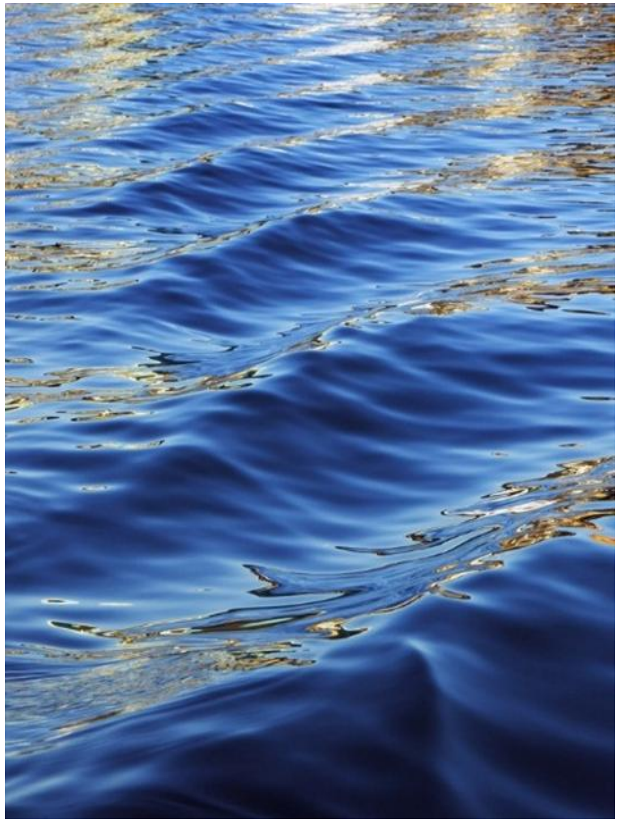
Geothermal application in the green building field”.

(Maria Cristina Pasi- Izar)

Intensive course for Russian junior staff on «Energy saving for Environmental Protection and Control»
Genova, September – November 2013



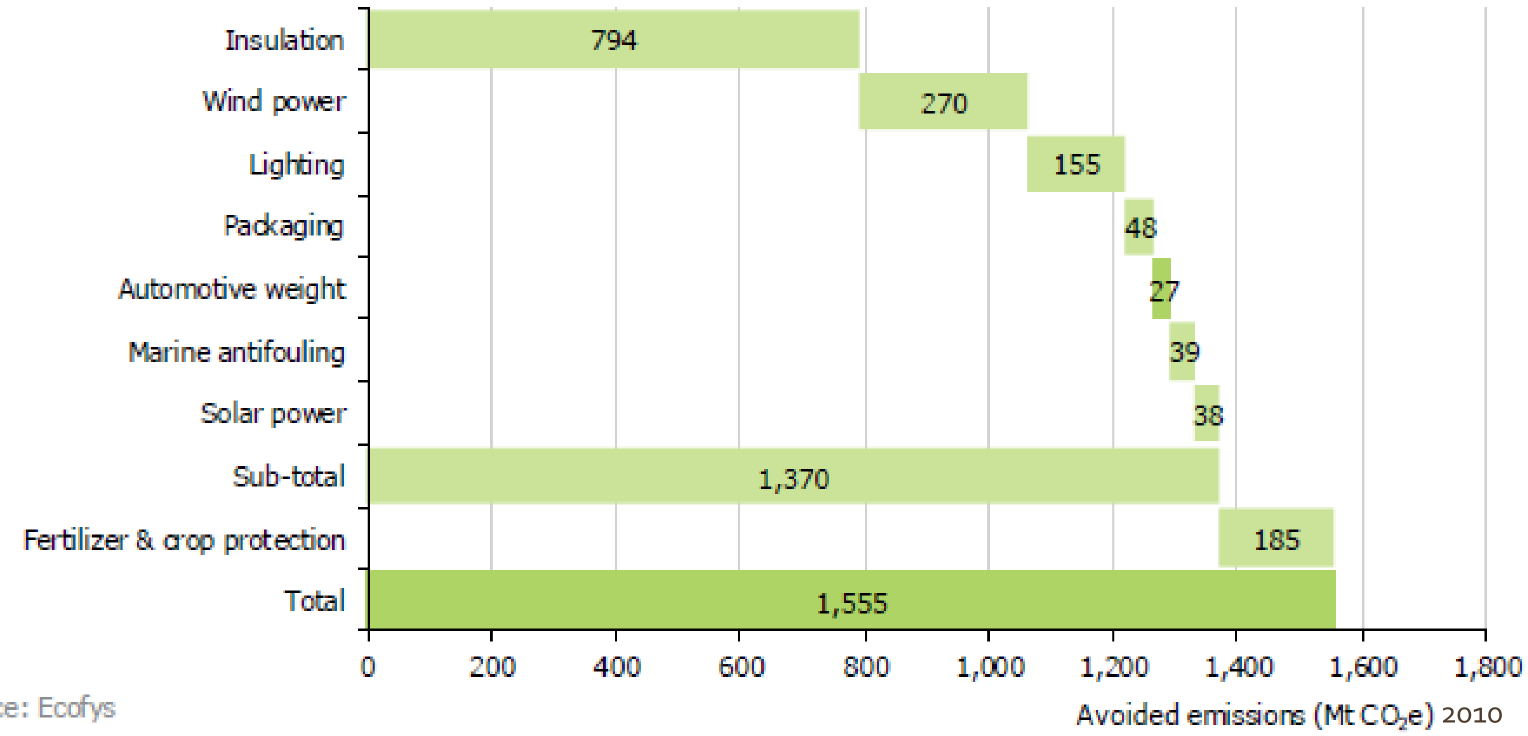
GREENMA Tempus Project n° 530620-TEMPUS-2012-1-IT-JPCR

LLL training and master in innovative technologies for energy saving and environmental control for Russian universities, involving stakeholders. «GREEN MASTER»

Title and contents

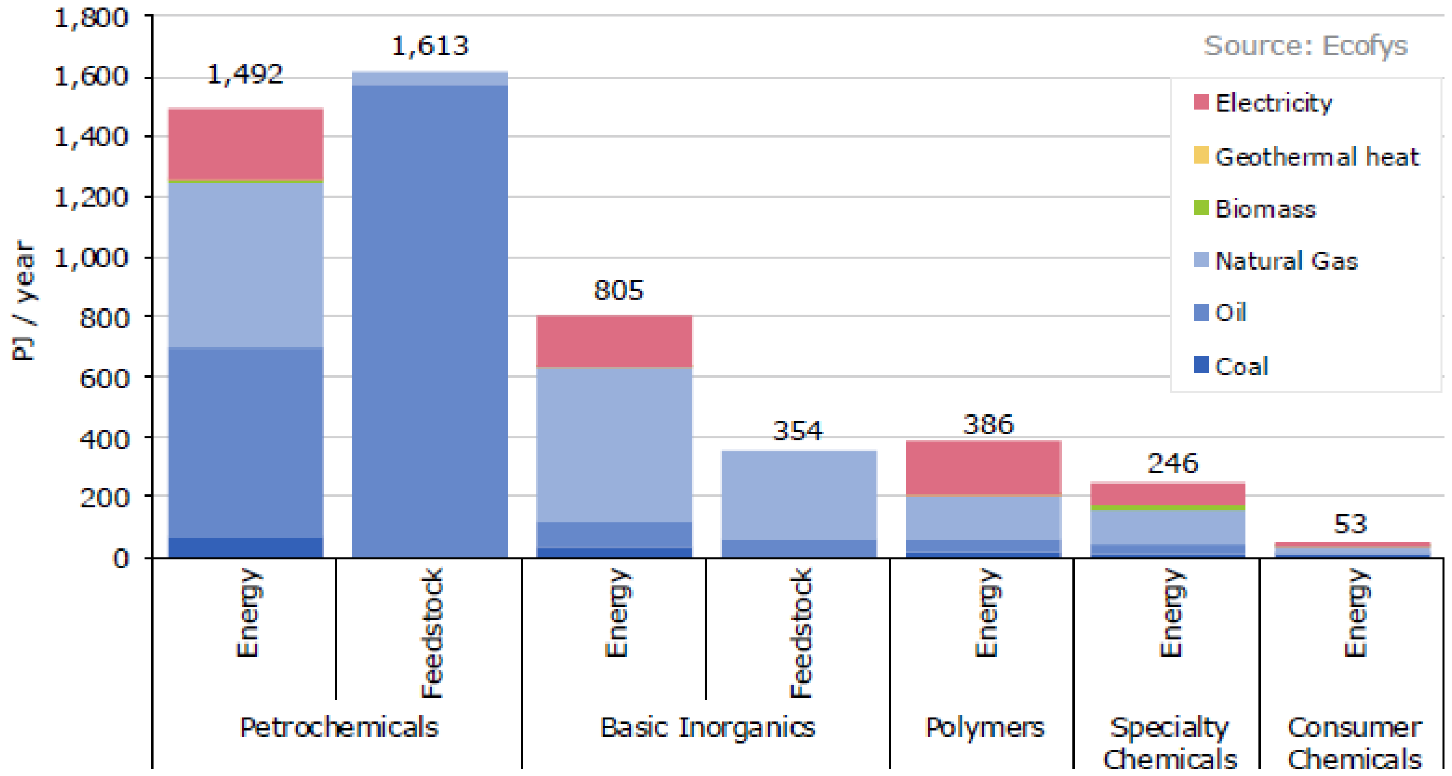
- **Energy policy at the crossroads -** Finding the road to a competitive, low carbon and energy efficient Europe
- **Geothermal energy source potential** in the EU recovery program
- **What is** geothermal Energy
- **Geothermal energy source applications** for heating, cooling and electric power generation
- **Geothermal energy source projects** short-medium and long term
- **Geothermal energy in the SMART city**

