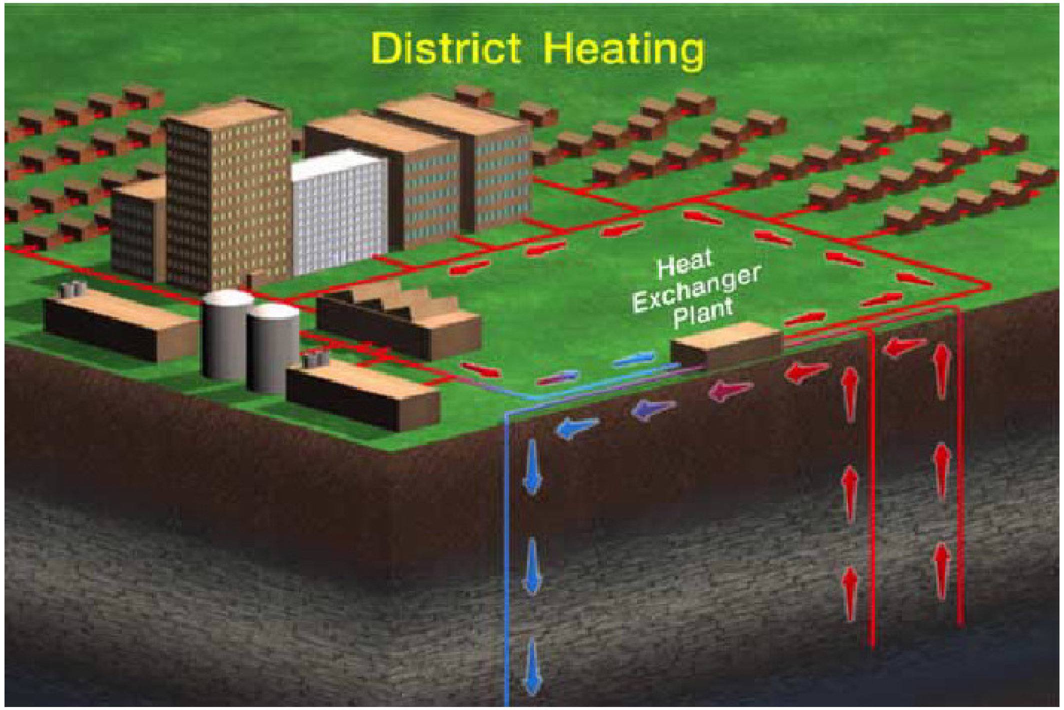
The conventional use of geothermal energy is usually divided into two categories:
high temperature resources
T> 150℃ are mainly used for electricity generation;
low temperature resources
T< 150℃ are mainly used directly for heating purposes.
There is a wide range of the use of geothermal energy.



HEAT PRODUCTION

Heat production can be obtained from geothermal energy in two distinct manners.

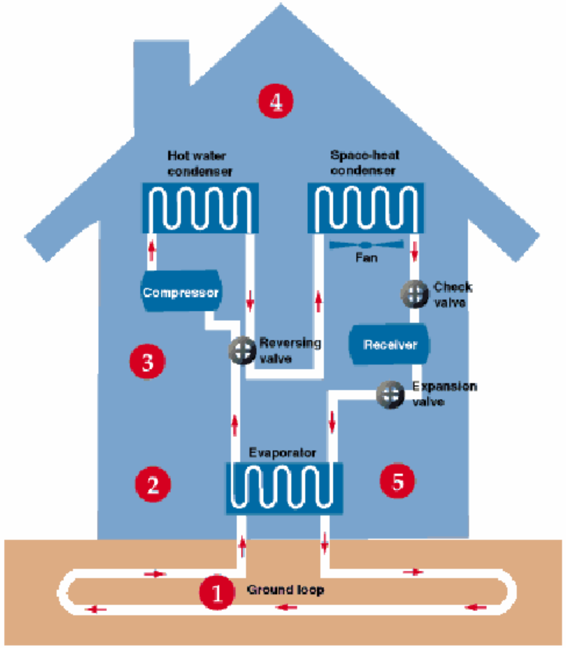
The first consists in directly exploiting the substratum aquifers, whose temperatures are included between 30℃ and 150℃ (so-called low and medium energy applications).



Hot water from one or more geothermal wells is piped through a heat exchanger plant to heat city water in separate pipes. Hot city water is piped to heat exchangers in buildings to warm the air.

The second way of producing heat is through the use of geothermal heat pumps (collectors buried or on aquifer), that are of so-called very low energy applications. Geothermal heat pumps are part of the renewable technologies which are gaining more and more success on the European market.

Main advantage: it can be used for space conditioning (heating and cooling).



1 -Ground source heat pumps start with a closed loop of buried pipes containing a fluid that can carry heat. The pipes may lay in shallow long curved trench, or they may jut deep into the ground.

2 -For heating (shown), the pipe fluid absorbs heat from the earth. The fluid passes through a heat exchanger (acting as an evaporator), where it transfers heat to a refrigerant.

