European
Geothermal
Energy
Council

GEOTHERMAL ELECTRICITY AND COMBINED HEAT & POWER

European
Geothermal
Energy
Council

Geothermal Electricity and Combined Heat & Power

Content **Page**

Introduction

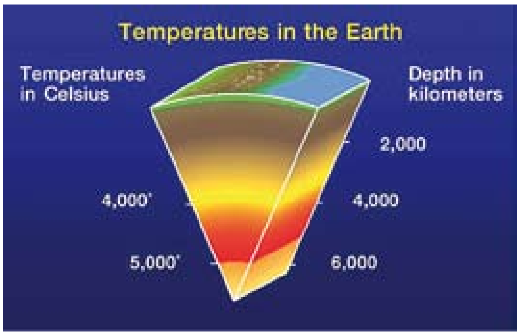
Geothermal manifestation

Geothermal energy is the heat from the Earth, or, more precisely, that part of the Earth's heat that can be recovered and exploited by man. Evidence of terrestrial heat is given by volcanoes, hot springs, and other thermal manifestations. Early mine excavations showed that the Earth's temperature was increasing with depth, under a gradient of 2-3°C/100m. The total heat flux from the Earth's interior amounts to ca 80 mW_{th}/m^2. It provides us with an abundant, non-polluting, almost infinite source of clean and renewable energy. The heat originates from the Earth core temperature (4,000°C at 6,000 km depth) and the radioactive decay of rocks, long life isotopes of Uranium, Thorium and Potassium.

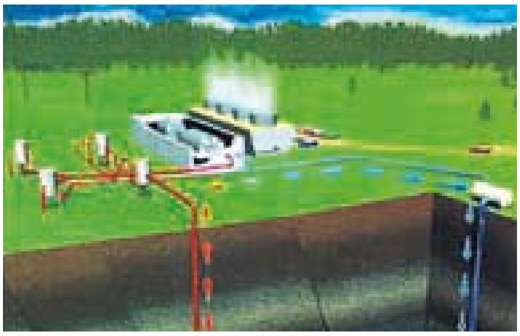
The total heat content of the Earth stands in the order of 12.6 x 10^{24} MJ, and that of the crust of 5.4 x 10^{21} MJ, indeed a huge figure when compared to the total world energy demand which amounts to ca $6 10^{13}$ MJ/yr i.e. a 100 million times lower. However, only a fraction of it can be utilised by man. Our utilisation of this energy has been limited to areas in which geological conditions allow a fluid (liquid water or steam) to "transfer" the heat from deep hot zones to, or near, the surface, thus giving rise to geothermal resources.

The heat outflows from the Earth's core, melting the rocks and forming the magma. Then, the magma rises toward the Earth's crust, carrying the heat from below through convective motions. It may flow as lava, smoothly or explosively, at the surface. In some areas it remains below the crust, heating the surrounding rocks and hosted waters. Some of this hot geothermal water migrates upwards, through faults and cracks, reaching the surface as hot springs or geysers, but most of it remains underground, trapped in cracks and porous rocks, forming the geothermal reservoirs. In such locations the geothermal heat flow can reach values ten times higher than normal.

Under standard conditions 30 to 50°C temperatures would be expected at 1 to 1.5 km depths; in geothermal areas enjoying higher than normal heat flows, temperatures are likely to reach 100 to 150°C at similar depths. In areas close to lithospheric plate margins, geothermal resources would display a wider temperature range, from 150°C to very high values, ultimately culminating at 400°C and supercritical fluid state.



Graph from Geothermal Education Office, California



Utilization of geothermal fluid

Geothermal Power Systems

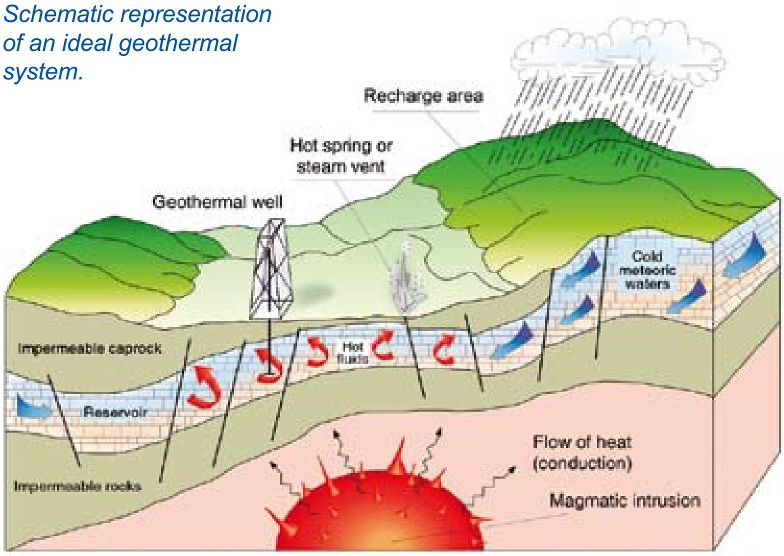
Schematically, a geothermal system may be described as convective water in the Upper Earth crust, transferring heat, in a confined state, from a heat source to a heat sink (usually a free surface). Hence, a geothermal system includes three components, a heat source, a reservoir and a heat carrier fluid.

The heat source can be either a magmatic intrusion at very high temperature at relatively shallow depths (5 to 10 km) or simply, in case of low temperature systems, hot rocks at depth.

The reservoir consists of hot permeable rocks from which circulating fluids extract heat. The reservoir is generally overlain by impervious cap rocks and connected to a superficial outcropping area subject to meteoric recharge, which replaces, at least in part, the fluids abstracted through spring or/and well discharge as depicted in the attached sketch.

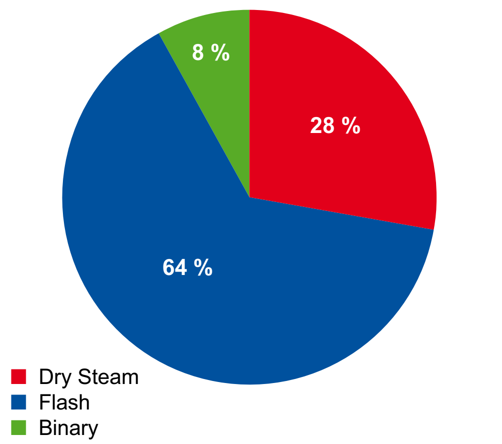
The geothermal fluid is water, most often of meteoric origin, in either liquid or vapour phase depending on its temperature and pressure. The geothermal water often contains dissolved chemicals and gases such as CO_2, H_2S, etc…

Hot water and steam are extracted by drilling wells into the reservoir thus enabling to exploit this clean and sustainable resource. In this respect,



Schematic representation of an ideal geothermal system.

