VISION 2020 - 2030

Sector: Geothermal heating and cooling

1. Introduction:

Per definition, geothermal energy is the energy stored in form of heat beneath the earth's surface.

Geothermal heating and cooling is currently produced in two different ways:

- The first one (very low temperature (enthalpy) up to 30°C) is based on the relatively stable groundwater and ground temperatures at typically shallow depths (up to 500 m) – and therefore also near structural elements of buildings. Typically, but not necessarily, heat pumps are used to raise the energy to the temperature level required by the heating, cooling, and ventilation systems for the thermal conditioning of spaces and processes. Heat is extracted from or conducted back into the ground by means of a heat pump, providing a certain energy input into heating, cooling and ventilation systems for the thermal conditioning of spaces and processes. In certain conditions and configurations, this system can be used to change ground temperatures artificially, in order to be used as heat or cold storage. UTES (Underground Thermal Energy Storage) represents a new growing market for combined heating and cooling mainly for commercial and institutional buildings.

- The second one (low and medium temperature-enthalpy) extracts the heat from ground and groundwater at higher depths and temperature varying between 25/30°C and 150°C. Direct applications are found in agriculture (horticulture, drying, fish-breeding...), industrial process, and balneology. It may also be applied to supply energy to a district heating or a combined heat and power installation or to drive local absorption heat pumps to provide cooling to the grid. District heating (and cooling) may also be supplied from residual heat left over after the production of electricity from a high enthalpy geothermal heat source..

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2. Market evolution :

Trends:

Unlike the other renewable energy sectors, geothermal sector growth appears to be on the right track for reaching the White Paper objectives outlined for 2010. Starting with 1995 up to 2008 the annual new installed heat pumps had been increased by 5 times. The growth is non-linear (Fig. 1). This means that more than 100.000 systems had been installed in the year 2008 (Fig. 2).