Energy saving policy: an option for geothermal energy in GHG emissions reduction

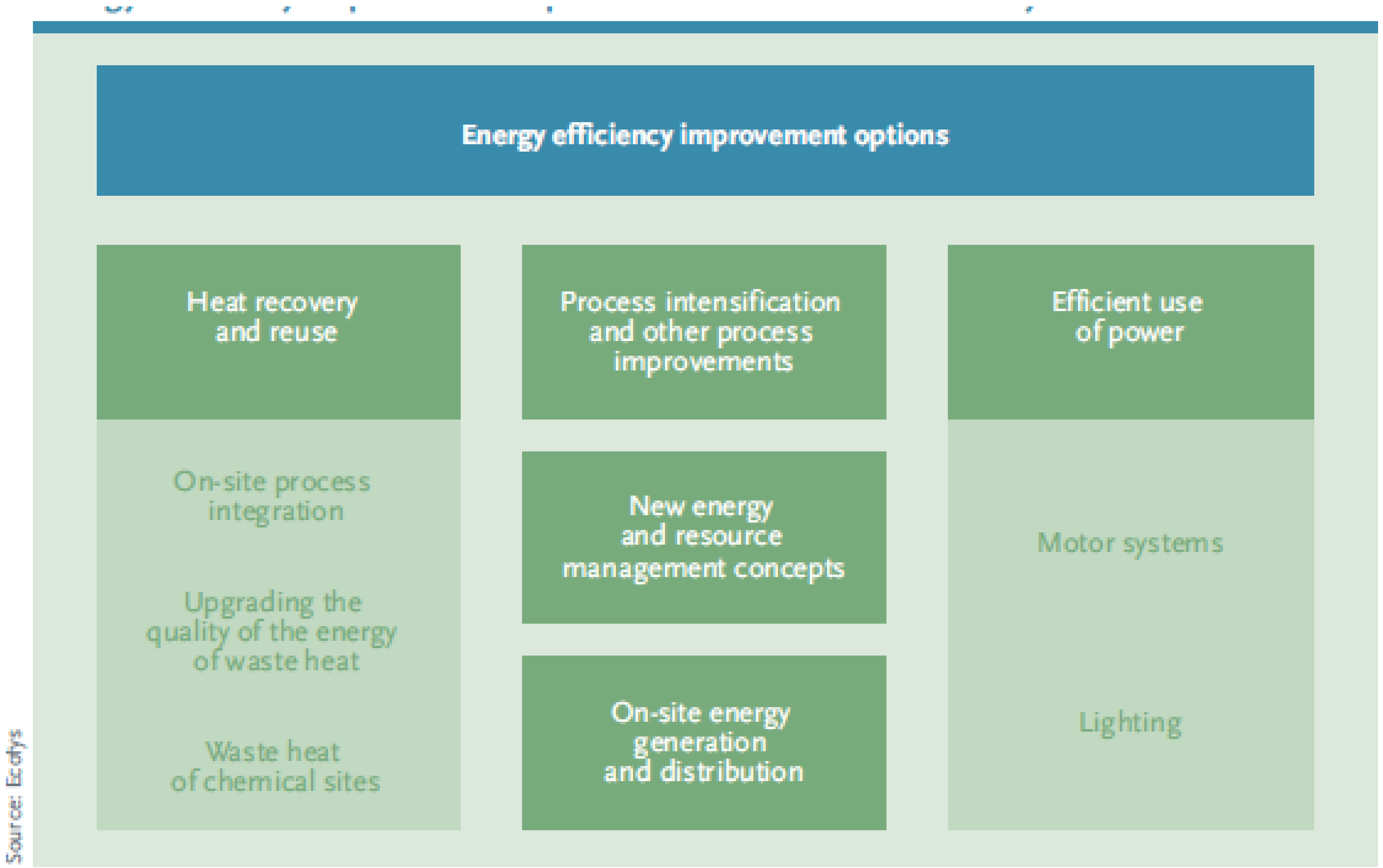


Source: Ecofys

Energy consumption typologies in the EU chemical Industry 2010



Energy efficiency improvement options in Green building



The 2 options in Green building: Renewable geothermal energy and energy efficiency improvement

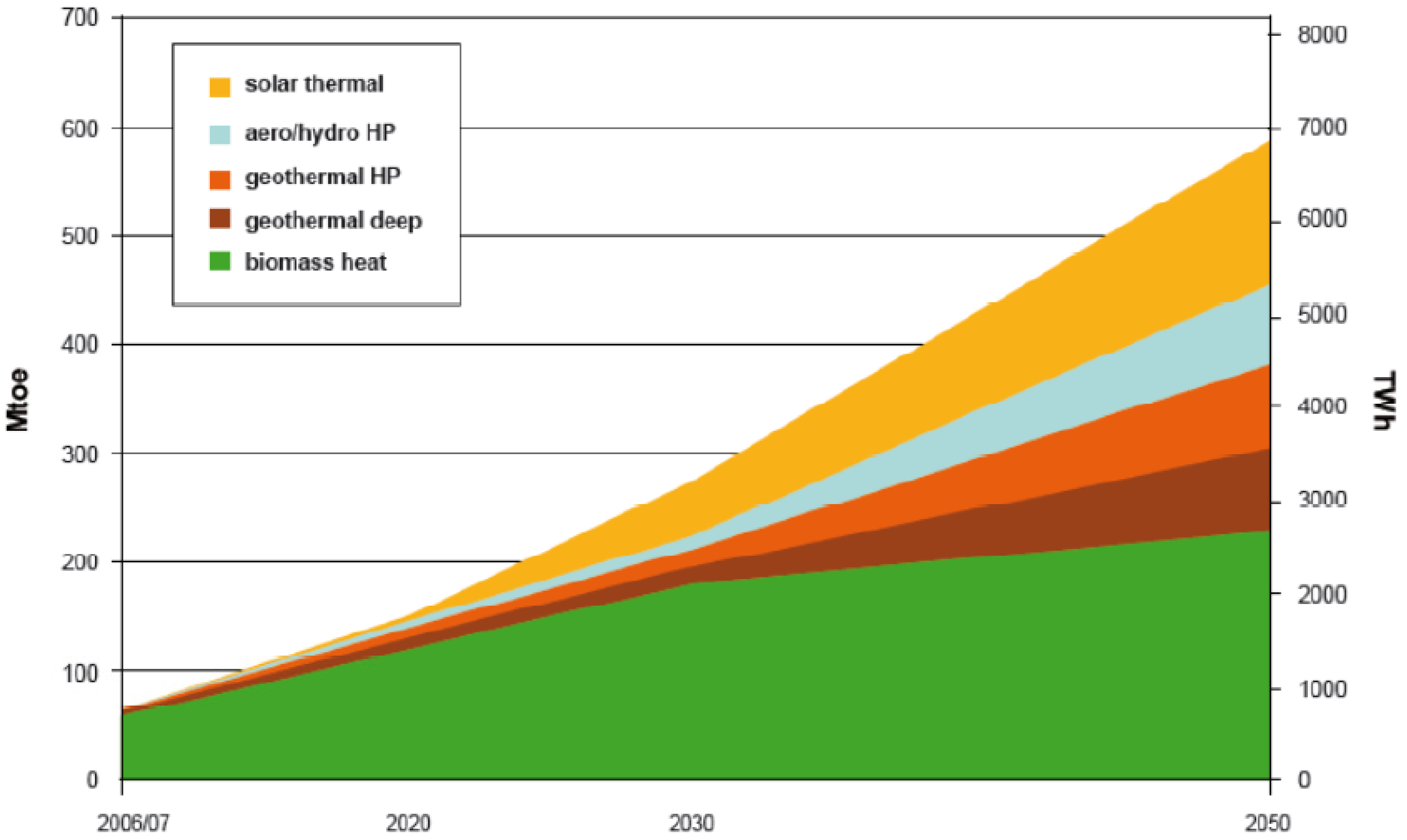
- Renewable energy constitutes a basic pillar in the strategy supported by EU to reinforce the sustainable development of our economies and citizens' welfare.
- Almost 50% of the total European consumption of energy is used for the generation of heating and cooling for either domestic or industrial purposes.
- Heating energy is mainly produced through the combustion of fossil fuels
- Cooling is, with few exceptions, achieved by processes driven by electricity, which
- The majority of energy use takes place in urban areas, characterized by higher population density where districts heating and cooling networks represent a critical infrastructure to ensure large scale integration or renewable energy sources