World Geothermal Power plant distribution - 2009



a reliable expertise and engineering skills have been developed in order to achieve relevant reservoir assessments and drilling locations. Once available at production well heads, geothermal fluids can be used for electric power generation or non-electric (direct uses) heating purposes or both (combined heat and power).

Power plants need steam to generate electricity. The steam rotates a turbine that activates a generator (alternator), thus producing electricity. Conventional power plants burn fossil fuels to boil water. Geothermal power plants, instead, use steam produced from geothermal reservoirs, located at several hundred to a few thousand meters below ground. This steam production process does not require any artificial nor natural combustion whatsoever, i.e. it avoids man-induced CO_2 emissions. There are three types of geothermal power plants, dry steam, flash steam and binary cycle respectively.

Largest installed capacities correspond to flash plants (64%) (see plant distribution diagramme); binary units, despite their presently low ranking (8%), due to smaller plant ratings, raise fast growing interest as they address widespread, low to medium temperature, resource settings.

A total of ca 500 geothermal units were reported online in 2008. The maximum addresses about 250 binary plants, totalling a 800 MW_e installed capacity (i.e. a unit 3.3 MW_e plant load). The sizes of flash and dry steam plants average 31 MW_e and 44 MW_e respectively.

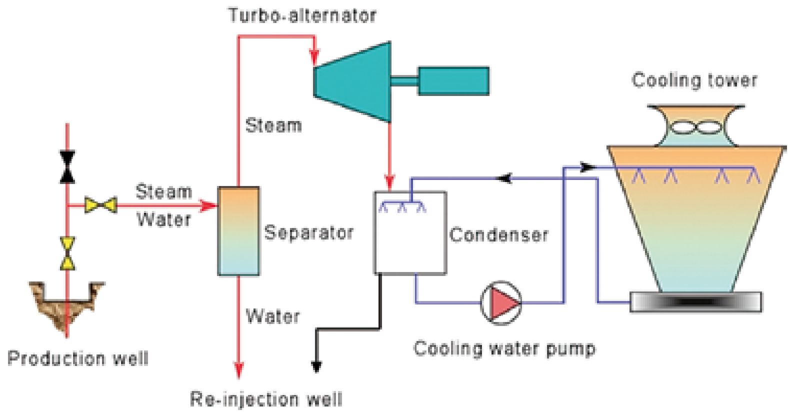
Dry steam and Flash power plants

Dry steam power plants utilise straightforwardly steam, which is piped from production wells to the plant, then directed towards turbine blades. The first, ever exploited, geothermal field, still in operation, at Larderello in Italy, is among the very few drysteam fields recorded worldwide.

Conventional drysteam turbines require fluids of at least 150°C and are available with either atmospheric (backpressure) or condensing exhausts. In the backpressure system steam is passed through the turbine and vented to atmosphere. This cycle consumes twice more steam per produced kilowatt-hour (kWh), at identical turbine inlet pressure, than a condensing cycle. However, backpressure turbines may prove rewarding as pilot or/and stand by plants in case of small supplies from remote isolated wells and for generating electricity in the early stages of field development. They become mandatory in case of high non condensable gas contents, in excess of 12% in weight, in the vapour phase.

Condensing units are more complex in design, requiring more ancillary equipment and space and up to twice long construction/installation delays. Turbine specific steam consumption varies from 8 to 10 t/h depending on temperature and pressure. 55 to 60 MW_e plant installed capacities are quite common but, recently, 110 MW_e plants have been commissioned and are currently operating.

Flash steam plants, by far the most common, address water dominated reservoirs and temperatures above 180°C. The hot pressurised water flows up the well until its pressure decreases to the stage it vaporises, leading to a two phase water-steam mixture and a vapour lift process.



Flash steam power plants

The steam, separated from the water, is piped to the plant to drive a turbo-alternator. The separated left over brine, together with the condensed steam, is piped back into the source reservoir, an injection process meeting waste disposal, heat recovery, pressure maintenance and, last but not least, resource sustainability requirements.

Berlin 44 MW flash power plant - El Salvador.

Larderello standard unit of 20 MW dry steam power plant - Italy

Binary cycle power plants

Binary, known also as organic Rankine cycle (ORC), plants operate usually with waters in the 100 to 180°C temperature range. In these plants, the heat is recovered from the geothermal fluid, via a heat exchanger, to vaporize a low boiling point organic fluid and drive an organic vapour turbine. The heat depleted geothermal brine is pumped back into the source reservoir, thus securing sustainable resource exploitation. Since the geothermal and working fluids are kept separated during the process there are little if any, atmospheric emissions. Adequate working fluid selection may allow to extend the former design temperature range from 180°C to 75°C.

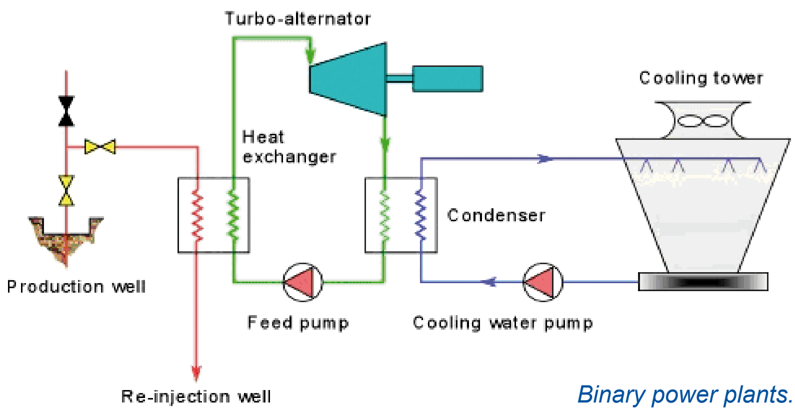
Upper and lower temperature limits depend on the organic fluid stability and techno-economic considerations respectively. At low temperatures the size required by the heat exchangers could defeat project economic viability. Apart from low to medium temperature utilisation, geothermal and waste fluid binary processes can be contemplated to avoid well scaling damage further to in-hole flashing, in which case submersible pumps are used to produce the geothermal fluid under pressure.