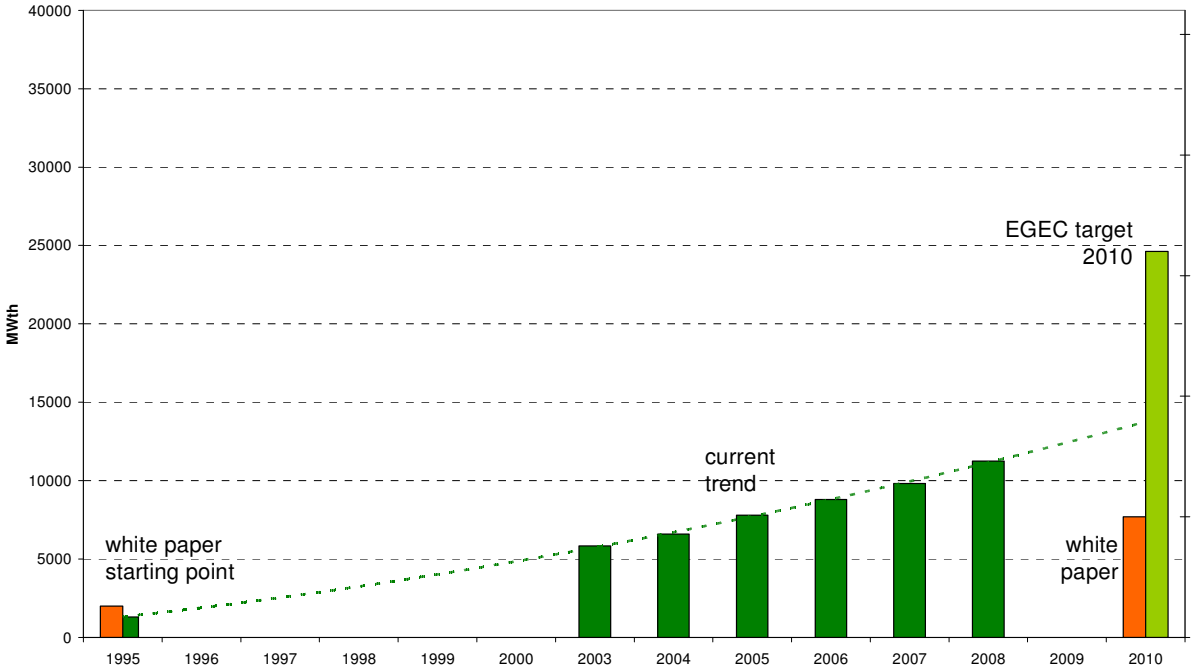

Fig. 1 : Annual installed capacity of geothermal heating & cooling

- **Geothermal heat pumps**

There are different types of geothermal heat exploitment systems.

- Closed loop applications (vertical boreholes)
- Closed loop applications (horizontal, shallow excavated systems)
- Closed loop applications (foundation integrated systems)
- Direct expansion
- Groundwater applications (well based systems)

The most popular one uses vertical collectors, others use horizontal collectors. Most of geothermal heat pumps exchange their heat with ground and groundwater and, in a less widespread way, even through the foundations of buildings (geothermal heat pumps on piles).

Among the different geothermal sectors, the geothermal heat pump industry is currently the most dynamic one. Low enthalpy ground source (the shallow systems) have been experiencing a rapid growth without the requirement of structural subsidies.

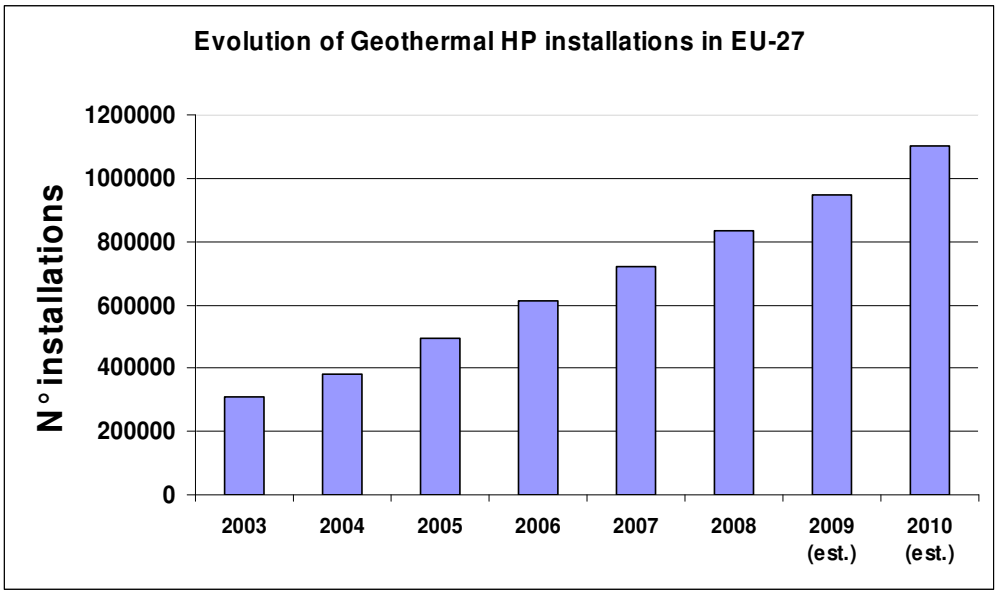

Fig. 2 : Annual amount of geothermal heat pump installations in the European Union

- **Direct uses**

In the European Union, applications linked to direct uses of geothermal heat are widely spread: 18 countries out of 27 use low and medium enthalpy geothermal energy.
Heat from combined Heat & Power installations represents a small percentage. The first low temperature power plants and EGS systems are currently just being installed.

