EDF
Technology unveiled
R&D OCTOBER 2013
innovation.edf.com

Strokkur geyser, Iceland

The Earth: a considerable source of energy

The use of geothermal ground heat dates back thousands of years. Today, it is mainly used to heat and cool buildings, either directly through district heating systems or indirectly through heat pumps, in the case of very low temperature resources (under 30°C). It can also be used for certain industrial processes. There are various types of geothermal energy (very low, low, medium and high temperature) which are categorised in accordance with the purpose for which the energy is used (heat, electricity, cogeneration). In this issue of *Technology unveiled*, we focus on cogeneration, which is generally known as deep geothermal energy. Only very high temperature resources are used to produce electricity. Sites on which the geological conditions guarantee access to temperatures of between 180°C and 350°C are used for commercial purposes. Geothermal energy offers the advantage of being a non-intermittent source of energy (base or semi-base load) and, in the case of very low temperature geothermal energy, it is available (almost) everywhere.

Deep geothermal energy

MAKING USE OF GROUND HEAT TO PRODUCE ENERGY

Today, the world's installed geothermal capacity stands at over 11 GWe and is mainly concentrated in a few geographic areas (US, Indonesia, Philippines, Mexico, Italy, New Zealand and Iceland). The scattered nature of the world's installed geothermal capacity reflects that of the resources, which are closely connected to the geological environment. Electricity from a geothermal source currently represents a small percentage of the world's electricity needs (less than 0.5%). However, the emergence of new technology should significantly increase the contribution of geothermal energy to the energy mix. In France, geothermal energy makes up a tiny share of electricity production, despite a significant technical potential estimated to stand between 6,000 and 9,000 MW. Today, in France, the prospects for electricity generated from a geothermal source mainly concern two target areas: the Rhine Rift Valley and the West Indies.

Experimental power plant in Soultz-sous-Forêts

Projects in Alsace

The EDF Group's deep geothermal energy business is run by ÉS Géothermie, a subsidiary of the Electricité de Strasbourg Group (ÉS), which has developed and operated geothermal power plants in the Rhine Rift Valley for over 20 years. ÉS Géothermie has to acquire all of the know-how that is necessary to exploit the potential of fault troughs.

Dr Elodie Jeandel, project manager at the European Institute for Energy Research (EIFER).

GEOTHERMAL ENERGY OPERATING PRINCIPLE

Electricity from the depths

GEOTHERMAL SCIENCE LOOKS FOR HOT WATER IN THE DEPTHS OF THE EARTH TO CONVERT ITS HEAT INTO ELECTRICAL ENERGY

Geothermal energy is a renewable energy source that takes advantage of the thermal machine that is our planet. Surface events that release a considerable amount of energy (volcanic eruptions, earthquakes, geysers, etc.) are a demonstration of this thermal activity. The Earth's total internal energy is enormous: 2.1018 terajoules, which corresponds to the amount of primary energy consumed by the world over three billion years. Global heat loss, estimated at 46 TW following heat flux measurements on the Earth's surface, is proof of such energy. The Earth's energy budget consists of internal heat flux (in the Earth's mantle and core) within the Earth, the planet's cooling and the production of heat due to the natural decay of radioactive elements contained in the Earth's mantle and continental crust. The dissipation of thermal energy is mainly attributable to convection currents in the liquid mantle and conduction in the lithosphere. Plate tectonics are the external manifestation of these heat transfers, which govern the geological structure of the Earth. Most of the Earth's heat is released at divergent plate boundaries (oceanic ridges and continental rifts). Other types of boundary, where lithospheric plates dive into the mantle (subduction), feature active volcanoes and significant heat fluxes. The distribution of the world's geothermal resources is therefore closely connected to the heat flux map. This map explains the great geographic disparity of high-potential countries, whether they are producers or not. The geothermal gradient (the rate at which rock temperature rises as the depth below the surface increases) depends on how heat is transferred in the Earth (conduction or convection). The average geothermal gradient is 3.3°C every 100 metres and varies in accordance with the geological conditions (20°C every 100 metres in Réunion, 10°C every 100 metres in Alsace, 2°C every 100 metres at the foot of the Pyrenees). The exploitation of these resources depends on three parameters: temperature, flux and the presence of a natural coolant (water or brine). In a volcanic environment, the presence of magmatic heat sources gives rise to high temperatures at shallow depths, which allows power plants that can produce several tens of MW to be envisaged. In an environment that is not volcanic but comprises a thermal anomaly (Alsace, Rhone Valley, Aquitaine), electricity production would only be possible with innovative hydraulic stimulation techniques.