Renewable geothermal energy in Green building

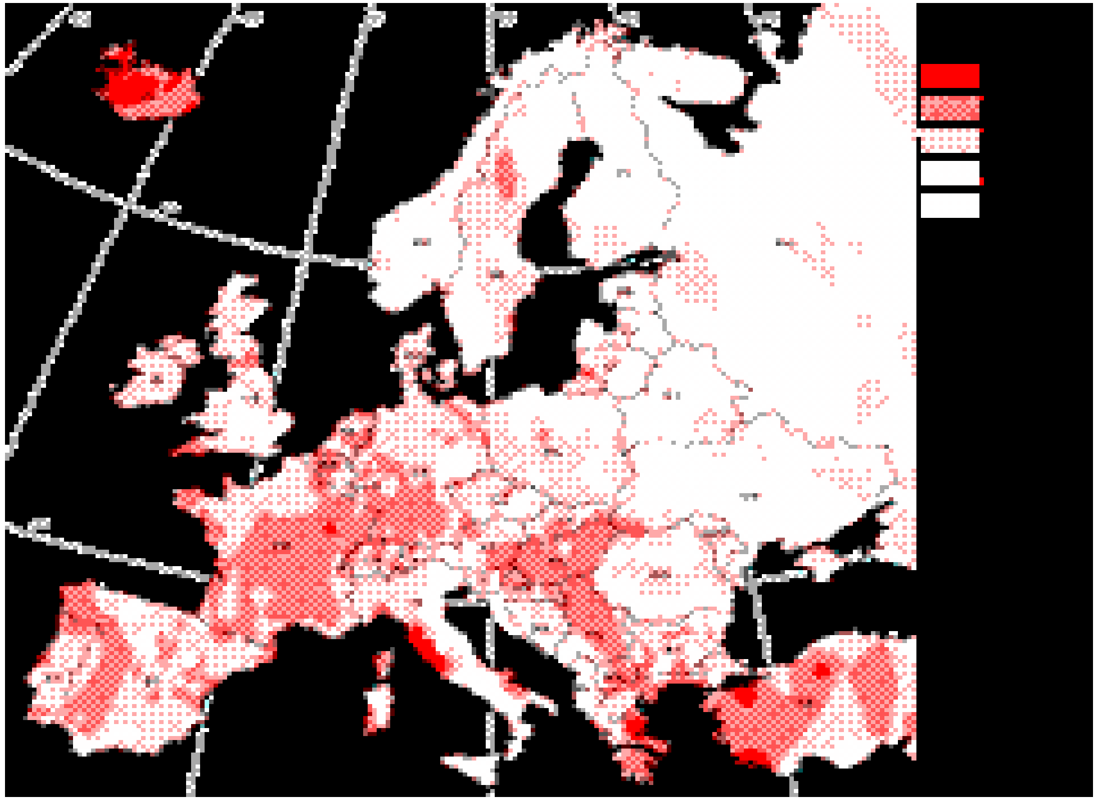
In 2020 over 25% of heat consumed in the European Union could be generated with renewable energy technologies. The large majority of renewable heating and cooling will still be produced from biomass sources, although solar thermal is expected to have the highest average growth rate among the renewable energy technologies for heating and cooling in the decade 2010 – 2020. Increasingly competitive geothermal, aerothermal and hydrothermal heat pumps will gain market shares as efficiencies rise. The first Enhanced Geothermal Systems (EGS) drillings will be realised, producing heat at temperature suitable for direct use. Improved thermally driven cooling systems (eg from solar or heat pump technologies) will make it possible to cover around 5% of cooling demand from the service and residential sectors by 2020.

Furthermore, by 2030 renewable heating and cooling technologies could supply over half of the heat used in Europe. Improved compact and seasonal thermal energy storage systems will be crucial to meeting the heating and cooling requirements in buildings. In most of Europe, biomass will be used for small-scale heating as well as industrial processes; 2nd and 3rd generation biofuels will also play an important role. Solar thermal will satisfy approx. 15% of the overall European low temperature heat demand and it will be increasingly able to meet the heat demand of medium and higher temperature industrial processes. Geothermal heat pumps and geothermal direct use will be firmly established.

Heating potential by renewable energy sources in EU



Geothermal energy in Europe



Geothermal energy in Europe

On a world-wide scale, the earth continuously emits about 12 TW of heat from the land surface alone. For all Europe, the geothermal heat flux, transporting heat from beneath into underground layers in accessible depth, can be assessed to a total of 814 GW. This amounts to 7100 TWh or 610 Mtoe annually for Europe, of which 260 Mtoe per year are produced under the surface of the EU 27. And in the shallow underground, this amount of heat is complemented by solar irradiation and infiltrating surface water.

Hence the potential of geothermal energy in Europe is huge. Shallow geothermal energy can be used virtually everywhere, mainly in the form of ground source heat pumps (GSHP). At present, deep geothermal technology is deployable in a number of areas already, and EGS technology, successfully demonstrated meanwhile, can open other regions for deep geothermal use. The extent of the deployment is therefore limited only by the demand for heat. By 2050, a value in excess of 150 Mtoe of heat production is deemed possible (45% of heat demand under the RDP scenario).

Geothermal energy installations capacity in Europe

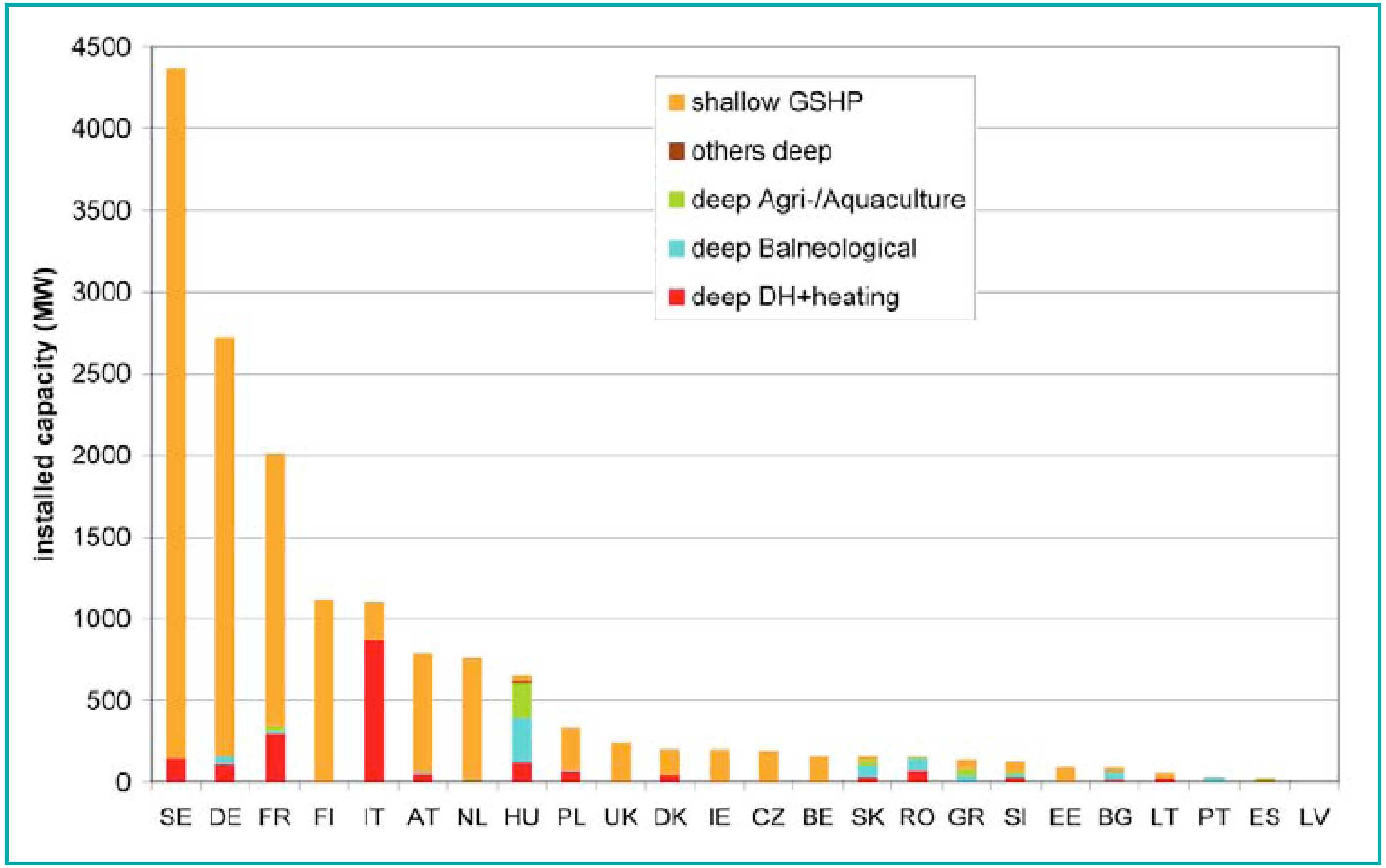


Figure 2 – Distribution of installed capacity (MWth) in EU 27 member states (after data from WGC, 2010; EurObservER, 2011; EGEC, 2011)