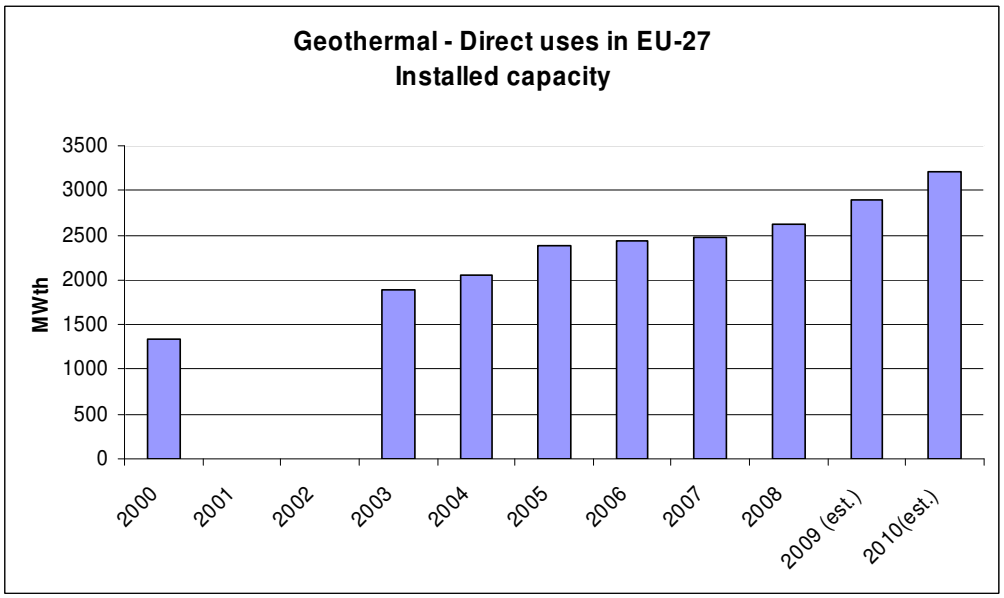

Fig. 3 : Total number of geothermal - direct uses installed capacity in the European Union

3. Deployment towards 2030 : a technological perspective :

There is no principle geographical restriction for the production of geothermal energy, geothermal heating and cooling supply can match the H&C demand anywhere because the resource is available everywhere :

- On the one hand, geothermal heat pumps can use the heat stored at shallow depth without any geographical restriction.

- On the other hand, higher temperatures are available at greater depth everywhere, which constitutes a further resource for direct use. Producing from this resource is restricted by the investment and operating cost required to drill to this depth and the availability of the technology for producing this heat.

Currently, Geothermal energy is converted into electricity and used for district heating, as well as for heating (and cooling) of individual buildings, including both small and large schemes (offices, shops, residential houses, schools, greenhouses, bathing etc.)
A number of new and innovative applications of geothermal energy have been developed, and some of those have already been demonstrated (ice/snow-melting, desalination,…).

Existing houses represent an overwhelming share of the low temperature energy demand that logically can be supplied by geothermal district heating systems. Geothermal district heating will be increasingly targeted at *existing* buildings and old inner cities rather than new housing developments.
Current benchmark studies indicate that direct use geothermal energy and district heating grids are probably the most effective option for this market both in terms of carbon footprint and economics.
However these developments are intrinsically fairly complex – needing the replacement of existing fossil energy based infrastructures - and require therefore longer development times.

But, at present, direct use of geothermal heat is subject to the availability of existing resources, as it is illustrated in the following map:

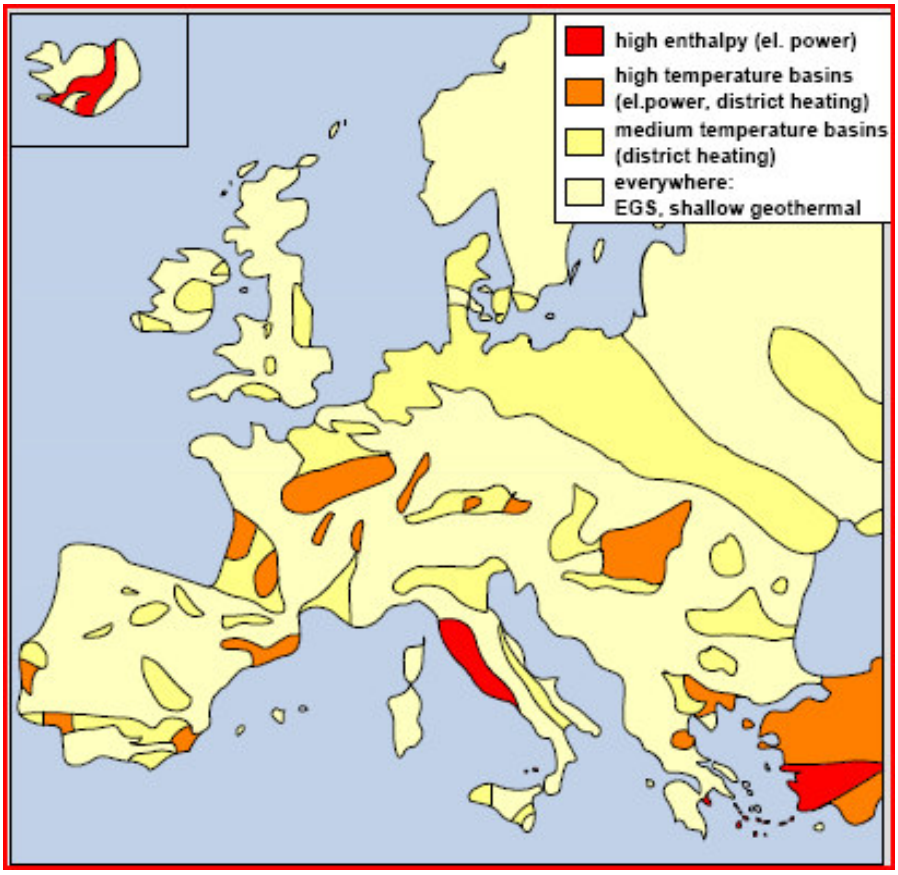

Fig. 4 : geothermal resources in Europe

The key challenge for the widespread direct use of geothermal heat will be the ability to reliably engineer the subsurface heat exchangers (EGS) in a reproducible way to harvest the heat flux at the required temperature.

Thus, to present the vision of the deployment of the geothermal heating and cooling until 2030 is nothing else than to describe the path and costs reduction that permit to go from the nowadays “hunter-gatherer” economy of geothermal energy to a systematic and optimized exploitation of geothermal resources.

The key steps for this deployment are indicated in the following tables:

Shallow geothermal source

Challenge	Impact	Time frame	Critical assumptions
Integrate geothermal energy as a standard in the housing energy system	Increased penetration of the geothermal heat pumps into the market for new residential and commercial buildings	2010-2020 : linear increase of the market share 2020-2030 : constant part of the market at some ten of percent	RES must become the standard in new energy efficient buildings in all countries.

Develop heating and cooling networks integrating geothermal heat pumps and geothermal storage (UTES)	Widespread of H&C networks based on geothermal energy.	Geothermal penetration : 2010-2020 : linear increase of the market share 2020-2030: constant part of the market of tertiary building and small H&C networks at more than 50%.	Rapid diffusion of H&C networks, which have to become the standard in urban planning
Develop geothermal solutions for retrofitting of existing infrastructure	Linear increase use of the penetration of the geothermal heat pumps in retrofitting of old buildings	2010-2020 : linear increase 2020-2030 : constant market share among retrofitted buildings at some ten of percent	Develop products and methodologies for cost effective building energy refurbishment. Higher performance of high temperature heat pumps, or adopting the buildings to low temperature space heating, Importance of improved energy efficiency standards as part of renovation activities to be stressed in buildings regulation