Binary processes are emerging as a cost effective conversion technology for recovering power from, water dominated, geothermal fields at temperatures below 180°C. Recently, a new candidate binary process, known as the Kalina cycle, has been developed, displaying attractive conversion efficiencies. It's distinctive features address an ammonia-water working fluid mixture and regenerative heating. In brief, it takes advantage of the low boiling point of the water-ammonia mixture to allow a significant fraction of it to be vaporised by the excess heat available at turbine exhaust. The gains over conventional ORC plant efficiencies have been estimated at 40%, although its reliability and performances are yet to be demonstrated on long term plant service.

10 MW_e Ribeira Grande binary unit - Azores islands.

Reclamation of low temperature geothermal sources, achievable via binary cycles, can significantly increase the overall worldwide exploitation potential. Small scale geothermal binary plants (< 5 MW_e ratings) can be widely implemented in rural areas and, more generally, respond to an increasingly disseminated human demand.

Binary systems represent a means for upgrading overall plant efficiencies of "conventional" flash cycles. Contrary to dry steam plants, where the water phase reduces to steam condensates, flash units produce large amounts of separated water and waste heat, which remains lost unless otherwise utilised as heat proper (space heating/ process heat for instance) or as binary power downstream from the flash steam turbine. This power cascading scheme produces low cost energy extras at zero mining costs.



Binary power plants.

Enhanced Geothermal Systems (EGS)

At places where no natural geothermal resources in form of steam or hot water exist, the heat of the rock can be used by creating artificial permeability for fluids extracting that heat. Known as "Hot Dry Rock" technology (HDR), this method is under development since the 1970s. Meanwhile the crucial break-throughs have been made.

Because in most of the current projects of that type the ground is not "dry" in the strict sense, and the aim is more on opening pre-exisiting fractures and fissures for permeability, than to create completely new ones, the technology today is called Enhanced Geothermal Systems (EGS), and comprises everything from a stimulation of already existing sites with insufficient permeability, to the classical HDR idea.

In June 2008, the commissioning and official inauguration of the first EGS power plant at Soultz-sous-Forêts, in the upper Rhine Graben of Northern Alsace, concluded thirty years of EU R&D actions dedicated to heat and power extraction from low permeability/near impervious, deep seated (5 km), basement rocks. The system is currently operating with two production wells, equipped with submersible pump sets, and one injection well, achieving all together a 35 l/s circulation rate and an installed capacity of 1,5 $MW_{el.}$

EGS power plant - Soultz-sous-forêts (France).

North of Soultz, in the upper Rhine Graben, a commercial project completed in a higher grade EGS environment, applying the rock stimulation techniques implemented at Soulz, is now on line. The operating CHP plant exhibits net power and heat outputs amounting to 3 MW_{el} and 6 MW_{th} respectively.

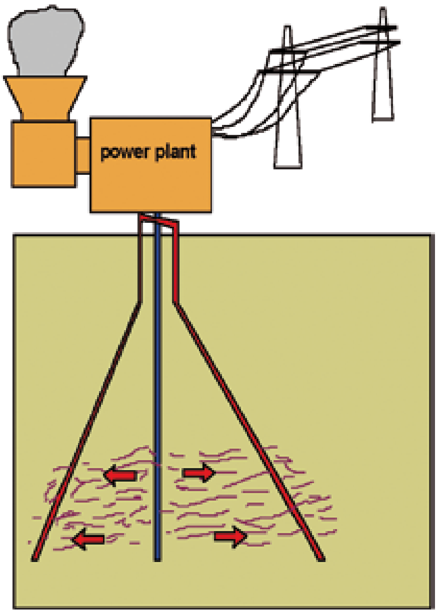
Since the validity of the concept has been demonstrated, EGS plant ratings should move from 3-10 MW_{el} in the early development stages of the technology towards 25 to 50 MW_e units produced from multiwell (five to ten) clusters as currently practiced in the oil and gas industry.

Principle of EGS system for geothermal power production

EGS concept will allow geothermal power production everywhere.

Hence, the EGS concept, schematised in the attached sketch, aims at dramatically increasing the geopower potential normally expected from conventional "natural" hydrothermal settings. Such an ambitions goal implies that the following prerequisites be fulfilled

- identify and exploit the natural fracture networks hosted in basement rocks ;
- boost their conductivity/connectivity via massive stimulation techniques to favour the creation of large fractured rock volumes and related heat exchange areas;
- complete a heat extraction system based on a multi-production/injection- well array ;
- circulate large amounts of water via pumping/ lifting/buoyancy into this "man made geothermal reservoir" to maximise heat and power production ;
- achieve adequate heat recovery and system life to secure system sustainability



Enhanced Geothermal System.

EGS power plant - Soultz-sous-forêts (France).

Most of the resource base addresses the heat stored in deep seated, conductive/radiogenic dominated, tight sediments and hard crystalline basement rocks. The essence of EGS technology is the engineering of man made geothermal reservoirs by stimulating these low permeability/low connectivity rock environments to recover a fraction of this vast dormant energy. It may therefore be regarded as the ultimate challenge of the geothermal community, bearing in mind that the recovery of say 1 % of the heat stored within the 5 to 10 km depth over continental Europe, i.e. 1023 J (100,000 EJ) could over European primary energy demand for centuries ahead.

Recent EGS designs have replaced the former HDR (hot dry rock) concept of heat mining, which aimed initially at connecting two wells, via a set of hydrofracked parallel (sub)vertical fractures, by stimulating instead (pre)existing natural fractures and have them connected to production and injection wells.

Major efforts to develop the EGS technology should pay off as they would result in the creation of a substantial source of base-load electricity production, available over wide spread land areas, irrespective of daylight/weather constraints and most hydrothermal attributes inherent to competing renewable energy sources and “conventional” geothermal reservoirs respectively.

Clearly, the core of the technology requires to master the build-up of a geothermal reservoir designed as a huge underground heat exchanger. The foregoing could be pioneered at Soultz in a a priori hostile low grade, dominantly conductive, EGS environment and developed commercially soon after at the Landau site which benefited from a more favourable permeability pattern, further enhanced thanks to the methodology previously developed in Soultz.