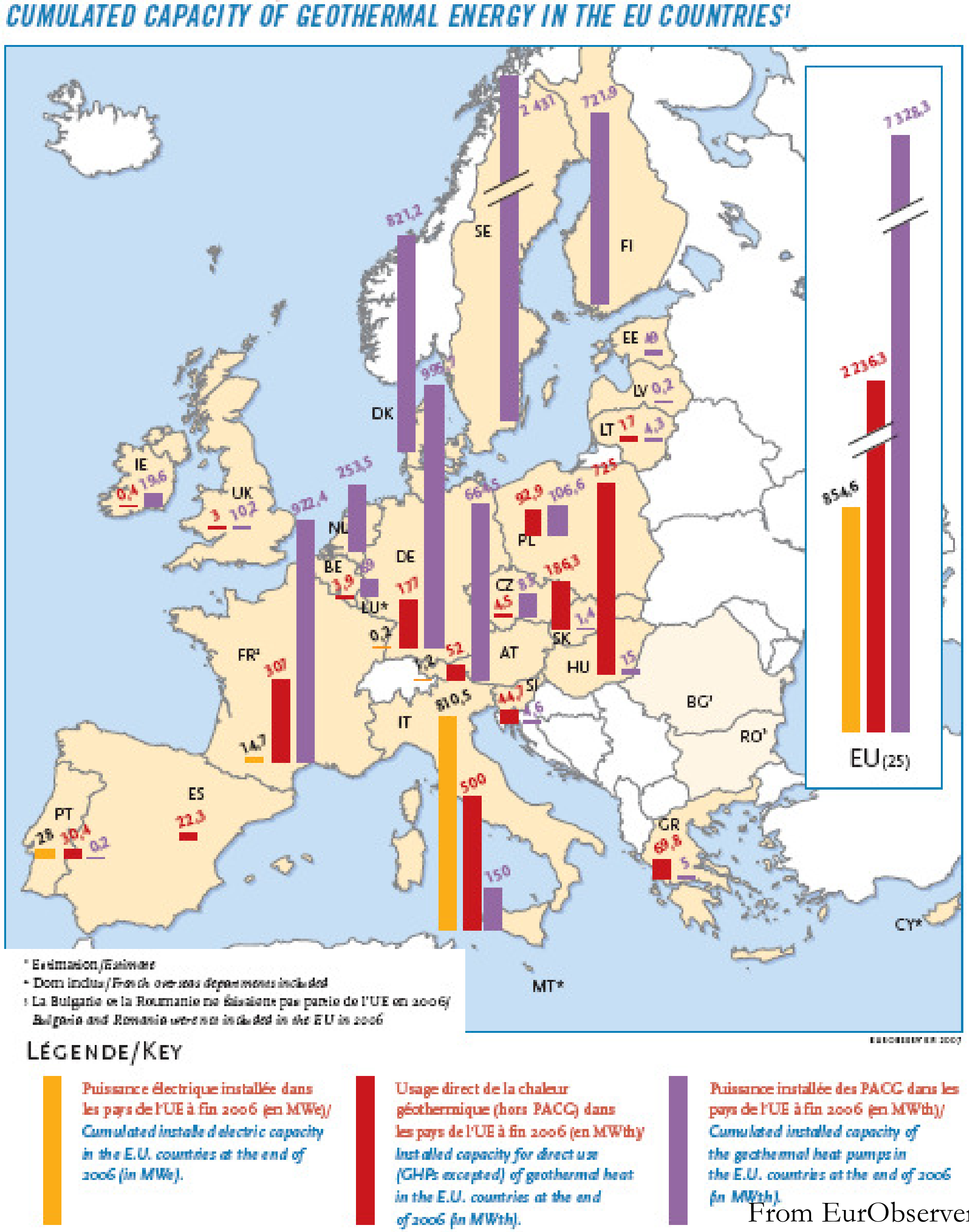
3 -The refrigerant, which flows through another closed loop in the heat pump, then boils. The vaporized refrigerant travels to the compressor, where its temperature and pressure are increased.

4 -The hot gas continues to two heat exchangers (acting as condensers), one to heat the house's water and the other for space heating. At each, the refrigerant gives up some heat. A fan blows across the space-heat condenser to move the warmed air through the house. The refrigerant, again a liquid, repeats the process.

5 -In summer, the cycle reverses to remove heat from the house. Some of the heat is used for hot water; the remainder is dumped into the earth via the ground loop.

“Geothermal energy is a source of renewable energy stored in the form of heat, below the solid surface of the ground”

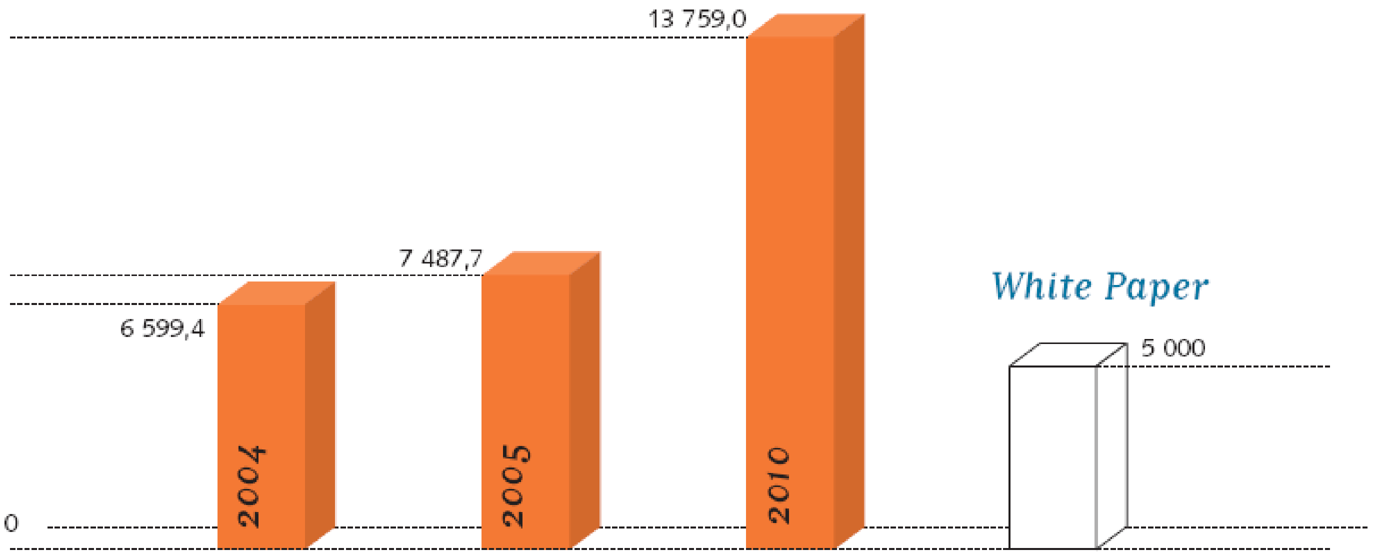
This definition integrates all heat pumps with underground sensors in the overall group of geothermal heat pumps