Deep geothermal source

Challenge	Impact	Time frame	Critical assumptions
Exploit favorable sedimentary basins for deep conventional geothermal energy at their full capacity	Systematic exploitation of deep geothermal where there is a resource and a potential use at the surface.	2010-2020 : rapid progression of geothermal projects 2020 -2030: increasing focus on existing urban areas and inner cities.	Environmental and social impacts mastered High exploration cost covered by incentives. Development of cheaper exploration-only drilling technology.
Deployment of EGS technology	Geothermal heat from CHP for industrial process and space heating and cooling	2010-2020 : first operations 2020-2030 : widespread implementation of the technology	Strong involvement of O&G and drilling industry Development of cheaper exploration-only drilling technology Development of large heating networks to absorb the heat

4. Vision for Short term (2020) and Mid term (2030) scenario

1) Costs perspective

Summary of Geothermal Panel targeted costs 2030:

Heating and Cooling	Costs 2009 Range(€-cent/kWh)	Average (€-cent/kWh)	Costs reduction by 2030 (% 2009 costs)
Deep Geothermal - District Heating	4 to 8	5	5 %
Geothermal Heat Pumps – large systems and UTES	5 to 10	6	10 %
Geothermal Heat Pumps – small systems	9 to 15	10	10 %

Residential geothermal heat pumps with a capacity of 10 kW are routinely installed for around 1-3 K € per kW for closed loop systems. When the capacity is over 100 kW (large residentials, tertiary buildings, schools, museums), open loop systems cost range is 0,5-0,8 K €.
UTES systems for commercial and institutional buildings as well as for district heating and cooling have a capital cost of 100-150 K € per MW_{th} (10% of the investment cost) referring to Swedish and Dutch experiences. The running cost is commonly 20-30 € per MWh (SPF varies normally in the range of 5-7).
District heating systems may benefit from economies of scale if demand is geographically dense, as in cities, but otherwise piping installation will dominate the capital costs. The capital cost of one such district heating system in Bavaria was estimated at somewhat over 1 million € per MW.

The Geothermal Panel, fixing research priorities for all geothermal technologies until 2030, estimates to decrease costs:

- by 5% for Geothermal District heating: reach 4 €-cent/kWh_h
- by 10% for Geothermal Heat Pumps: reach 5 €-cent/kWh_h for large systems and 9 €-cent/kWh_h for small systems

The general technological objectives of the Geothermal Panel are:

> increasing the information about the useful geothermal potential, amongst the various stake holders: end-users, advisers, authorities, etc

> for direct uses: improving plant efficiency, decreasing installation and operational cost. Transportation of heat for more than a few kilometers is currently uneconomical, the development of geothermal direct heating or cooling is subject to the availability of suitable geothermal sources close to the

user. Therefore the development of EGS is critical for a larger-scale development;

> develop EGS technology:

- exploration strategies and development of affordably priced, exploration-only drilling technology
- improvement of drilling technologies
- improvement of enhancement treatments bringing geothermal reservoirs to an economic use (following the EGS-concept) and sustainable use of EGS (investigate proppant technologies etc., developing)

> for Geothermal Heat Pumps: decreasing installation cost[1], increasing Seasonal Performance Factor (SPF) and optimization of the system (ground heat source/heat pump/distribution, gas driven heat pump systems for single houses), support of activities towards a decreased overall energy demand in buildings

> for UTES applications: diffuse the technology better, education and training of designers and installers and improvement of and standardization of design procedures and components.

Main research priorities for geothermal heating and cooling will be:

1) Combined Heat and Power: cogeneration with Enhanced Geothermal Systems and Low temperature power plants, micro cogeneration
2) Develop commercial deep geothermal projects for industrial use and agriculture applications, desalination and innovative applications
3) Development of large integrated District Heating and Cooling systems in which geothermal energy is flexibly used in different forms, individually or in combination with other Renewable Energy Sources
4) Heat Pumps performance improvement
5) Underground systems testing devices and methods
6) Measuring consequences on the environment

The roadmap to overcome the technological challenges will be described in the Strategic Research Agenda.

[1] Today, capital cost reduction achieved of more than 25% compared to 2005, the operating cost (system efficiency and maintenance) can also be significantly reduced.