As a result, future actions should focus on reliable strategies, replicable on a variety of geological settings thus minimizing the failure risk. This requires the following nucleus of expertise and know how to be acquired :

- geomechanical assessments of the in-situ stress field and fracture trends ;
- well drilling and completion design ;
- overall (hydraulic, chemical, thermal) rock stimulation procedures and prediction/mitigation of microseismic induced events.

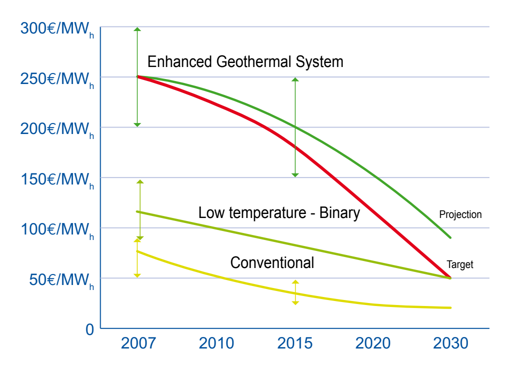
Ultimately, the technology needs to be disseminated among most EU Member states and address a wide range of geological structures in order to demonstrate its replicability and sustainability. It goes without saying that cost reduction, conversion cycle efficiency and plant reliability should reflect the maturation of the technology.

A critical step deals with the cost incurred by drilling and completing deep/ultra deep wells, which represent over two thirds of total system expenditure and makes EGS a highly capital intensive energy process, unless mining costs be significantly reduced. Novel innovative drilling technologies should therefore be given a high priority in relevant, far sighted, R&D actions.

Cost trends

Current EGS power generation costs stand within the 0.20-0.30 € /kWhe range.
Impacts of technology innovation, learning curve practice and Combined Heat and Power (CHP) optimisation among others, should bring down cost figures below 0.10 € /kWh by year 2030.

Costs EGS



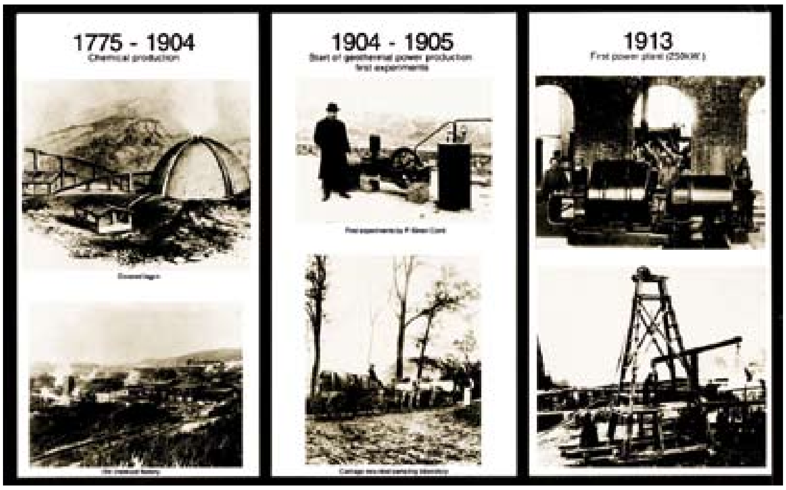
First experiment to produce geothermal power, done in Italy in 1904 by prince Ginori Conti

Geothermal electricity history

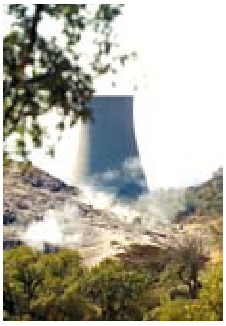
In the early 1900's, geothermal fluids were already exploited for their energy content. A chemical industry was set up in Italy during that period, in the area known now as Larderello, to extract boric acid from natural hot water outlets or from purposely drilled shallow boreholes. From years 1910 to 1940 the low pressure steam, in that area of Central Tuscany, was utilised to heat industrial and residential buildings and greenhouses. In 1928, Iceland, another pioneer in the utilisation of geothermal energy, began exploiting its abundant geothermal resources (mainly hot waters) for domestic heating.

The first attempt to generate electricity from geothermal steam dates back to 1904 at Larderello. The success of this experiment (see illustration) proved the industrial value of geothermal energy and marked the beginning of an exploitation route that was developed significantly since then. Actually, electricity generation at Larderello was a commercial success. By 1942 the installed geothermoelectric capacity had reached 128 MWe.

This application, exemplified by Italy, was followed by several countries. In Japan, the first geothermal wells were drilled in 1919 and, in 1929, at The Geysers, California, in the USA. In 1958, a small geothermal power plant started operating in New Zealand, in 1959 in Mexico, in 1960 in the USA, and in many other countries the following years.



Geothermal Book - Italy.



Panorama Larderello - Today

Geothermal electricity in Europe

As far as conventional geothermal electricity is concerned, the vast majority of eligible resources, in Continental Europe at large, is concentrated in Italy, Iceland and Turkey; the presently exploited potential represents so far 0.3% of the whole renewable energy market.

There are two major geothermal areas in Italy, Larderello-Travale/Radicondoli and Monte Amiata respectively, achieving a 810 MW_e installed capacity.
They represent two neighbouring parts of the same deep seated field, spreading over a huge, ca 400 km^2, area, which produces superheated steam. On the Larderello side, the exploited area and installed capacity amount to 250 km^2 and 562 MW_e respectively. On the Travale/Radicondoli side, to the Southeast, the installed capacity is 160 MW_e and the exploited area 50 km^2. The steam condensates recovered from Travale are reinjected into the core of the Larderello field, via a 20 km long water pipeline.

The Monte Amiata area, in Northern Latium, includes two water dominated geothermal fields, Piancastagnaio and Bagnore. On both fields a deep resource has been identified under the shallow producing horizons. Weak social acceptance from the local communities are slowing down the full development of the promising, high potential, deep reservoir. Presently, five units are operating, one in Bagnore and four in Piancastagnaio, totalling a 88 MWe installed capacity. Projects, adding a further 100 MW_e capacity, have been commissioned and will be completed in the near future.