From EurObserver 2007

2010 PROSPECTS: heat

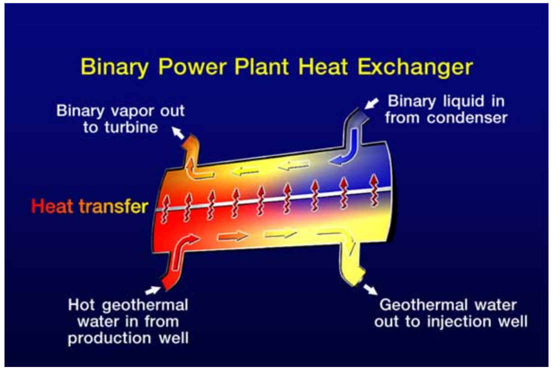
White Paper objectives that were calculated for the EU have been largely exceeded. This result is explained in part by the arrival of the new member States, but also by very high growth in the heat pump market. It is more difficult for experts to determine exact low and middle energy geothermal capacity.



ELECTRICITY PRODUCTION
from conventional geothermal systems

Geothermal electricity production consists of converting the heat of high temperature aquifers (from 150°C to 350°C) through the use of turbo-generators.

If the temperature of the aquifer is included between 100°C and 150°C, it is also possible to produce electricity, but in using binary cycle technology in this case. In this process, a heat exchanger transmits the heat of the aquifer to a fluid (isobutane, isopentane, ammonia…) with the property of vaporising at a temperature lower than that of water.



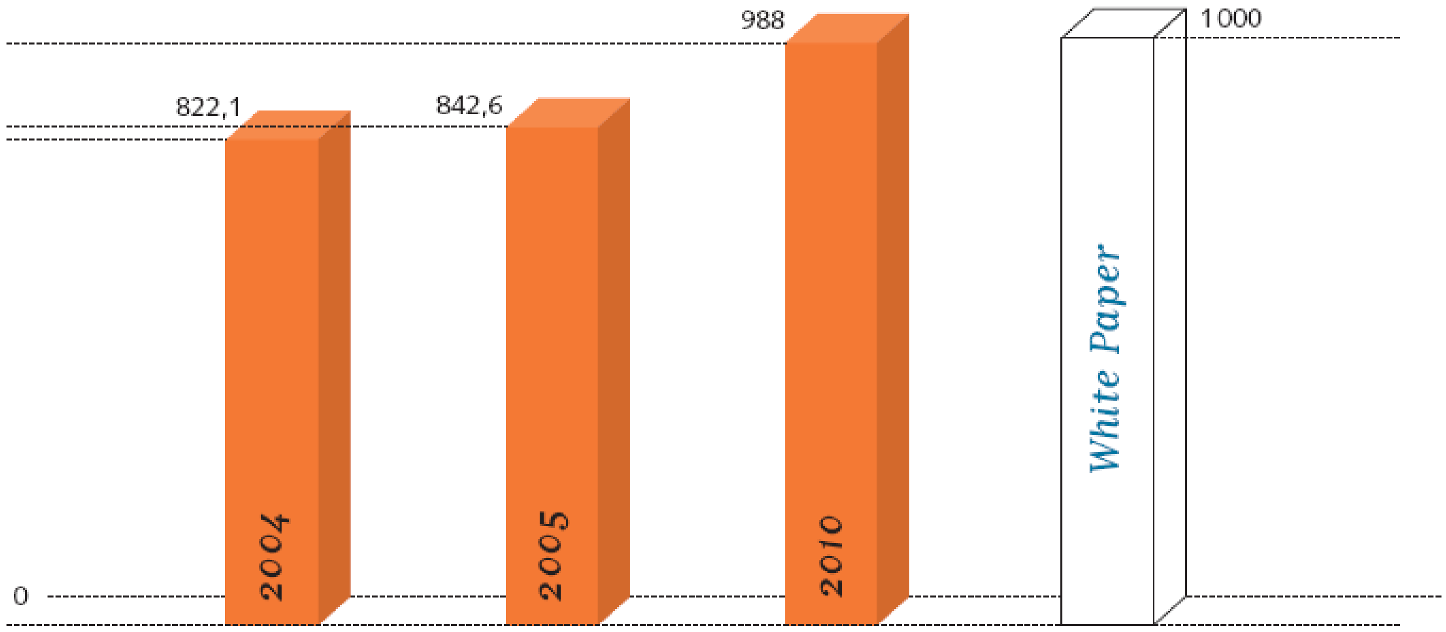
WORLDWIDE INSTALLED CAPACITY OF GEOTHERMAL ELECTRICITY GENERATION IN 2005 AND IN 2007*

Pays/*Countries*	Puissance installée *Capacity installed* 2005	2007	Puissance en fonctionnement *Capacity in running* 2007
États-Unis/*USA*	2 564,0	2 687,0	1 935,0
Philippines/*Philippines*	1 930,0	1 969,7	1 855,6
Indonésie/*Indonesia*	797,0	992,0	991,8
Mexique/*Mexico*	953,0	953,0	953,0
Italie/*Italy*	791,0	810,5	711,0
Japon/*Japan*	535,0	535,2	530,2
Nouvelle-Zélande/*New Zeland*	435,0	471,6	373,1
Islande/*Iceland*	202,0	421,2	420,9
Salvador/*El Salvador*	151,0	204,2	189,0
Costa Rica/*Costa Rica*	163,0	162,5	162,5
Kenya/*Kenya*	129,0	128,8	128,8
Nicaragua/*Nicaragua*	77,0	87,4	52,5
Russie/*Russia*	79,0	79,0	79,0
Pap.-Nelle-Guinée/*Papua-New Guinea*	6,0	56,0	56,0
Guatémala/*Guatemala*	33,0	53,0	49,0
Turquie/*Turkey*	20,0	38,0	29,5
Portugal/*Portugal*	16,0	28,0	28,0
Chine/*China*	27,8	27,8	18,9
France/*France*	14,7	14,7	14,7
Allemagne/*Germany*	0,2	8,4	8,4
Éthiopie/*Ethiopia*	7,3	7,3	7,3
Autriche/*Austria*	1,2	1,2	0,7
Thaïlande/*Thailand*	0,3	0,3	0,3
Australie/*Australia*	0,2	0,2	0,2
Monde/*World*	**8 932,7**	**9 737,0**	**8 595,4**