Geothermal energy installations capacity in Europe –Non EU

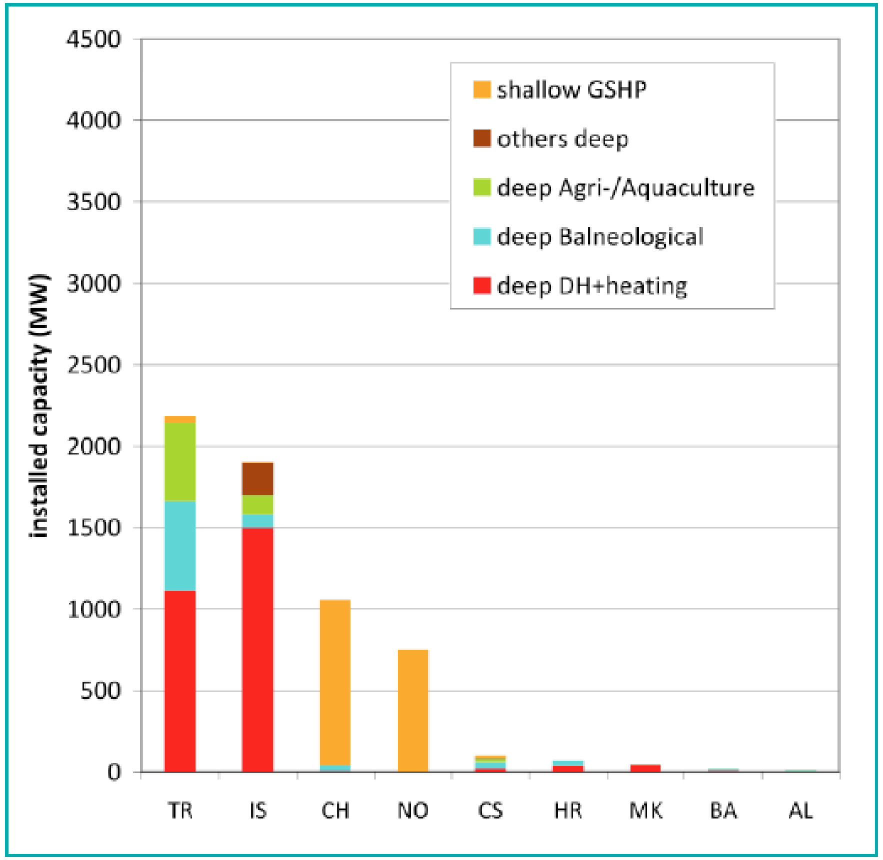
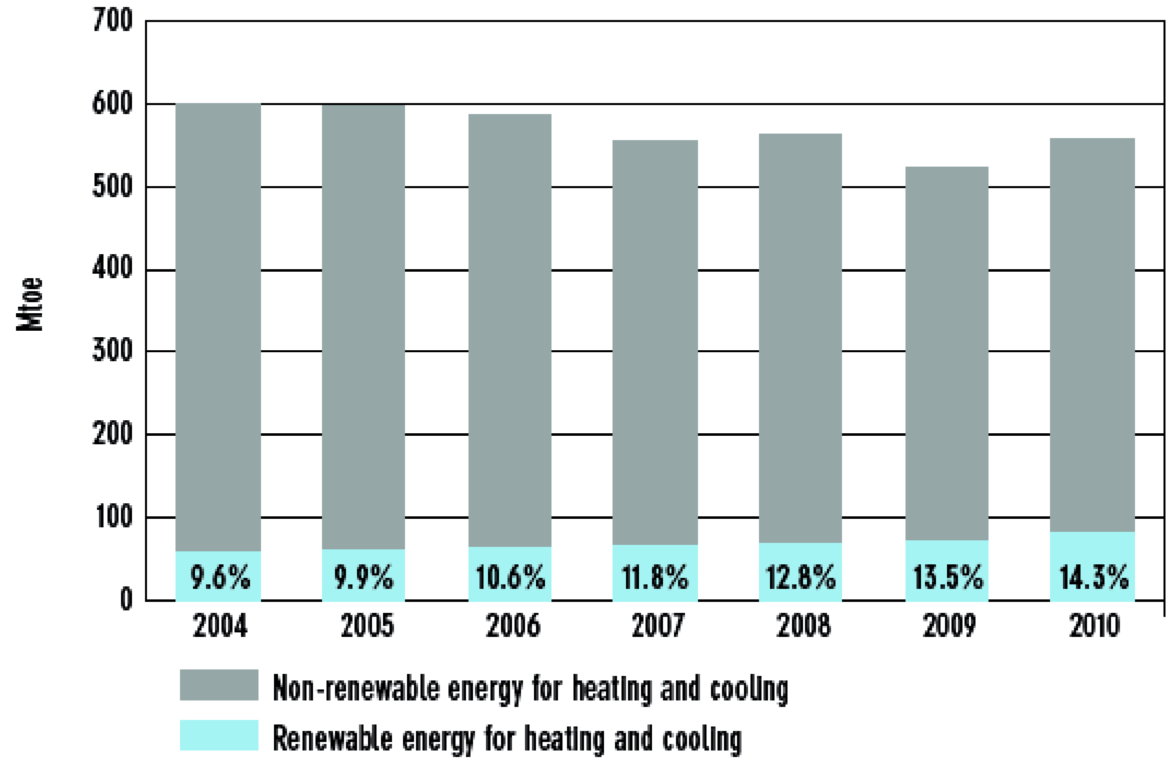


Figure 3 – Distribution of installed capacity (MWth) in some non-EU countries (after data from WGC, 2010)

Heating and cooling supply in EU- 27: ratio renew/non renew



What is Geothermal energy?

The energy stored in the form of HEAT beneath the earth's surface, at different temperatures in the ground and the ground water at different temperature and Enthalpy value according to the grade of deepness and the geology of the earth

The three typologies of thermal energy

There are three main typologies of geothermal energy in relation to the Temperature extraction level

T ≤ 30° C (stable underground level , minor than 400 m depths, extraction by pumps for heating and cooling applications via temperature adjustments)

The three typologies of geothermal energy

30 ≤ T ≤ 100°C (stable ground and ground water heat source, extraction by pumps for direct heating)

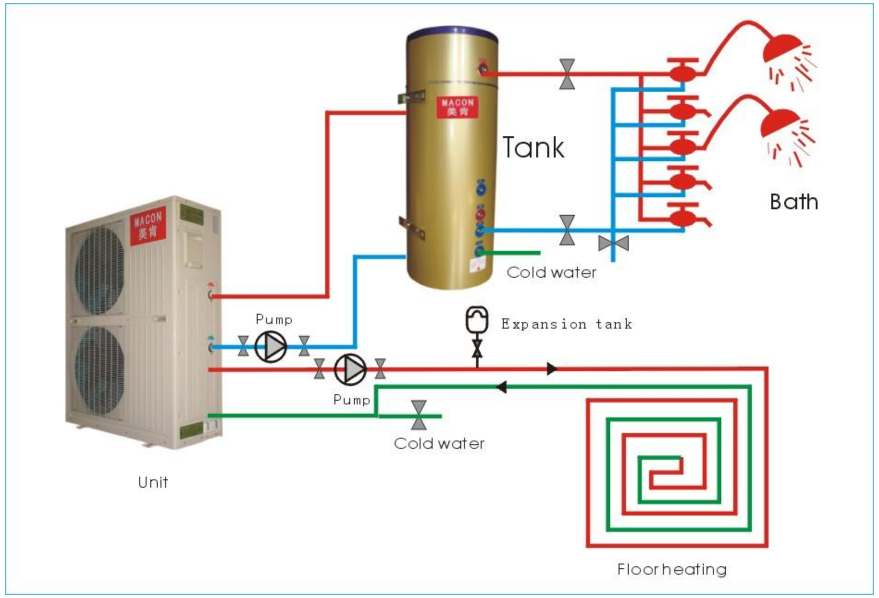
The three typologies of geothermal energy

3. Well over 100°C up to 300°C (high Enthalpy, applications in electric power generation, heating applications in industrial processes)

The application fields in the Smart city concept

Cathegory 1:

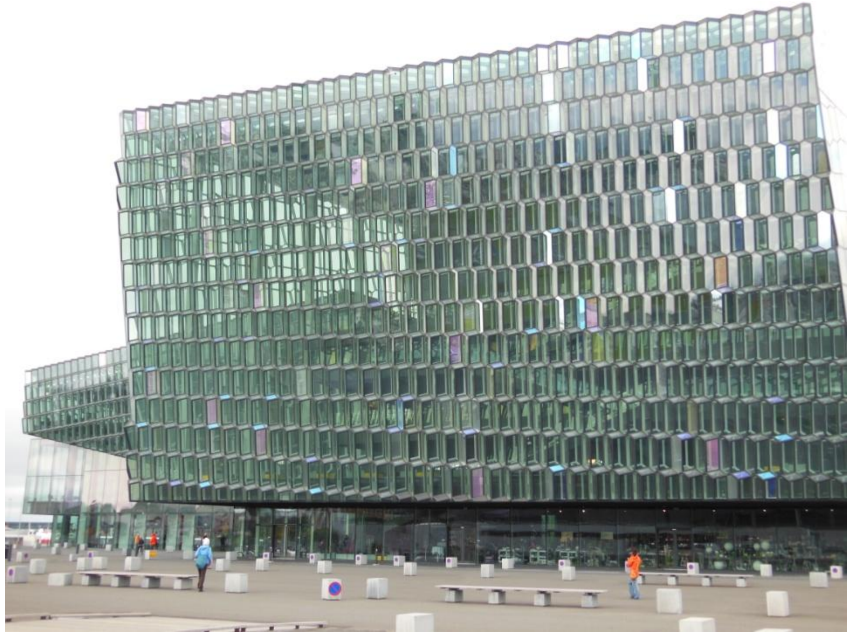
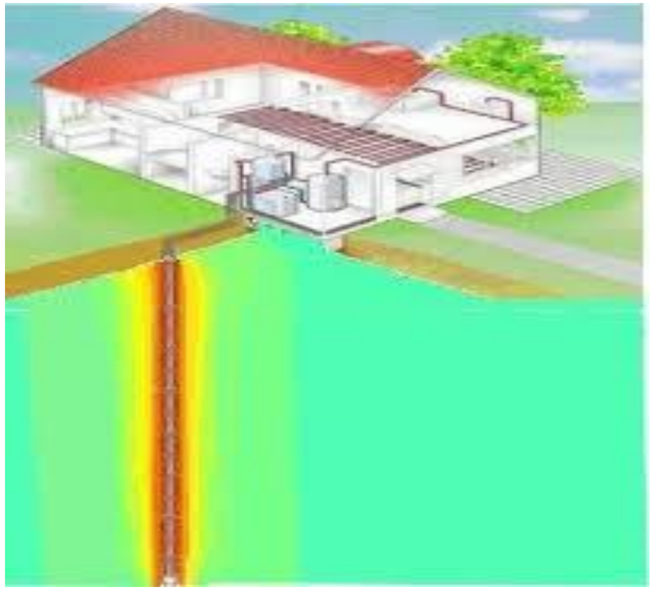
- Direct application in cooling systems, heat or cold storage (UTES: Undreground Thermo Energy Storage) in commercial buildings.
- Direct irrigation and heating of green housed crops
- Indirect heating by inclusion of thermodynamic devices such as heat pumps at low energy level



The application fields in the Smart city concept

Cathegory 2:

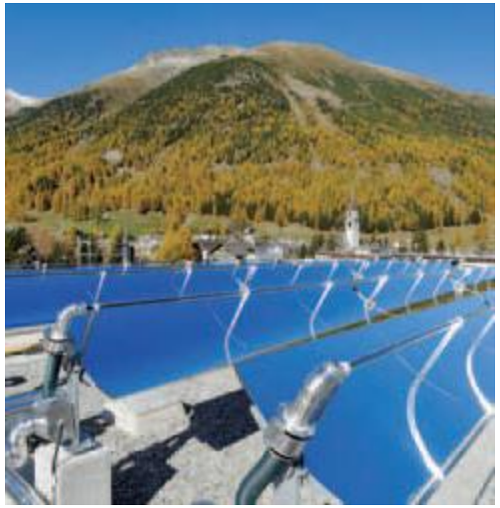
- Direct application in heating systems for buildings , aquaculture and drying systems
- Direct application in de-iceing systems in the smart cities district roads and airports