Krafla, Iceland

Iceland

Geothermal resources in Iceland relate to the active volcanic environment of the island, located on the mid-Atlantic ridge and its sea floor spreading attributes. Iceland has proved a leading country in direct uses of geothermal energy, mainly in greenhouse and district heating (89% of the total domestic heating demand) and is increasing its electricity production, which reached (@2008) a 420 MW_e installed capacity. Although significant, this capacity ought to be compared to the huge potential of the island, estimated at ca 4000 MW_e, a figure far above national power requirements, ca 1500 MW_e, among which hydropower holds the dominant share (1300 MW_e).

Turkey's geothermal resources are mainly located in Western Anatolia on the Aegean sea façade. District heating stands presently as the most important utilisation with 65000 heated homes. This, in spite of mild climatic conditions which still makes geothermal heat competitive as a result of the high cost of electric heating, 8 to 10 times higher than geothermal heat. Electricity production in the Kizildere water dominated field is supplied by a 15 MW_e design plant (start up, 1988) capacity, actually standing at 12 MW_e. Binary plants have been commissioned. The largest geopower (flashed steam) plant, rated 45 MW_e, is presently in advanced construction stage at Germencek. The national geothermal electricity potential has been (conservatively) estimated at 200-300 MW_e.

In Greece, high temperature geothermal resources are located in the Aegean volcanic island arc, in the Milos (Cyclades) and Nisyros (Dodecanese) islands, thanks to direct drilling and testing assessments. Electricity generation from a 2 MW_e rated pilot plant ceased further to the strong opposition of the local community and mismanaged communication by the geothermal operator. The country potential in the Aegean archipelagos and, at a lesser extent through, in the northern, mainland located, grabens is estimated at ca 200 MW_e. Otherwise, several low temperature fields are exploited, on presently limited bases, for greenhouse heating and process heat applications.

In Russia, geoelectric development took place in the Mutuovski field of Kamchatka which, although belonging politically to Europe, ought to be regarded as geographically Asian. Here, exploration which started in the mid 1980's, identified an important potential (ca 200-300 MW_e) from a superheated, shallow seated, geothermal system. Following an early 12 MW_e pilot plant phase, a 50 MW_e rated unit was commissioned and operated online. Whenever restricted to the sole Kamchatka peninsula and its geological extension to the southern Kuril islands, the projected Russian installed capacity of geothermal electricity is limited to 80 MW_e. Otherwise, direct uses, amounting to 327 MW_e, are widely developed in space heating and agricultural applications.


Larderello, Italy


Larderello, Italy

A similar situation exists in the small fields of the Guadeloupe and Azores volcanic islands, which are politically European but geographically and geologically American. At Bouillante (Guadeloupe, France), a small, 4.7 MW_e rated, plant was built in 1984, meeting 2% of the island electricity demand. Its capacity has recently been increased to 15 MW_e. In the Sao Miguel island (Azores, Portugal), 43% of the electrical production is supplied, from a high temperature (230°C @ 1200 m) saline brine, by three flashed steam plants (23 MW_e total installed capacity) online since 1980. An additional 12 MW_e capacity is scheduled in the near future.

Recently, binary power has been produced in Austria and Germany from low temperature geothermal sources. The conversion process ; which consists of vaporising a low boiling point working fluid ,either a hydrocarbon -Organic Rankine Cycle (ORC)- or an ammonia/water mixture- Kalina cycle-raises considerable interest as it makes it possible to produce electricity from cooler geothermal sources (typically within the 100-120°C temperature range, exceptionally down to 70-75°C depending upon the availability of a cold water source). However, no high plant ratings can be expected for obvious thermodynamic reasons. Hence, improvements should concentrate on cycle and plant efficiencies along side cogeneration production. As a result, two development routes are contemplated

(i) small plant designs targeted at 1MW_e/2MW_{th} CHP capacities, close actually to those implemented already in the EU [(0.5 - 3 MW_e) / (1-6M_{th})], and
(ii) a microgeneration standard for small scale ORC modules.

To the question of how could geothermal energy expand its power market penetration share, the EGS (Enhanced Geothermal Systems) issue is the answer. The rationale behind the concept is the following: whereas drilling technology is in the mature stage and efforts dedicated clearly to reducing its costs, stimulation technologies of geothermal rock environments are still in the pilot stage. There exists many geothermal prospects enjoying high temperatures but lacking sufficient rock permeability to allow fluid circulation. Such tight rock, poorly conductive, systems could be turned into technically and commercially exploitable reservoirs, provided their permeability be enhanced by engineering adequate stimulation procedures, such as hydraulic fracturing and acidising. Development of these technologies will make it possible to access a huge geothermal potential.

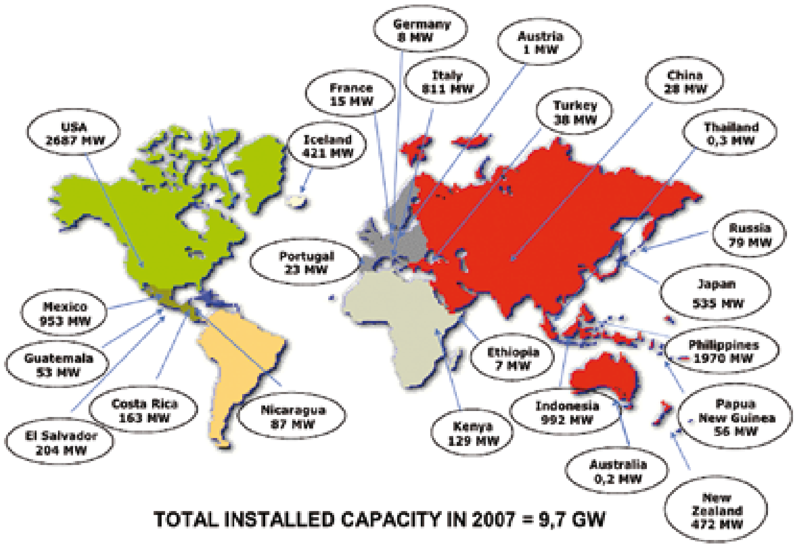
Among the ongoing EGS projects worldwide, the Soultz European test site is in the most advanced stage, providing already an invaluable data base. A critical aspect of the EGS technology addresses the seismic hazards induced by the hydraulic fracturing process. Without the EGS contribution, the geoelectricity target expected in 2010 stands at 1800 MW_e.