From EurObserver 2007

2010 PROSPECTS: electricity

Each country that is involved in geothermal energy is seeking to increase its installed capacity: Italy 100 MWe, Portugal 17 MWe and France 35 MWe (Soulz-sousforêt and Bouillante 3, new binary cycle power plants in Germany and Austria.

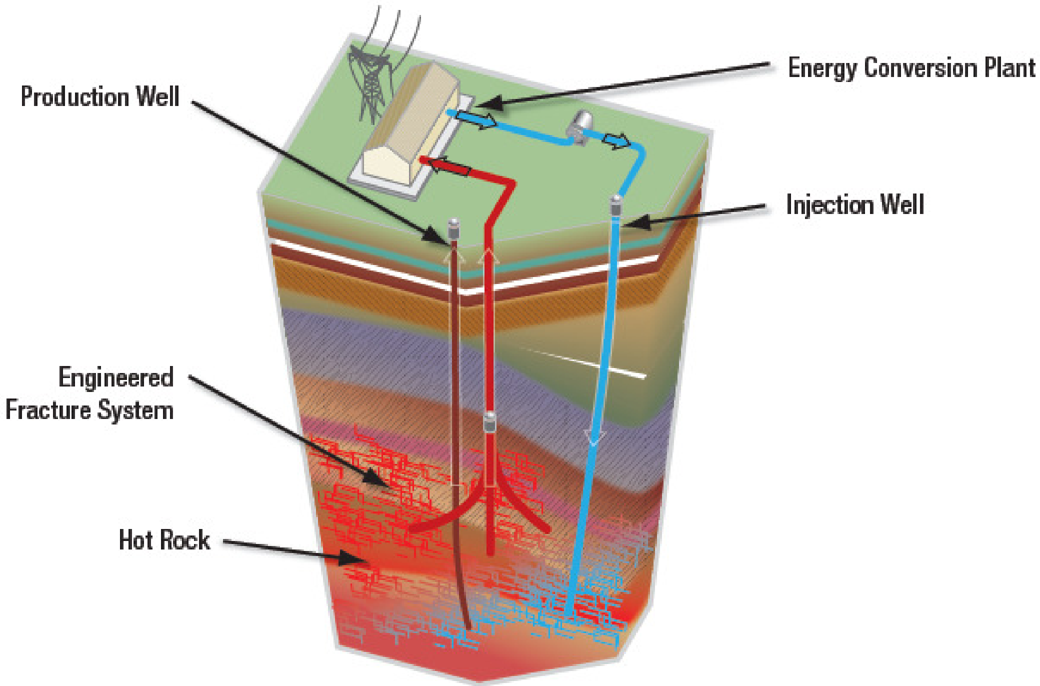


Toward the future

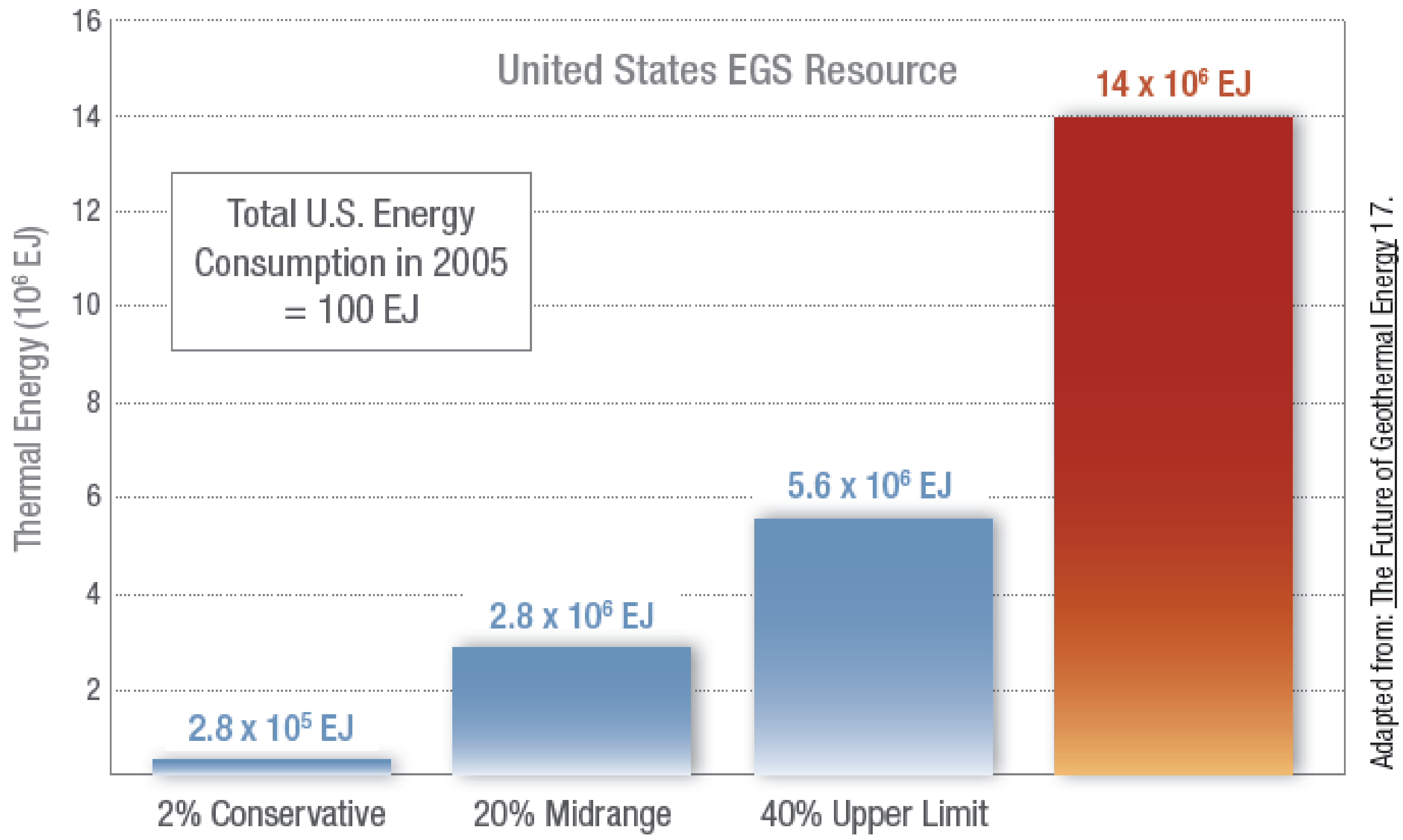
- **Economic and environmental constrains have changed**
  - increase of the energy price, threats of global warming (greenhouse gas concentration in the atmosphere)
  - new EU objectives: 20% Renewable Energy in 2020
- **Several major geothermal projects have been developed (Germany, Iceland), renewed interest for unconventional geothermal energy worldwide (Australia, US)**