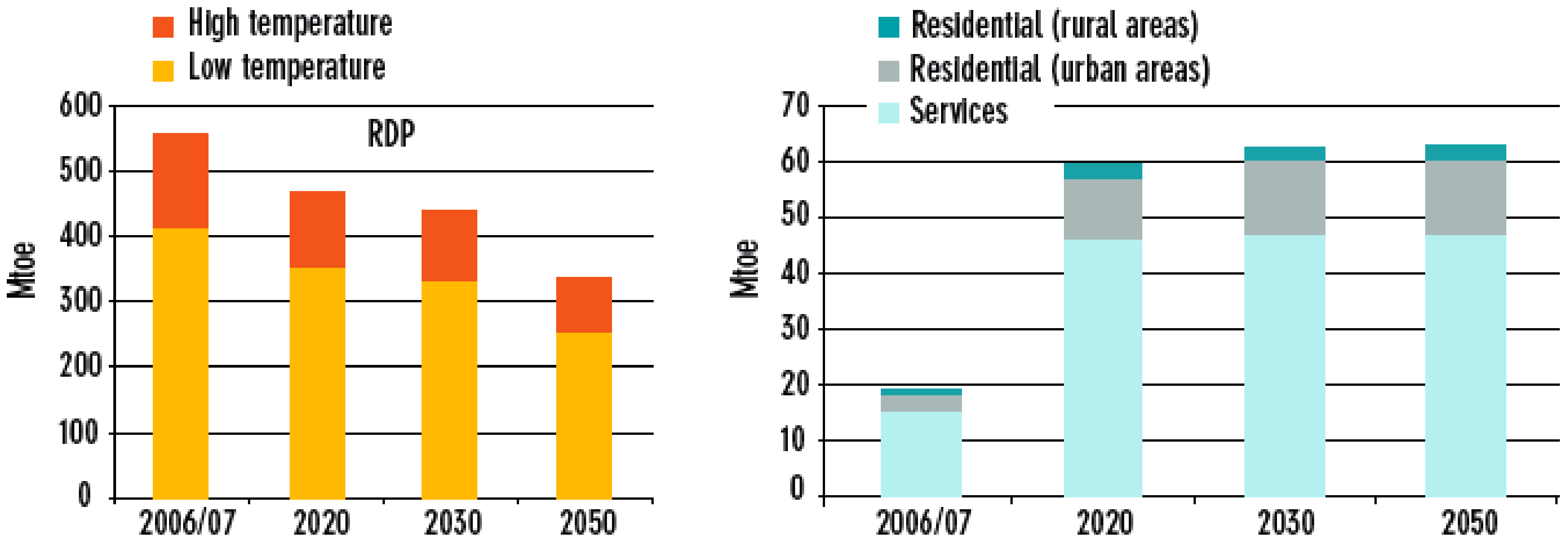

The application fields in the Smart city concept

Cathegory 3:

- Electric power generation for private, pubblic, industrial buildings
- Direct application in endothermic chemical reactions and industrial energy eating process es



Heating and cooling typologies in residential applications in EU-27



Potential contribution and Key Research innovation areas up to 2020 in greenbuilding

By

Geothermal	By 2020: 10.5 Mtoe By 2050: 150 Mtoe	• Integration of design of the shallow geothermal system and building energy system with regard to optimum thermal use and operational strategy. • Optimisation of components such as borehole heat exchangers, well completion materials, compressors, pumps etc., including improved drilling methods. • Innovative exploration, drilling and production methods for deep geothermal resources, including related surface installations, for reducing overall cost and risks caused by geological uncertainties. • Reducing cost and increasing the lifetime of Enhanced Geothermal Systems - EGS (focus on exploration, drilling, hydraulic fracturing, formation treating, reservoir predictive models, and heat production).
Cross-cutting	Energy saving potential by 2020: Industrial heat pumps: 20 Mtoe District Heating: 50.7Mtoe / year District Cooling: 5.5 Mtoe / year	• Efficiency increase for heat pump technology (both electrically-driven and thermally-driven applications). • R&D to make available integrated, flexible, highly efficient and environmental friendly district heating and cooling systems, in particular through a better valorisation of local resources, development of low-temperature networks and the integration of innovative thermal storage. • R&D to increase storage density using phase change materials and thermochemical materials. • Development of advanced algorithms for optimal planning, management and control of hybrid systems.

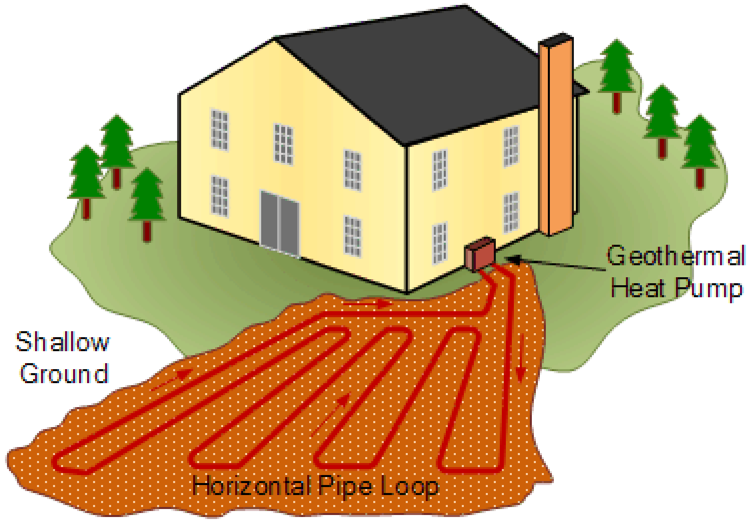
Applications and technologies for residential buildings: the shallow geothermal heat pump system

- In the residential sector, the main geothermal technology to cover heating and cooling demand is the shallow geothermal heat pump system (the ground-source heat pump).
- The technology is suitable for small, individual houses as well as larger multi-family houses or groupsof houses.
- Capacities range from under 10 kWth to over 500 KWth.
- The depths of geothermal heat exchange ranges from a few meters to more than 200 m, depending upon technology, local geology and design considerations

Applications and technologies for residential buildings: the shallow geothermal heat pump system

- Geothermal heat pumps can deliver all thermal energy required for:

1. space heating
2. space cooling
3. domestic hot water (DHW)



Applications and technologies for residential buildings: the shallow geothermal heat pump system

- The number of geothermal heat pumps with a capacity below 50 kW crossed the threshold of 1 million units in 2010.
- Markets : Northern Europe: The highest numbers can be found in Sweden, Germany and France. The market penetration (installations per capita) is highest in Sweden, Finland and Austria.
- Markets: southern Europe: Geothermal heat pumps are already used in Southern Europe, however, further R&D and practical experience is crucial to fully exploit the advantages of geothermal heat pumps in warmer climates in supplying heat and cold from one single installation.

Technologies and applications for southern zones green building

GEO.4	System concepts and applications for geothermal cooling in warm climates
Objective	Shallow geothermal energy offers advantages for cooling using the ground as a heat sink. However, this by now is mainly limited to Northern and Moderate climates with a pronounced summer/winter temperature swing. In warm climates or in the case of applications mostly used for cooling, additional re-cooling of the ground, hybrid systems, and short-term storage options etc. need to be developed in order to allow for sufficient share of cooling from the ground
State-of-the-art	Cooling in shallow geothermal systems has started in areas with colder climates, where adding this feature is relatively simple on the side of the resource. Numerous good systems show that the concept works well under these conditions. Unfortunately, the highest cooling demand is in warmer climates, where ground temperatures are higher naturally, and design for high shares of cooling is more of a challenge.
Targets	• Allow shallow geothermal cooling for regions and applications not suitable by now, increase regional range of applicability to all Europe. • Increase efficiency of cooling in warm climate by 25%
Type of activity	60% Development / 40% Demonstration

The development plan for the shallow geothermal heat pump system for residential buildings

GEO.2	Improving the understanding of the shallow geothermal reservoir
Objective	To improve the understanding of the shallow geothermal reservoir as an entity and as a process will require the identification and characterisation of the important parameters (thermal, hydrogeological, environmental as well as engineering). To investigate the scientific facts related to environmental impact of shallow geothermal systems to allow regulatory authorities to better develop and amend regulations.
State-of-the-art	Heat transport in the underground, both conductive and advective, has been studied in shallow geothermal R&D-projects since the 1980s. Suitable design methods and operation strategies are available today, but still not all of the processes are fully understood, and there remains the potential to optimise. In particular in the field of groundwater quality for open-loop systems insufficient progress has been made. In respect to environmental impact, long-term consequences in particular need more investigation.
Targets	Increase of efficiency by at least 25 % through better overall system design and operation. Avoidance of negative effects to ground and groundwater.
Type of activity	25% Research / 75% Development

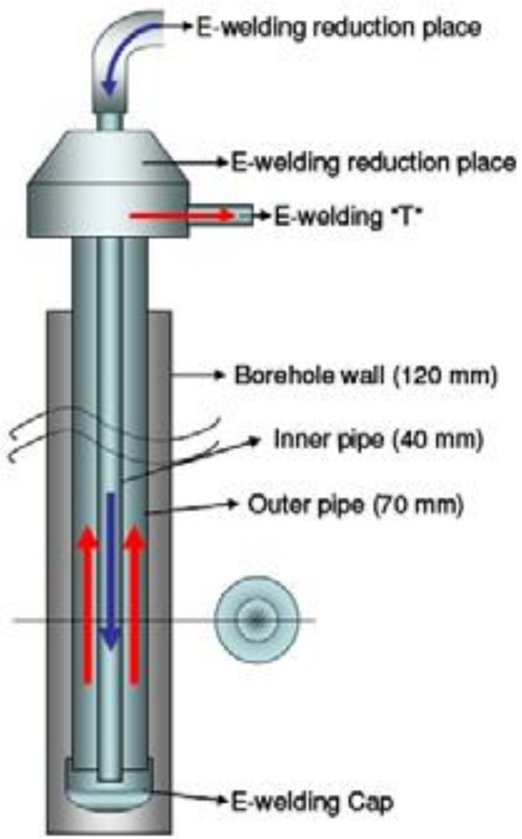
Applications and technologies for residential buildings: the Ground Coupling Technology