2) Potential and market deployment

a) Up to 2020

Today, in 2009 Geothermal energy sources provides more than 10 GW_{th} for heating and cooling in the Europe Union, equivalent to more than 4 Mtoe per year, whereby geothermal Heat Pump systems contribute to the largest part. In EU-27, the contribution in 2020 will amount to around 40 GW_{th} installed corresponding to about 10 Mtoe.

- **Direct Use:** The most promising areas are the building of new district heating & cooling networks (Geothermal District Heating & Cooling, with 5 €-cent/kWh, is one of the most competitive energy technology), optimization of existing networks, and the increase of new and innovative geothermal applications in transport, industry and agriculture. The first development regions will be those blessed by the most accessible resources (for example the Pannonian, Tuscanian or Parisian basins) as well as higher grade resources where combined heat and power projects will be developed (e.g. the Bavarian Malm reservoir).
  A renewed activity for geothermal district heating and direct use can already be identified in France, Germany, Italy and the Pannonian basin countries, as well as from new areas like, the Netherlands Spain and Ireland. In addition the unit size of geothermal projects (linked to the production of an individual well) will direct project development towards existing or to be developed district heating or cooling networks. With absorption heat pumps, local cooling can be provided using the district heating grid as energy provider (heating and cooling using the same distribution network).

- **Heat from cogeneration geothermal systems:** During the next 10 years, geothermal combined heat and power plants with low temperature installations and Enhanced Geothermal Systems will be developed. The sector forecasts predict to reach 6 GW_e in EU-27. A binary system (Kalina or Organic Rankine Cycle or similar) at low temperature has a simultaneous electrical and thermal capacity of ca. 5 MW_e and 10 MW_{th}, respectively.
  An EGS plant today has a capacity of 3-10 MWe, but future commercial plants will have a capacity of 25-50 MW_e and 50-100 MW_{th} (producing from a cluster of 5 to 10 wells, as in the oil&gas industry). CHP installations could provide heating representing 2 Mtoe by 2020.

- **Geothermal Heat Pumps**: The quantitative development of the European geothermal market in the next ten years is expected to be fuelled mainly through the introduction and consolidation of shallow geothermal systems, with a quite mature market in Sweden and Switzerland and developing markets in Austria, Germany and France.. In other emerging European markets in which a high growth is possible, it is expected over the next years (Italy, France, Spain, UK, Hungary, Romania…). Mature countries (namely Sweden and Germany) will

see a steady increase, mainly fuelled by sales in the renovation segment, but all other countries will see a significant growth. Fast development for geothermal heat pumps illustrates how shallow geothermal energy resources, previously regularly neglected, have become very significant, and should be obviously taken into account in any energy development scenario.

Heating & Cooling - EU-27	**2007**	**2010**	**2020**
Shallow Geothermal (MW_{th})	5 700	11 500	30 000
Deep Geothermal (MW_{th})	4 100	4 500	9 000
Total Installed Capacity (MW_{th})	**9800**	**16 000**	**39 000**
Heat and Cold Production (Mtoe)	**2,6**	**4,3**	**10,5**

b) Post-2020

Targets set, by the Geothermal Panel, for the geothermal sector in 2030

Heating & Cooling - EU-27 (Mtoe)	**2007**	**2010**	**2020**	**2030 - Conservative[2]**	**2030 – Enhanced market[3]**
Geothermal Heat Pumps	1,5	2,3	6	*12*	*34*
Geothermal Direct uses	1	1,8	2,3	*6*	*12*
Heating from CH&P	0,1	0,2	2	*12*	*12*
Total Heat and Cold Production	**2,6**	**4,3**	**10,5**	**30**	**60**

[2] Business As Usual (BAU) scenario.
[3] Enhanced market by developing new technologies and new applications.