“New” perspective:
Enhanced Geothermal Systems EGS

For all intents and purposes, heat from the earth is inexhaustible. Water is not nearly as ubiquitous in the earth as heat.



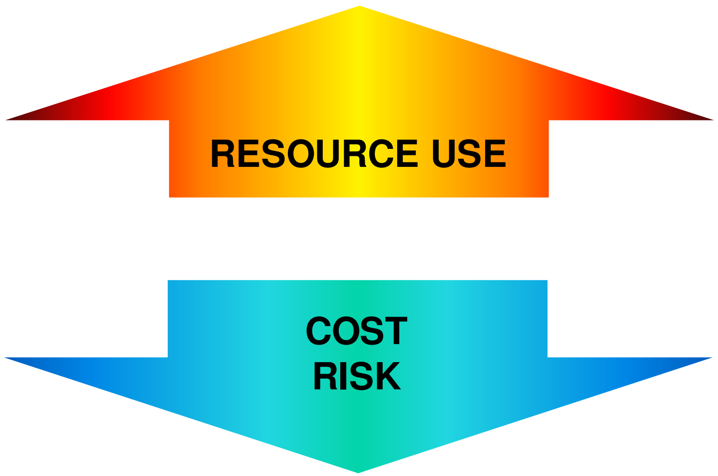
EGS concept covers specifically reservoirs at depth that must be engineered to improve hydraulic performance


16
14
12
10
8
6
4
2
Thermal Energy (10^6 EJ)
United States EGS Resource
Total U.S. Energy Consumption in 2005 = 100 EJ
14×10^6 EJ
5.6×10^6 EJ
2.8×10^6 EJ
2.8×10^5 EJ
2% Conservative
20% Midrange
40% Upper Limit
Adapted from: The Future of Geothermal Energy 17.

The Enhancement challenge:

Extending the resources far beyond a conventional use of geothermal resources requires the use of non-conventional methods for exploring, developing and exploiting geothermal resources that are not economically viable by conventional methods.

The final objective: development of a technology to produce electricity and/or heat from a basically ubiquitous resource - the internal heat of the Earth - in an economically viable manner relatively independent of site conditions.



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

ENhanced Geothermal Innovative Network for Europe (ENGINE)

P. Ledru, P.Calcagno, A. Genter*, L. Le Bel, BRGM, France
E.Huenges, D. Bruhn, GFZ, Germany
M. Kaltschmitt, IE, Germany
C. Karytsas, CRES, Greece
T. Kohl, GEOWATT, Switzerland
A. Lokhorst, TNO, Netherlands
A. Manzella, CNR-IGG, Italy,
S. Thorhalsson, ISOR, Iceland
* presently Scientific Coordinator of the Soultz project