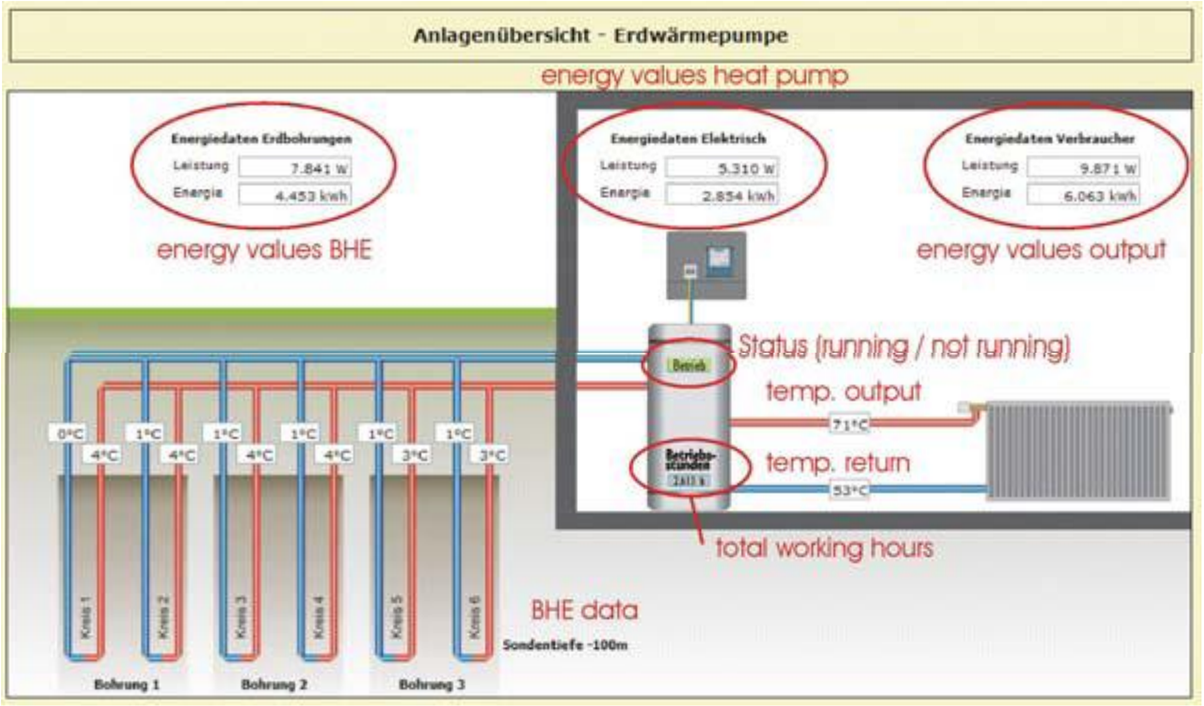
The ground-coupling technology is the borehole heat exchanger (BHE)

Features:

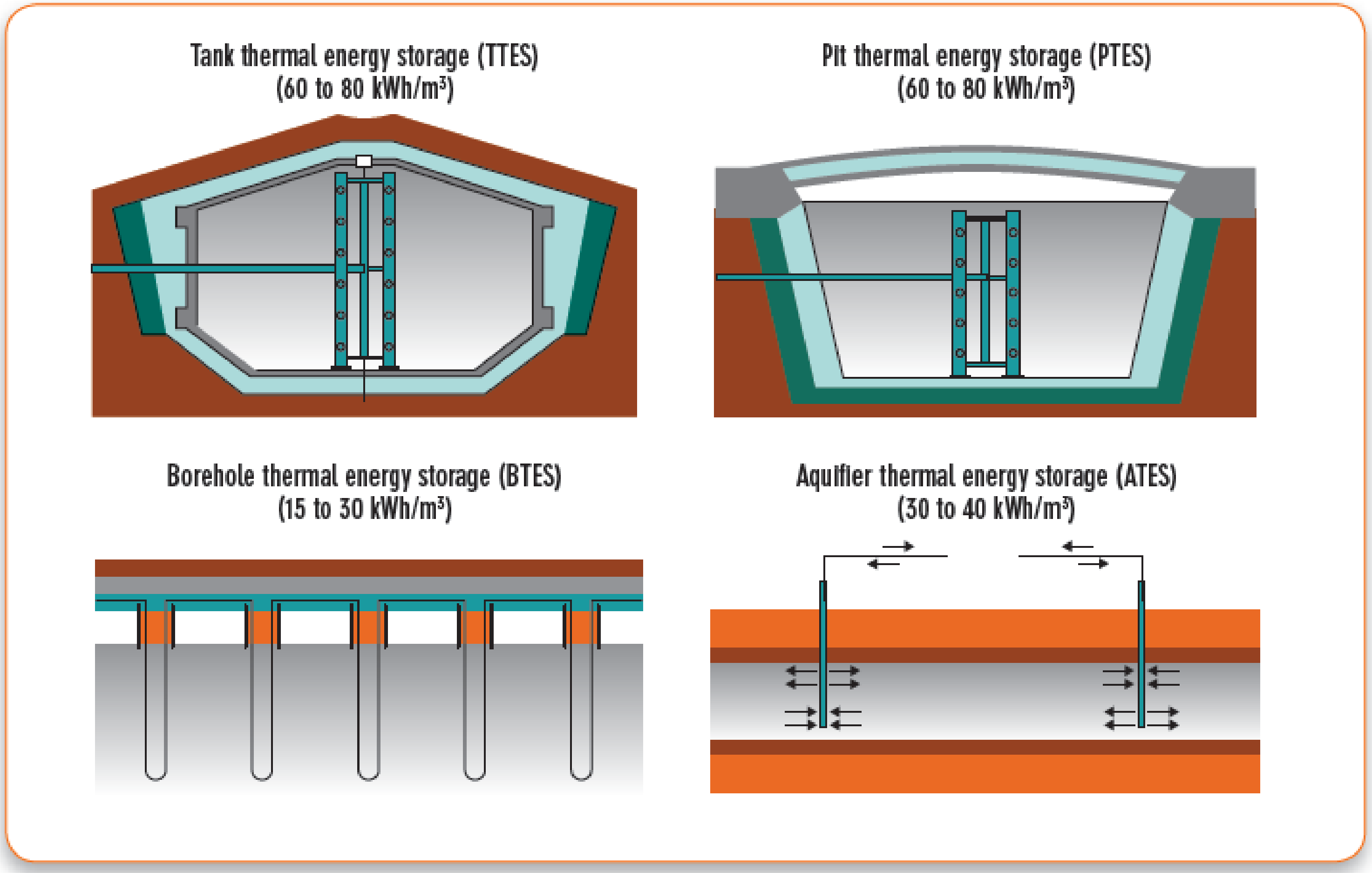
- a good efficiency of a BHE results in a small temperature loss between the ground and the fluid inside the BHE. This temperature loss is controlled by the borehole thermal resistance which could be reduced by more than 40 % over the next ten years.
- A study of the Swiss Heat Pump Association (Fördergemeinschaft Wärmepumpen Schweiz, FWS) calculated the cost for a BHE-system (drilling, heat exchanger, and heat pump) for a small house, and found a reduction of 27.5% over 12 years, from 1992 to 2004. In fact, the situation concerning the first cost is a bit more complicated. While the specific cost for BHE and connections decreased, an increase can be seen for the required BHE length.
- This solution is definitively more expensive

the Ground Coupling Technology BHE exchanger

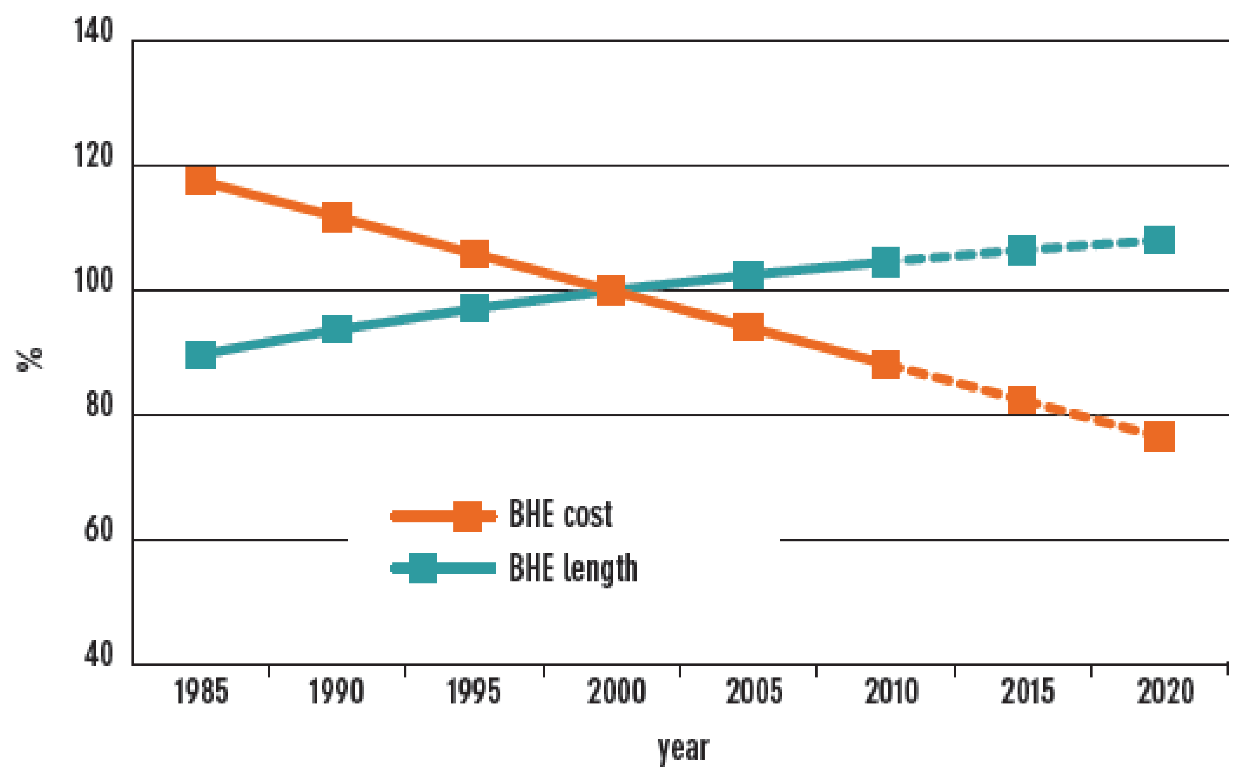




The Borehole Heat exchanger



Applications and technologies for residential buildings: the BHE technology cost trend