The average growth rate of installed capacities is slowly decreasing, from 4.8% during the 1990-2000 decade to 3.7% and 3.3% for 2000-2010 and 2010-2020 respectively, without accounting for any EGS contribution. Only can a relevant supporting policy achieve the development of new, deeper or/and costly, geothermal resources. Another barrier to further exploitation relates to the resource to demand adequacy: for instance, in areas of high geoelectric potential, such as Iceland and Far East Russia, there is enough offer and supply. On the other hand, a great increase in direct uses is projected, from 16,000 MW_{th} in year 2010 to 39,000 MW_{th} in 2020. It is presently difficult to assess the impact of support policies to be adopted by EU member states in order to meet the Kyoto protocol commitments. It is even more difficult to appraise the impact of new frontier technologies as well as the contribution of EGS issues in the European geothermal scenario.

Geothermal sources, eligible to electricity production, are fairly limited and not equally shared throughout Europe, whereas direct uses prospects shape much more favourably. However, to date, only a small part of the whole geothermal potential has been explored and exploited. Prospects, in this respect, are very promising and opportunities for extracting heat in non-hydrothermal, artificially fractured, systems, via a closed loop circulation can be quite significant in a long run, far sighted, perspective. Summing up, geothermal electricity development in Europe stands at 1500 to 2000 MW_e in year 2010, while for 2020 it can be estimated to match the 4000 to 6000 MW_e target.


Unterhaching, Germany


Soultz, France



TOTAL INSTALLED CAPACITY IN 2007 = 9,7 GW

Geothermal electricity worldwide

The growth of developing countries will result in a two fold increase of the global electricity demand over the next 25 years, from 15,000 TW_h in 2005 to 30,000 TW_h in 2030. The present renewable energy quota is 21.5% (mainly hydro), while the projected share will be 25.8% in 2030.
Geothermal Energy provides approximately 0.4% of the world global power generation, with a stable long term growth rate of 5%. At present, the largest markets are in the USA, Philippines, Mexico, Indonesia, Italy and Iceland. Future developments are limited to areas worldwide, particularly under current technologies. The present installed capacity of 9 GW will increase up to 11 GW in 2010. It displays investment costs, depending on the quality of the resource (temperature, fluid chemistry and thermodynamics phase, well deliverability,..), ranging approximately from 2 to 4.5 €/MW, and very attractive generation costs, from 40 to 100 €/MW_h. It is a resource suitable for base load power.

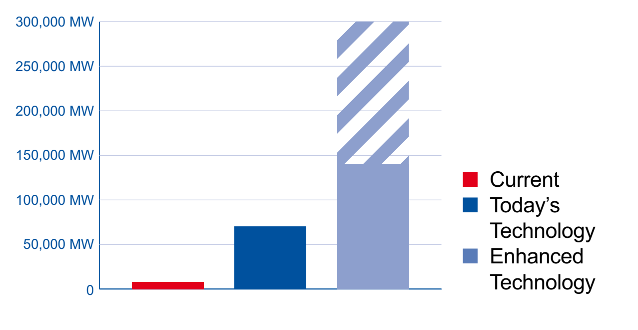
It can be considered as broadly cost-competitive, despite relatively high capital investment costs for the development of the geothermal field (resource assesment, mining risk, drilling and piping), owing to its very high availability and stable energy production. The next generation should be able to benefit from the implementation of the Enhanced Geothermal System (EGS) production, alongside an intensive increase of low-to-medium temperature applications through binary cycles and cascading uses.

Geothermal electricity potential - 2050

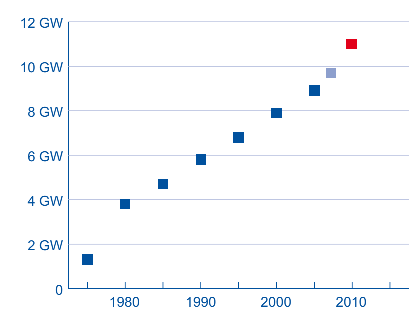
Estimating the overall worldwide potential is a delicate exercise due to the many uncertainties involved. Nevertheless, it is possible to try an estimation, taking into consideration the economically exploitable zones, making an intense development in the low-medium temperature range, which is the most abundant geothermal resource. The expected value of 70 GW is a realistic target for year 2050.
Moreover, including new technologies (permeability enhancements, EGS, Supercritical fluids and magmatic resources..), it is possible to have an additional contribution for minimum doubling the total world electrical geothermal production by 2050, with 40 countries (mostly in Africa, Central/South America and the Pacific) that can be wholly geothermal powered.

Geothermal Energy is already widely used in the world, for power production, and it could provide electricity anywhere: at places where no natural geothermal resources in form of steam or hot water exist, the heat of the rock will be used by creating artificial permeability for fluids extracting that heat (EGS)..

World Geothermal potential - 2050



Installed Capacity Wordlwide



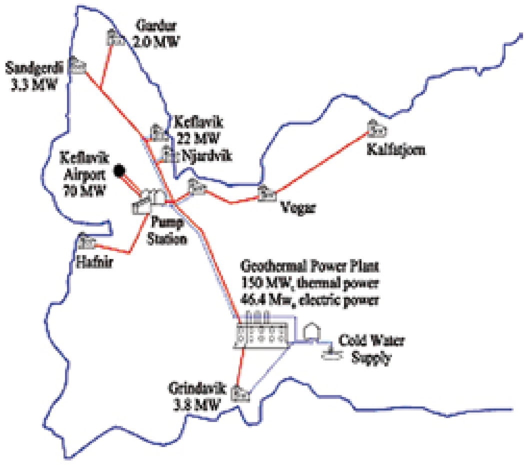
Installed capacity from 1975 up to end of 2007 (light blue) and to 2010 (red).

Aerial view
Power Plant
Svartsengi

Combined Heat & Power

Geothermal CHP is nothing new. As a matter of fact, a low temperature (81 °C) geothermal resource has been exploited, since the late 1960's, at Paratunka, Kamchatka, Russia, combining power generation (680 kW_e installed capacity) and direct uses of the (huge) waste heat for soil and greenhouse heating purposes. Such a temperature cascading use is what geothermal CHP is all about. Actually, heat may be regarded as a by product of geothermal power production in terms of either waste heat released by the generating units or excess heat from the geothermal source. The latter opportunity has been exploited by the Sudurness Geothermal District Heating Corporation in Iceland.