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

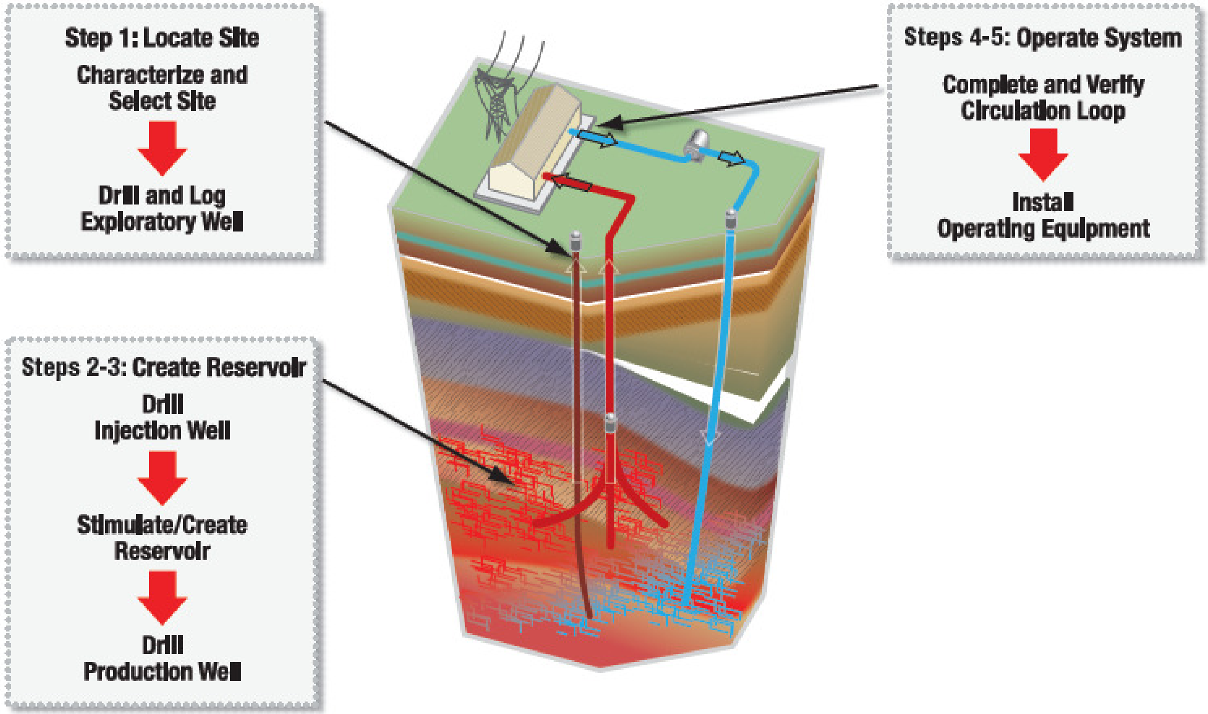
- **Start 1 November 2005, 30 months, 2,3 M€, 31 European partners + 4 from Third Countries, 20 countries involved in Geothermal R&D**

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

“The future of geothermal energy”



DOE-sponsored study, by a panel of independent experts led by the Massachusetts Institute of Technology (MIT).

Followed by “An evaluation of EGS technology”

1: Site characterization

REQUIRED TASK	AVAILABLE TECHNOLOGIES	TECHNOLOGY STATUS	ADEQUACY	
			Near-Term	Long-Term
Determine temperature gradient and predict temperature at depth	Various temperature measurement tools in shallow boreholes	Commonly used throughout industry. Gaps are primarily data, not technology.	YES	YES
	Geothermometry (chemical and isotopic measurements)	Some interpretation of geothermometry requires sophisticated understanding of numerous interacting factors, such as shallow equilibration.	YES	NO
Determine stress field using surface-based technology	InSAR	The strength of Interferometric Synthetic Aperture Radar (InSAR) is its ability to provide observations of ground displacements with a precision of a few millimeters in images with 20-meter spatial resolution covering 100-km distances.	YES	YES
	Global Positioning System (GPS)	The GPS provides only regional coverage unless many instruments are used with close spacing. GPS may provide regional indication of stress.	YES	YES
Determine geologic characteristics and history (lithology and structure)	Geophysical surveys	Surveys are routinely used in mineral and petroleum exploration. Seismic interpretation is inadequate for many geothermal environments. Magnetotelluric surveys can be improved. Electrical resistivity surveys are technically acceptable, but equipment can be improved. Magnetic surveys are technically acceptable.	YES	NO
	Lithologic analysis	The science, methods, and equipment used for this analysis are mature.	YES	YES
	Geologic mapping	The science, methods, and equipment used for mapping are mature.	YES	YES

From "An Evaluation of Enhanced Geothermal Systems Technology"

1: Site characterization

REQUIRED TASK	AVAILABLE TECHNOLOGIES	TECHNOLOGY STATUS	ADEQUACY	
			Near-Term	Long-Term
Detect fluid-filled fractures	Self-potential; streaming potential	Self-potential is commonly used for shallow hydrothermal systems.	NO	NO
Evaluate background seismicity	Seismometers located in shallow surface holes	Surface seismometry is a mature technology.	YES	YES
Predict potential for stimulation	Geologic models from the oil and gas industry	Data and experience are inadequate for modeling of most projected EGS environments due to lack of sufficient measurements under geothermal conditions.	NO	NO

From "An Evaluation of Enhanced Geothermal Systems Technology"

1: Exploratory well
and reservoir characterization

REQUIRED TASK	AVAILABLE TECHNOLOGIES	TECHNOLOGY STATUS	ADEQUACY	
			Near-Term	Long-Term
Characterize subsurface conditions	High-temperature logging and imaging tools Log interpretation methods	Some tools for one-time measurements of wellbore and system parameters are available, but they may be deficient at high temperatures. Geothermal log interpretation methods are derived from oil and gas experience.	YES	NO
	Stress measurement inferred from natural breaking of rocks in the wall of the wellbore and "mini-frac"	Principal stress direction and magnitude are estimated from limited testing capabilities. Imaging tools for breakouts currently require a heat shield.	YES	NO
	Core sampling and evaluation	Routinely used in mineral exploration. Interpretive techniques for geothermal applications are still evolving.	YES	NO
Isolate zones within the well for mini-fracs and flow testing	High-temperature packers	A prototype high-temperature packer for low-pressure applications is available, but little field work has been performed.	NO	NO
Conduct flow tests	Pressure, temperature, and fluid-flow measurement tools	Suitable downhole instrumentation for standard flow tests available up to 200°C.	YES	NO
Perform stress measurements	Micro-fracs and borehole breakouts, core-based measurements	Suitable technology available for lower-temperature applications. Technology lacks zonal isolation capability.	YES	NO
Interpret data to plan stimulation	Models predicting the effect of stimulation on fracture formation and growth	Current models have not been effective in a geothermal environment.	YES	NO

From "An Evaluation of Enhanced Geothermal Systems Technology"