Development EU plan for the BHE technology for residential application

GEO.1	**Optimisation of ground-coupling technology** **(i.e. technology to exchange heat with the ground in an optimal way)**
Objective	For geothermal systems with borehole heat exchangers or groundwater wells, the drilling of the necessary boreholes is a major cost factor. Hence systems can be made much more economic by improved and innovative drilling methods, allowing for cost reduction. A lot can be expected also from further reducing manual work in drilling and installation, by automation and robotics. R&D in drilling technology is required to further reduce the impact on the surroundings (e.g. sensitive clays, groundwater), to provide techniques to control borehole deviation, etc. In particular in the residential sector, other types of geothermal heat exchangers like horizontal loops, compact screw-shaped heat exchangers, simple energy piles, etc. are in use as an alternative to drilling of boreholes. Also here, the reduction of cost, through optimized and mechanised installation methods, is an issue and needs further R&D-work. The efficiency of heat exchange with the geological strata can be increased by R&D for optimisation of components such as borehole heat exchangers (design, pipe material, and grouting material), well completion materials, compressors, and pumps.
State-of-the-art	For ground coupling, the cost varies between different technologies and different geological settings. A borehole heat exchanger today costs between 30 and 60 €/m, with the lower prices prevalent in Scandinavia and higher prices e.g. in Austria and Germany. Assuming a typical single family house, this results in some 350-700 € per kW installed capacity of the ground heat exchanger only (i.e. excluding the heat pump). The efficiency of ground coupling can be measured by a parameter called borehole thermal resistance; values for current up-to-date technology can be as low as about 0.07-0.08 K/(W•m). To compare these values and their impact on the whole system, the Hellström-efficiency is used; currently values in the order of 75 % can be achieved.
Targets	Reduction of average installation cost by at least 25 % in 2020, and 50 % in a longer term. Increase of heat exchange efficiency to 2020 by 25 % (expressed by reduced borehole thermal resistance or Hellström-efficiency), allowing for either higher efficiency or reduced cost.
Type of activity	100% Development

Potential improvements by 2020 in terms of costs and performance for residential application

Heat pumps	Space heating & hot water	Cooling
Installed cost	-10% to -15%	-3% to -8%
Coefficient of performance	15% to 25% improvement	10% to 20% improvement
Delivered energy cost	-10% to -15%	-5% to -10%

Characteristics of various thermal energy storage technologies for greenbuilding application

Technology	Capacity kWh/t	Power kW	Efficiency (%)	Storage time	Cost (EUR/kWh)	Reduction of installation cost by 2020
Hot water tank	20-80	1-10,000	50-90	day-year	0.08 – 0.10	-20%
Chilled water tank	10-20	1-2,000	70-90	hour-week	0.08 – 0.10	-20%
ATES low temp.	5-10	500-10,000	50-90	day-year	Varies	-15%
BTES low temp.	5-30	100-5,000	50-90	day-year	Varies	-15%
PCM-general	50-150	1-1,000	75-90	hour-week	10 - 50	-30%
Ice storage tank	100	100-1,000	80-90	hour-week	5 - 15	-20%
Thermochemical	120-150	1-100	75-100	Day-Year	8 - 40	-35%

Generic Heat Pumps development projects for greenbuilding application

CCT.1	Cost-competitive heat pump kit for houses with existing boiler
Objective	Development of heat pump kit to be integrated in the heating system of houses with existing non-electrical boiler. The expected solution should present the following characteristics: • High efficiency air to water heat pump producing heating water with a temperature lift of minimum 45K. • The supply temperature should be changeable between 50 and 35 °C depending on the ambient temperature. • The existing boiler will be kept and will only be employed as a back-up system under extreme ambient conditions when the heat pump is not able to attain 60°C or to increase the temperature of the sanitary hot water. • Compact design in a form of kit with all the necessary components for an easy integration and installation with the boiler heating system. • The control of the system must allow optimal management and automatic operation of the heat pump unit and boiler • With a capacity in the range 4-8 kW, the system should be able to provide the required heat most of the time.
State-of-the-art	Expensive hybrid systems have been developed in recent years, leading to efficient heating and sanitary water production. The proposed kit will not attain such an efficient operation but will help to save energy and reduce gas consumption at a competitive installation and system cost.
Targets	25% decrease in the cost of the heat pump, including installation. The sCOP of the heat pump operating under the described conditions should reach at least a value of 4.
Type of activity	100% Development

Geothermal solutions projects for long term targets in greenbuilding application

- The medium to long term priorities for thermal energy storage can be expressed along three thematic lines:

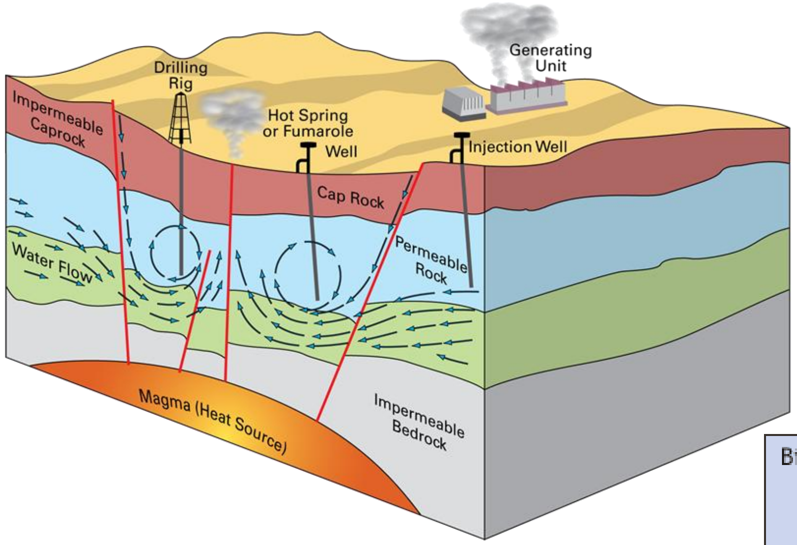
1. reliable and efficient system performance of thermal storage;
2. more efficient storage through improved heat transfer and heat transport;
3. increased storage density using phase change materials and thermo chemical materials.

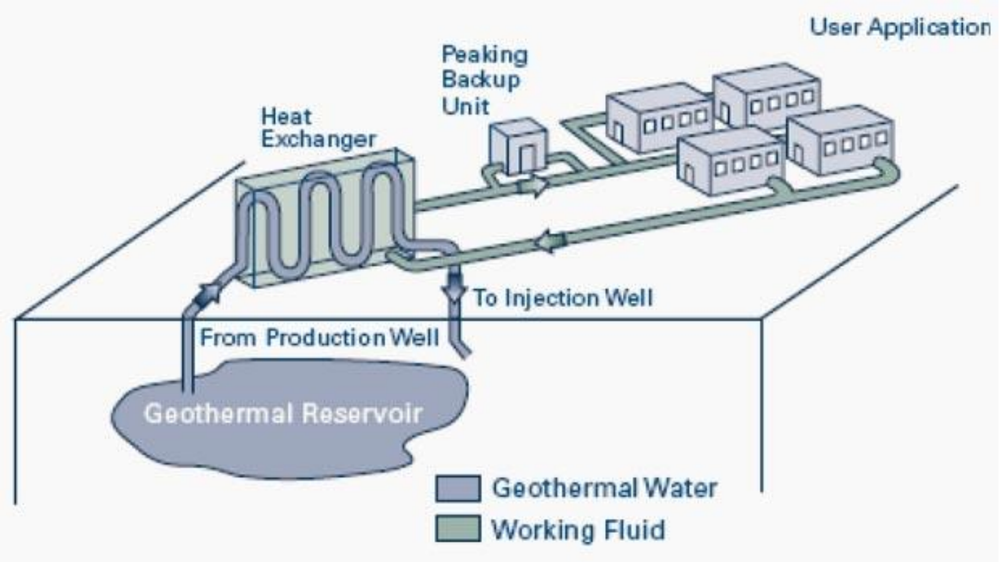
Where:

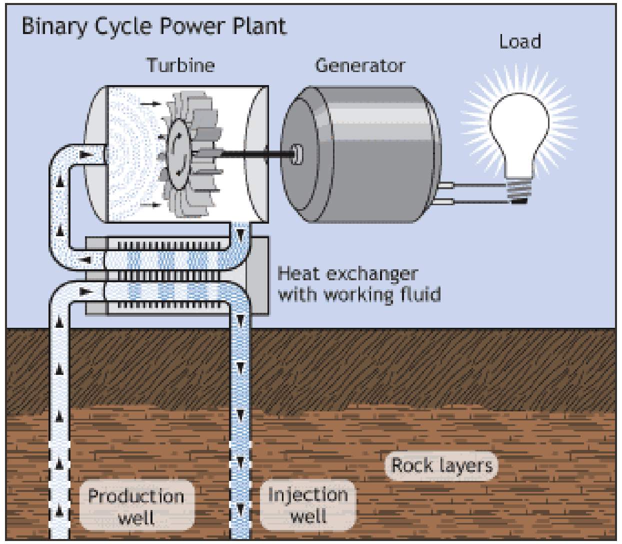
1. The first line incorporates the integration and optimization of storage in the heating and cooling system,
2. the second line aims at improving the main components in the storage auxiliary system and
3. the third line is dependent on materials development and improvement