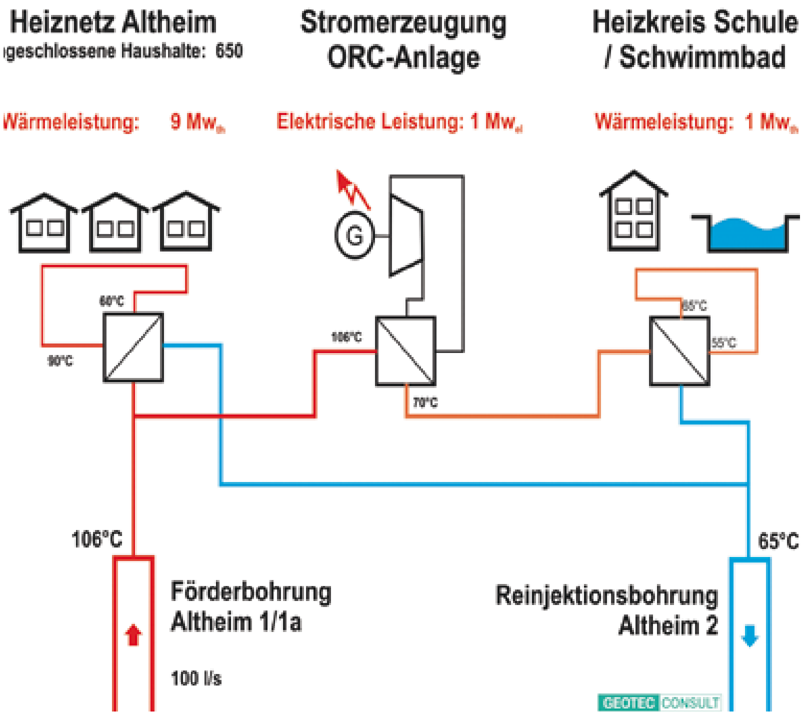
Here, steam from the nearby high enthalpy, liquid dominated, field heats, up to 95-105°C, cold ground water, which is piped to nine surrounding cities and the Kevlafik International Airport. This cogeneration scheme, unique of its kind, secures 45 MW_e and 150 MW_{th} power and heat capacities respectively, indeed a true geothermal paradise, combining, equally shared, power generation and heating issues.



Sudurnes Regional Heating System Layout

Power generation from medium enthalpy sources, standing in the 100-150°C temperature range, by using a low boiling point working fluid and an organic vapour turbine, a conversion process known as the Organic Rankine Cycle (ORC), can hardly seek economic viability, unless a heating segment be added to the utilisation grid.

Altheim CHP. System schematic



Heat plants

Power plants

Altheim CHP - Wellhead and pump station

Therefore, reclamation of these resources implies a structural synergy, illustrated so far in three geothermal CHP cogeneration plants operated in Austria (Altheim, Bad Blumau) and Germany (Neustadt-Glewe) and a fourth underway (Unterhaching, Germany). Several other CHP plants are presently under completion in Germany at Isar (Munich), Speyer and Landau.

Ideally, one could contemplate the integrated power, heating and (absorption) cooling design displayed in the attached cascading scheme.

The existing technology is currently trending towards increased efficiencies in order to optimize the power segment of CHP plants. In the past, geothermal CHP addressed high enthalpy resource settings, which in Europe are located in Italy, Greece, French DOM/TOM (overseas departments and territories such as Guadeloupe, West Indies), Spain (Canary Islands) and Portugal (Azores archipelago) (EU member states), Iceland and Turkey.

ORC set up at well Blumau 2

Actually, implementation of low temperature geothermal CHP binary plants can be contemplated in candidate areas exhibiting the required, medium enthalpy, temperature patterns. Such areas are encountered in the following regions:

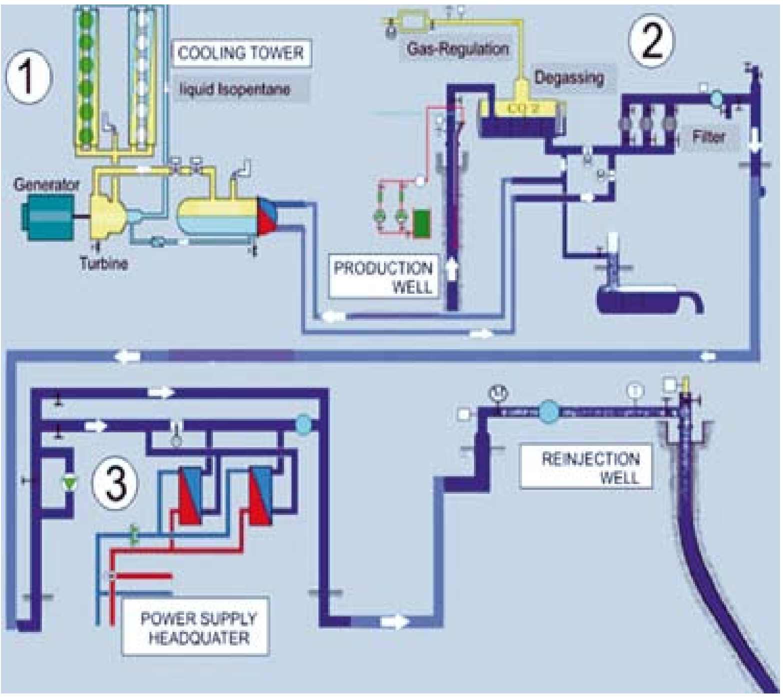
- the Alpine Molasse basins (north and south of the Alps),
- the Pannonian basin of Hungary and border areas of Slovakia, Slovenia, Serbia and Romania,
- to a lesser extent though, in areas stretching from the Paris basin (including Southern England) throughout Benelux, Northern Germany, Denmark and the southern most parts of Sweden ending into Poland and Lithuania.