2: Injection well

REQUIRED TASK	AVAILABLE TECHNOLOGIES	TECHNOLOGY STATUS	ADEQUACY	
			Near-Term	Long-Term
Reduce rock	Drilling bits	Roller bits are used in hard rock. Advanced bits (e.g., PDC-based drag bits) are used in oil and gas, and they drill 60% of footage worldwide. Alternatives to mechanical methods (flame jet, etc.) are in experimental stages.	YES	NO
Steer the direction of wells	Advanced steering tools	Wireline based systems are used in geothermal. Commercial advanced steering tools allow control over well trajectories. Tools providing limited steering control are in use by one geothermal firm. Commercial tools are limited to ~150°C.	YES	NO
	Logging while drilling/diagnostics while drilling	The technology is commonly used in the oil and gas industry. Commercial tools are limited to ~150°C.	YES	NO
Complete wells	Metal casing in various diameters and production tubing (e.g., slotted liner)	Fully commercial systems to complete wells are available. Advanced technology, such as expandable tubulars and casing-while-drilling and low-clearance casing systems, is emerging in oil and gas applications. Underreamers work only in "soft" rock. Elastomers used in these systems fail at high temperatures.	YES	NO
	Design methods for selective cementing	Various high-temperature cement formulations are available from the drilling service industry. Design methods for selective cementing of casing exist for wells with small temperature fluctuations.	YES	NO
Isolate zones during drilling	Open and cased hole packers and expandable tubulars and screens	Elastomer and cement packers commonly used for low-temperature applications. Experimental versions of low-pressure packers developed for geothermal applications are not generally available. Retrievable packers for high pressure operations in high temperature (>150°C for extended operation) wells are not available.	NO	NO

From "An Evaluation of Enhanced Geothermal Systems Technology"

2: Injection well

REQUIRED TASK	AVAILABLE TECHNOLOGIES	TECHNOLOGY STATUS	ADEQUACY	
			Near-Term	Long-Term
Log well	Logging tools (e.g., tools to measure downhole pressure, flow, temperature, image fractures)	Logging tools and sensors are available for operation up to about 150°C. Higher temperature versions of some tools are available but have limited lifetimes or require heat shielding. Unshielded prototypes for pressure and temperature are experimental.	YES	NO
Monitor well parameters	Micro-fracs and borehole breakouts, core-based measurements	Suitable technology available for lower-temperature applications. Technology lacks zonal isolation capability.	YES	NO
Interpret data to plan stimulation	Monitoring tools, sensors (e.g., tools to measure downhole pressure, flow, temperature, and seismicity)	Monitoring tools and sensors are available commercially for sustained operation up to about 150°C. Tools capable of operation at >200°C are still experimental.	YES	NO

From "An Evaluation of Enhanced Geothermal Systems Technology"

2: stimulation

REQUIRED TASK	AVAILABLE TECHNOLOGIES	TECHNOLOGY STATUS	ADEQUACY	
			Near-Term	Long-Term
Plan and design stimulation (e.g., zones, pressures, volumes, fluids, proppants)	Stimulation models for oil and gas; basic numerical models for geothermal applications	Stimulation modeling techniques for geothermal systems are not a mature technology.	YES	NO
Imaging and mapping of fractures	Microseismicity, gravimetry, self-potential, tiltmeter arrays	Surface microseismic and gravity tools are adequate for most purposes, but the resolution may be insufficient for EGS. Self-potential is not proven for this purpose. Tiltmeter results are difficult to interpret in zones of multiple fractures.	YES	NO
Identification of flow paths during and post-stimulation	Microseismicity, gravimetry, SP, tiltmeter arrays	The utility of existing techniques for tracking fluid flow has not been demonstrated. Microseismic techniques are not hardened for downhole use.	NO	NO
Effective real-time decision-making capability for stimulation	Oil and gas industry stimulation modeling and control technology	The oil industry has modeling and control capability for petroleum environments, but experience in geothermal systems is lacking.	YES	NO
Zonal isolation for stimulation	Stimulation packers, slotted liners	Packers that can operate at stimulation pressures and temperatures are not available. Slotted liners and related technologies may not perform adequately for EGS	NO	NO
Create/enhance flow paths	Hydraulic stimulation; chemical stimulation; and rate controlled explosives	Geothermal stimulations for EGS use water or water weighted with dense chemicals such as barium sulfate salts. Chemical and other stimulation methods have been used in hydrothermal systems.	YES	NO
Keep flow paths open	Proppants for both near well bore and far field use scaling, dissolution, and permeability control	Proppants are typically used in oil and gas stimulations. Temperature-hardened proppants have not been evaluated in geothermal environments. Scaling and dissolution control technologies are available, but may not be adequate for EGS conditions.	YES	NO

From “An Evaluation of Enhanced Geothermal Systems Technology”

3: operate the reservoir

REQUIRED TASK	AVAILABLE TECHNOLOGIES	TECHNOLOGY STATUS	ADEQUACY	
			Near-Term	Long-Term
Maintain acceptable flow rates and reduce or eliminate fluid loss	Submersible Electrical Pumps	SEPs have operating temperatures of 175ºC with power ratings of 1500 kW. Pump technology is not adequate for long-term high-temperature deep operation.	NO	NO
	Packers for fracture isolation	High temperature zonal isolation tools are not available to allow control of flow from multiple zones.	NO	NO
	Lineshaft pumps	Lineshaft pumps are a fully commercial technology, but depth-limited.	YES	NO
Maintain reservoir and track reservoir evolution	Monitoring tools, sensors (e.g., tools to measure pressure, flow, temperature, seismicity)	Monitoring tools and sensors are available for sustained operation up to about 150ºC. Downhole monitoring tools capable of sustained operation at >200ºC do not exist.	NO	NO
Monitor rock/fluid interactions	Geochemical analytical techniques; geochemical models	Geochemistry is understood for a large subset of relevant chemicals, but real-time detection technology has limited scope and poor accuracy. Geochemical models lack confirmatory field data.	YES	NO
Mitigate reservoir and surface problems (e.g., short circuiting, pressure drop)	Coupled modeling tools and simulators; cements; zonal isolation tools	Cements are routinely used in the hydrothermal industry for lost circulation. Zonal isolation tools that operate at high temperatures are not available.	YES	NO