Without forget that systems for the domestic sector must operate minimizing human intervention

Geothermal solutions for District heating and cooling in greenbuilding application







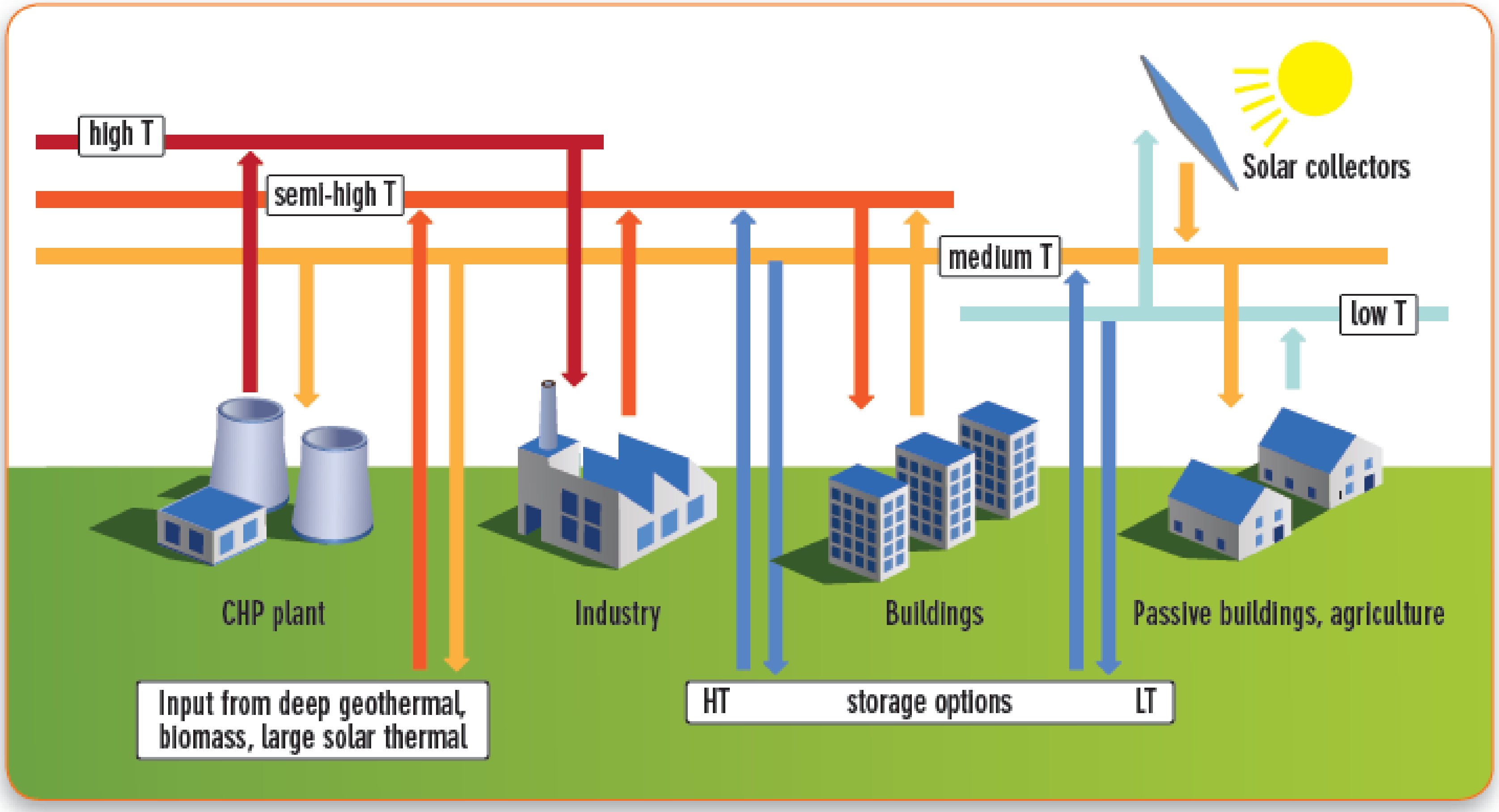
Geothermal solutions for District heating and cooling in greenbuilding application

Deep geothermal energy production is the technology application relevant to this sector, mainly based on direct heat supply by thermal water production and reinjection, but also using other technology like deep borehole heat exchangers (BHE) or heat from geothermal CHP plants. The capacity of such installations start from about 0.5 MWth (in particular deep BHE) and can achieve values in excess of 10 MWth. The heat is fed directly into a district heating system, if production temperature matches the required supply temperature, or it is used as a heat source for large heat pumps (including absorption heat pumps, engine-driven compression heat pumps, etc.). Moreover, cold production is possible through absorption chillers driven by geothermal heat. Further advancements in DHC technologies (including cascading67 and storage) will make it possible to use geothermal heat more efficiently. Geothermal technologies suitable for DHC networks can also be used for large individual buildings in the services sector

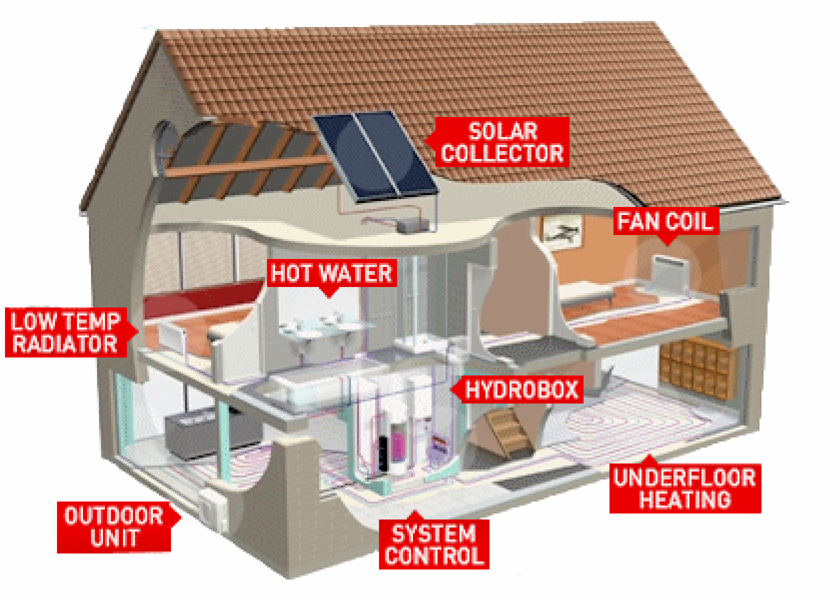
Geothermal solutions for District heating and cooling in greenbuilding application

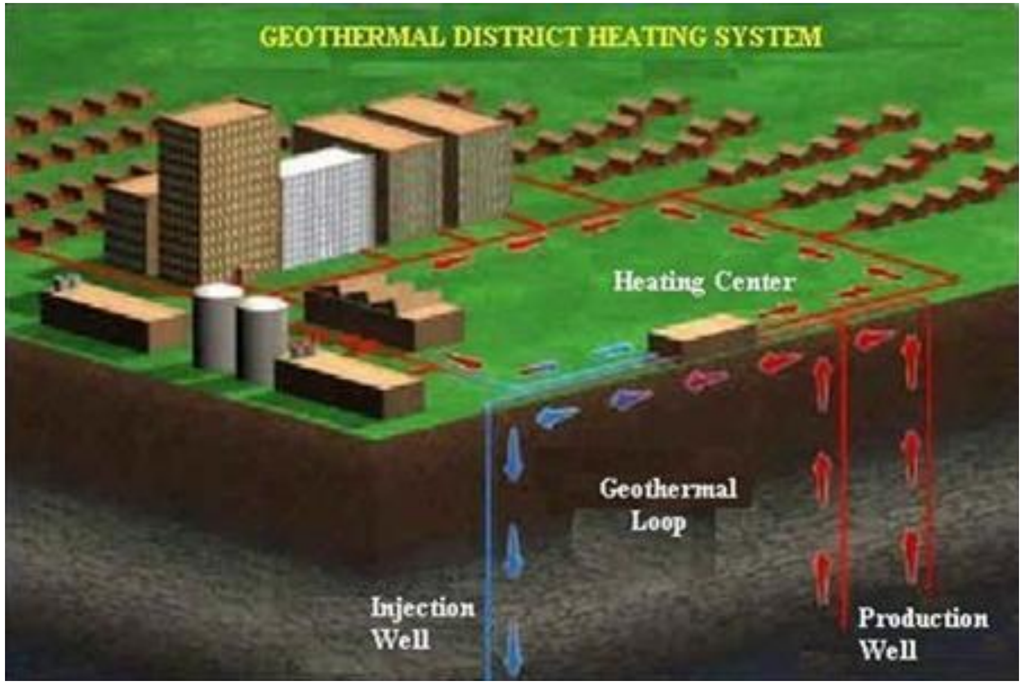
GEO.12	Surface systems for heat uses in DHC (incl.CHP)
Objective	Geothermal applications for DHC or large buildings require specific technologies to transform the geothermal energy into useful heat to be conveyed through a network or consumed in a building. There is scope for improvement in the technologies that exchange heat between the geothermal source and the heat transfer fluid in the network, both in terms of energy efficiency and resistance to corrosion (e.g. new materials or innovative design). Any further advancement in DHC technologies (including cascading and storage) can improve the efficiency and performance of geothermal district heating.
State of the art	Standard heat exchange and heat/cold distribution systems for conventional heat and cold sources are applied. The characteristics of geothermal heat (steady supply, mostly limited temperature, mineralised waters) determine system's design, however innovative solutions and components are needed.
Targets	Provide optimum heat transfer from the ground source to the distribution system so to increase heat exchange efficiency by 25% and component longevity in the thermal water circuit by 40%.
Type of activity	30% Development / 70% Demonstration

The ideal hibrid solutions for the SMART City heating and cooling



The ideal hibrid solutions for the SMART City heating and cooling





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