Graben systems, indeed a distinctive geodynamic attribute, offer attractive CHP issues. Such is the case of:

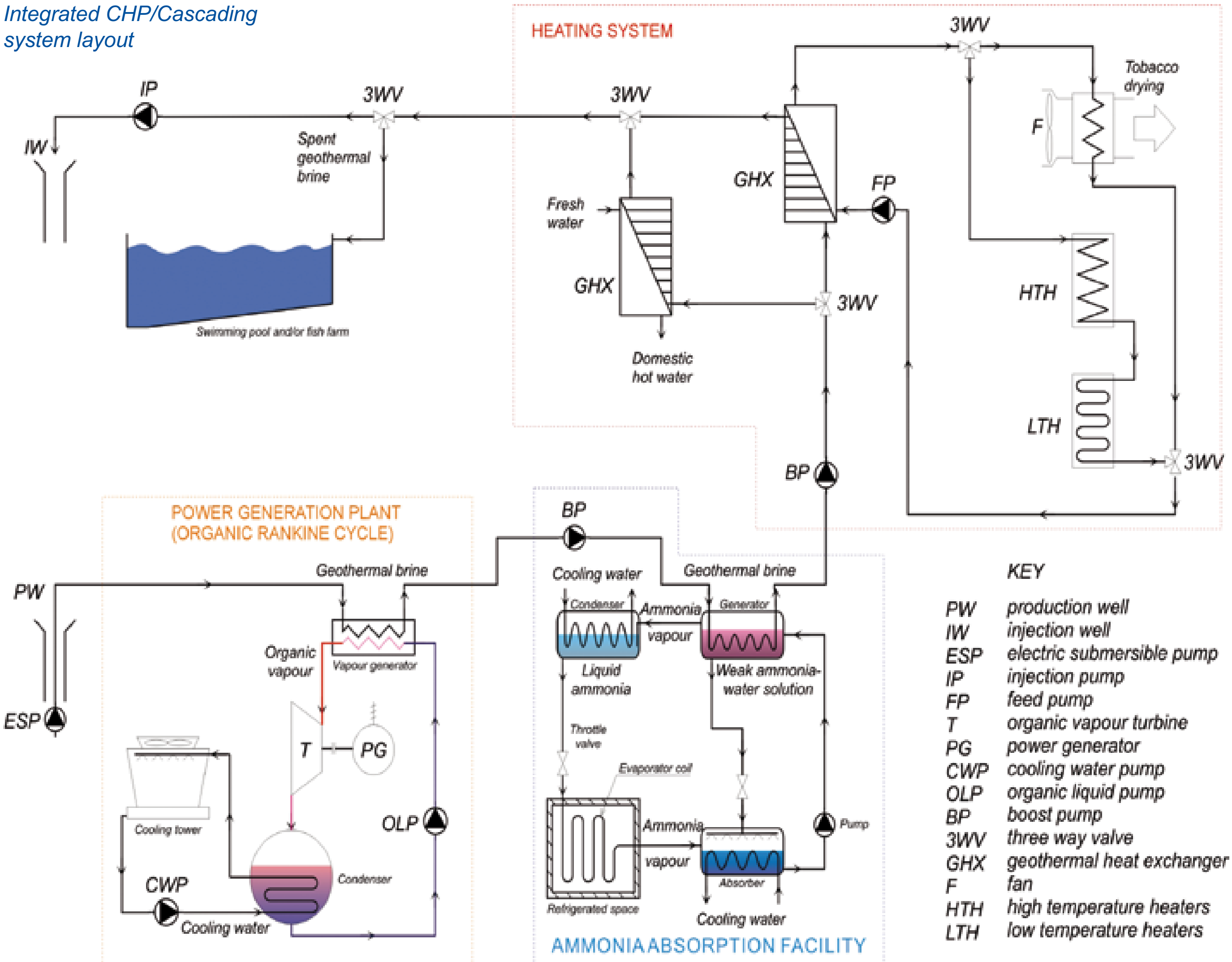
- the Upper Rhine Graben, targeted by several commissioned German CHP projects,
- the Rhone and Limagne graben structures in France,
- several, smaller but promising, settings identified in the Balkans (Serbia, Macedonia, Bulgaria, Northern Greece).

Last but not least, the geothermal CHP spectrum could be significantly widened thanks to a successful achievement of the leading EGS project carried out at Soultz-sous-Forêts, France. It could enable, presently "silent", areas of central, Southern and Western Europe to access the CHP route.
So, everything considered, geothermal CHP has a good chance.

Blumau CHP



Integrated CHP/Cascading system layout



What can we do with geothermal energy

Over the last decades a growing concern on environmental issues has been spreading around the world's people, and, contemporaneously, the demand of energy was shooting up too. It is also evident that energy sources are not equally distributed among the countries and quite often developing nations cannot afford buying fossil fuels abroad to supply their industries and to warm their dwellings. It is clear that an indigenous and easily exploitable energy source is needed in many countries around the world to give a boost to local activities and support a self-sustaining economic growth.

Geothermal energy can then represent a viable, local and environmental friendly solution for many such countries. In fact, geothermal energy is almost ubiquitously available and could be used to spare fossil fuels in dealing with different processes. Moreover, no burning is involved and no manmade emissions will affect the area (any geothermal area is already characterised by gas emissions which escape naturally from the ground, but no combustion is involved and the clouds over geothermal plants are made of steam). Also, there is no radioactive waste.

In a few words, geothermal is a clean, reliable and baseload energy (available year round and round the clock), that save money at home (no fuel to be imported from abroad), and can create jobs in local communities. In addition, it helps the implementation of the international and EU objectives to fight climate change.

EGEC

European Geothermal Energy Council

CREATING MARKETS FOR RES

Supported by

SIXTH FRAMEWORK PROGRAMME

Contact:

EGEC - European Geothermal Energy Council a.s.b.l.
Renewable energy House

63-65 rue d'Arlon
B-1040 Brussels
T : + 322 400 10 24
F : + 322 400 10 39
W : www.egec.org
E : com@egec.org

Photo and graphical elements credits : EGEC, Geotec Consult, Geothermal Education Office - California, ENEL, IGA, ORMAT, Enex, GRC, Orkustofnun, Geoheat Center (OIT), City of Altheim, GTN, Geofluid, G.E.I.E. Exploitation Minière de la Chaleur.

Published in December 2007 - Update 2009.
Text: Ruggero Bertani, Philippe Dumas and Pierre Ungemach
Design: ACG Brussels - Printed on ecologically friendly paper (chlorine-free paper)