Rittershoffen power plant

The challenge is to increase the natural permeability of these environments by increasing circulation in existing fractures and to connect the borehole to the natural geothermal reservoir.

KEY POINTS

Initial uses

- **20,000 years ago**
  Used as thermal baths and for heating and cooking by ancient civilizations.
- **XIV century**
  - Chaudes Aigues hot spring waters (82°C).
  - Exploitation of warm brackish water in Volterra (Italy) for the extraction of sulphur, sulphuric acid and alum.

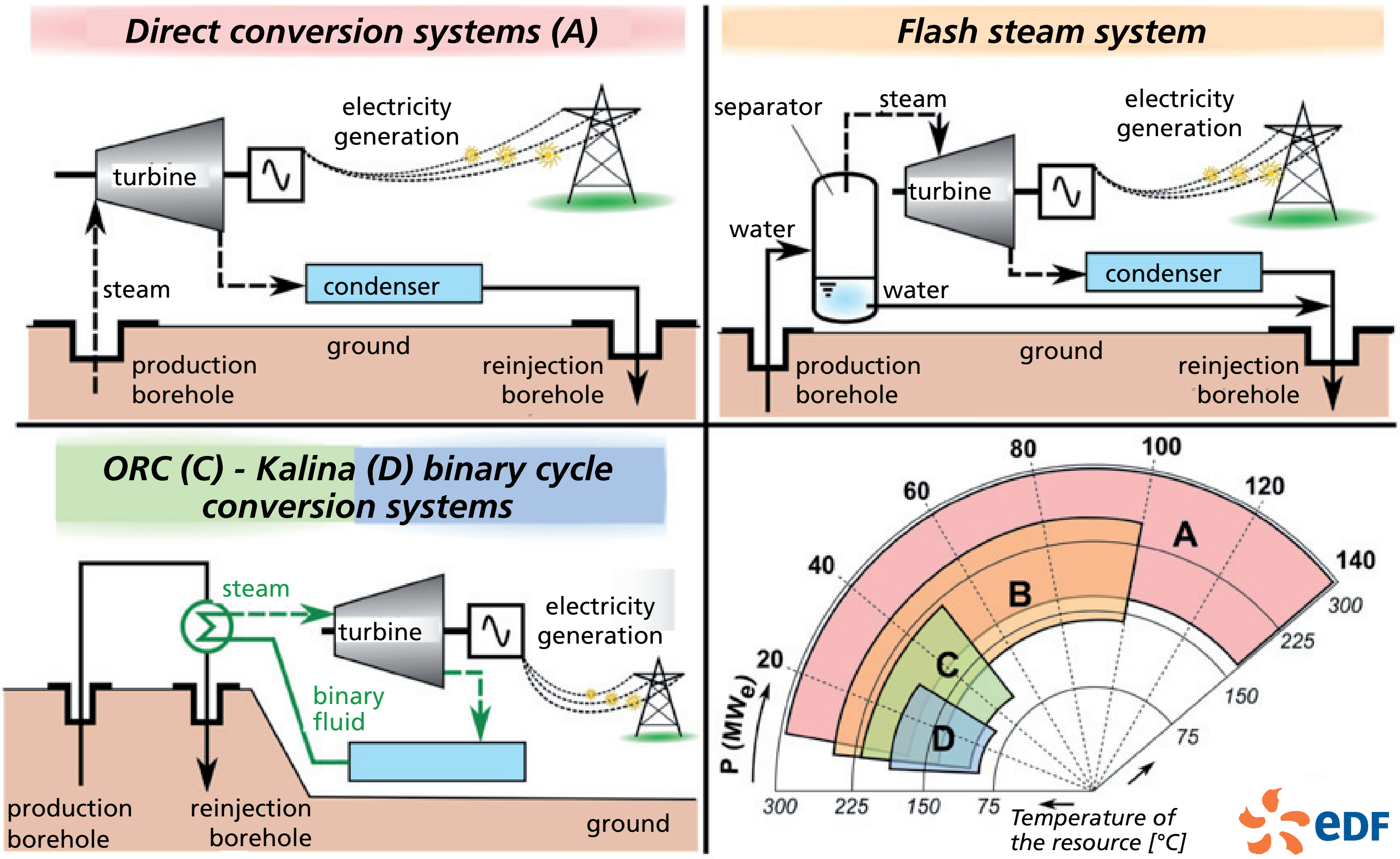
Initial industrial uses in the XIX century