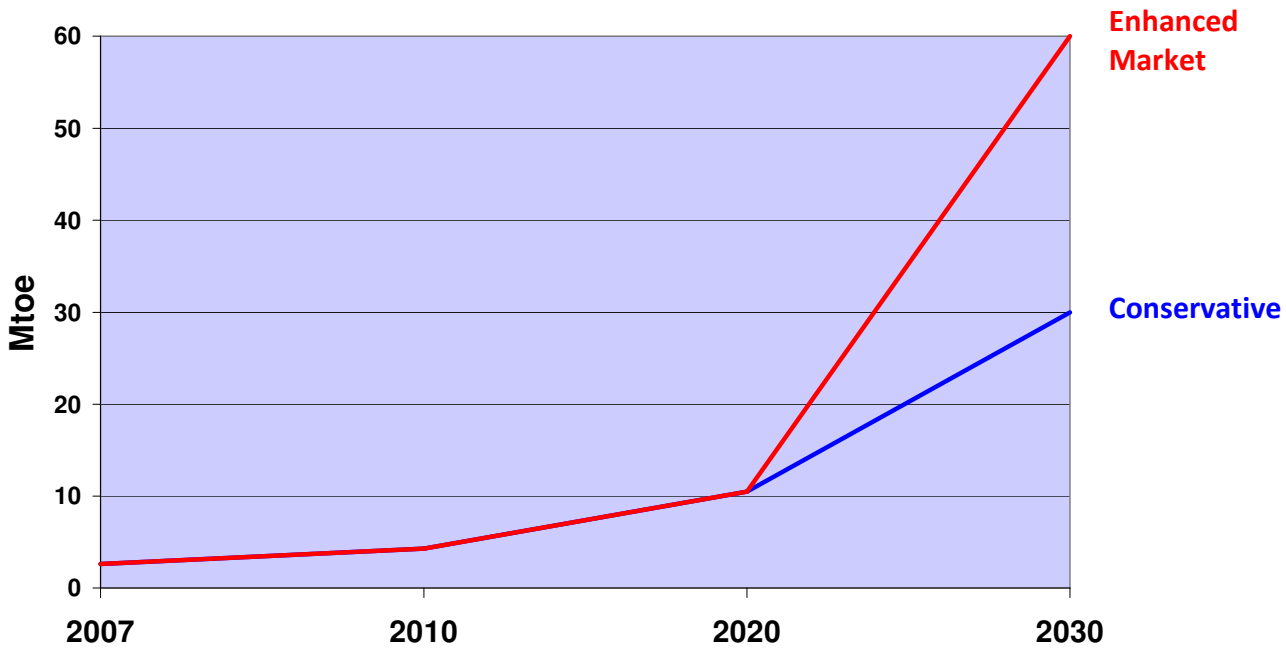

Fig. 5 : Geothermal Heating & Cooling Vision 2020-2030

Geothermal heat pumps will be firmly established in the markets of all EU countries, and a continuous growth is expected everywhere. They will be classically integrated in energy systems for buildings, combined with other renewable systems, in particular in Heating & Cooling networks. Multi-functional networks (buildings and industrial processes) will be developed too. Geothermal energy storage (UTES) will be developed for seasonal storage, with specific applications for waste heat from industry and storage of solar energy (high temperature storage). For low temperature heat pump supported applications, natural heat and cold from the air, or surface water will be stored underground and used for combined heating and cooling. Thus these systems will become an important provider for heating and cooling for individual houses, commerce and services, but also for district heating and cooling.

Direct uses will be further developed notably for agricultural applications heating greenhouses. New applications for pre-heating in industrial processes necessitating high temperature will start to be installed.

The Enhanced Geothermal Systems, a real breakthrough technology will experience a strong development in Europe, producing a large amount of electricity and combined heating/cooling with cogeneration installations. These installations will allow development of new district heating systems for dense urban areas.

The long term scenario (2050) requires Geothermal Heating and Cooling systems to be available and economic everywhere in Europe, for both individual buildings and Geothermal Heating/Cooling from enhanced and combined systems for urban areas.