From “An Evaluation of Enhanced Geothermal Systems Technology”

3: operate the reservoir

Manage induced seismicity	Pressure control; rock mechanics models	Operation protocols that limit injection/ production pressures are considered a useful management tool. Rock mechanics models are available, but cannot predict seismicity.	YES	NO
Control scaling	Scale control technology	Chemical management technologies (e.g., additives for pH control) are used in the hydrothermal industry to mitigate well bore and near-field scaling. Technologies for hydrothermal systems may not be as effective for EGS which will operate in chemical disequilibrium.	YES	NO
Validate reservoir model using field data	Monitoring tools and sensors (e.g., tools to measure pressure, flow, temperature, seismicity); tracers	Few sensors can operate at high temperature for long periods. A temperature sensor is available, but it must be hardened for geothermal conditions. Tracer tests are an established method of validating reservoir models. Smart tracers have not been developed.	YES	NO
Design field expansion	Reservoir simulation models	Existing models are not fully coupled to enable planning of field expansion. Sufficient data to validate models is not available.	YES	NO
Generate electricity	Heat exchanger and power plant	Power conversion technology is relatively mature in the hydrothermal industry. Currently evaluating for EGS applications.	YES	TBD

From "An Evaluation of Enhanced Geothermal Systems Technology"

Towards a demonstration program integrating the different research areas

A program is now needed to demonstrate that EGS reservoirs with the required characteristics (well distributed, sufficiently large heat exchange surfaces, sufficiently high flowrate and temperature, low flow impedance, low water loss) constitute a sustainable source of energy at a price competitive with other renewable energy technologies.

This demonstration should also define a strategy for upscaling EGS output to several 100 MWt and/or several 10 MWe. Priorities are defined towards the perspective of such a demonstration programme.

Geothermal energy R&D in the 7th Framework Programme and beyond

Topic ENERGY.2008.2.4.1: Increased electricity production from Enhanced Geothermal Systems and from low enthalpy geothermal sourcesIncreased electricity production from Enhanced Geothermal Systems (EGS)

•**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**

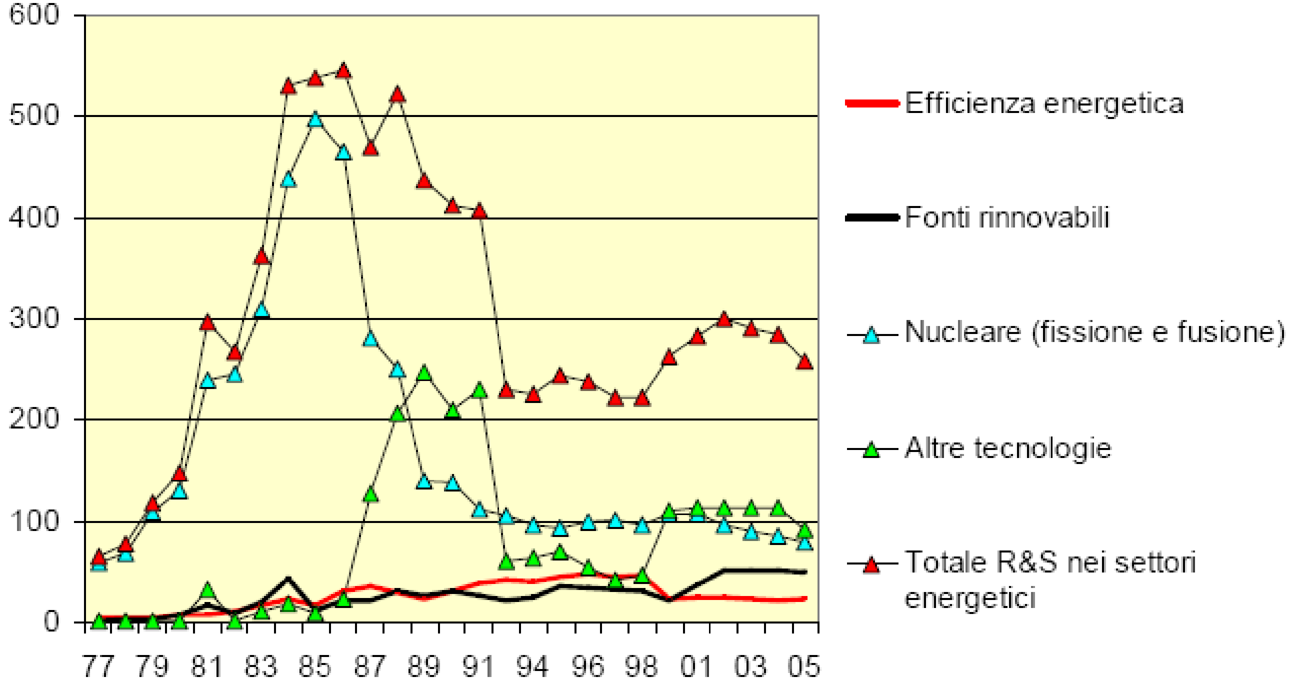
Altre fonti di finanziamento

- A livello italiano
  - Progetti POR, PON
  - Bandi Regionali (fondi CIPE, EU…)
  - Consorzi e convenzioni con industrie interessate

- A livello internazionale
  - World Bank
  - Consorzi e convenzioni con industrie interessate
  - IDDP, ICDP…

Collegamento con progetti di sequestro CO_2, uso di sistemi energetici e processi industriali in cascata

Figura 45 - Spese governative per R&S in campo energetico in Italia per principali settori. Anni 1977-2005 (M€)



Fonte: Banca dati AIE

Da "Rapporto Energia Ambiente 2006", ENEA