- Development of the 'covered lagoni' technique (capture of steam to extract it under pressure to feed evaporation boilers and to pump boric water) by F. Lardarel in Volterra.
- First industrial use of geothermal energy in Iceland: salt extraction.
- First borehole in France to capture fresh water from the Albian aquifer.

Developments in the XX and XXI centuries

- **1904:** First experimental power plant in Larderello (20 kWe).
- **1930:** First modern district heating network (Reykjavik).
- **1960:** 400 MWe of installed capacity (worldwide).
- **2000:** 8 GWe
- **2013:** 11.4 GWe

The energy conversion systems used depending on the resource's temperature



DID YOU KNOW?

The output of geothermal power plants is lower than that of fossil fuel or nuclear power plants as the temperature of the steam is lower. Output can be improved and the temperature of the resource (water or steam) can be increased by drilling deeper and by moving closer to magma chambers, where the temperature can reach 600°C and pressure exceeds 220 bar. This is known as supercritical geothermal energy. A research project is currently taking place in Iceland in order to further our understanding of this solution.

Depending on the temperature and pressure of the geothermal fluid, three techniques allow heat to be turned into electricity.

Direct conversion systems can be used if the geothermal fluid is steam; in this case, it goes directly to a turbine.

Flash steam systems exploit a geothermal fluid which is pressurised or takes the form of a liquid/steam mixture. This is the most common surface-based cycle.

Binary conversion systems are used when the temperature (or the chemical composition) of the geothermal resource does not allow it to be used directly. This technique splits the system into two: the geothermal fluid and a working fluid circulate in two separate closed loops. Heat is transferred between the two fluids by a heat exchanger. Two types of working fluid are used: organic fluids (ORC cycles) or a water-ammonia mixture (Kalina cycle). The chemical composition of the geothermal fluid and its potentially corrosive nature impose specific constraints on the thermodynamic cycles used. To avoid the discharge of components that are naturally present in the ground into the atmosphere or surface water, the geothermal fluid and the noncondensable gases present have to be re-injected into the reservoir after use (closed cycle). Attention also has to be paid to noise, odour and visual nuisances. In the case of some geothermal power plants, efforts are made to integrate the plant into the landscape and to optimise the infrastructure. Management of microseismicity caused by the stimulation of geothermal reservoirs in Enhanced Geothermal Systems (EGS) demands rigorous control over injection pressure values as well as seismic monitoring of the power plant. When the geothermal reservoir's target rock is naturally radioactive, the installations' radioactivity has to be monitored and radiation protection measures have to be put in place.

Outlook

According to experts, the potential of geothermal energy is interesting but currently under-exploited. In several countries, geothermal electricity is a competitive source of power as it is the only source of renewable energy that meets baseload demand. Around 40 countries are producers and a few global leaders (US, Iceland and New Zealand) export their know-how abroad. The market is growing, primarily in emerging markets and, to a lesser extent, in the US and Europe. It could double in size within the next ten years. Projects remain risky as they represent a significant financial investment and the amortization and development periods are long. It is therefore vital to control risks by lowering costs and producing a competitive source of electricity. Several projects still depend on public funding as private operators are concerned about their profitability. Raising feed-in tariffs is an important lever that can contribute to their profitability. The potential of a resource can only be confirmed (or ruled out) after the boring phase, which is very costly. A standard exploration protocol cannot be applied universally, although general recommendations may be made. Few operators control the whole value chain (exploration, boring, reservoir management, engineering, exploitation, maintenance, environmental management). In the case of France, geothermal electricity is currently limited to two facilities: Bouillante (Guadeloupe) and Soultz-sous-Forêts (Alsace), which account for a total installed capacity of 17.2 MWe. There is currently renewed interest in the deep geothermal energy market, shown through requests for and the issuing of several exploration permits. This second wind has given rise to a strong desire to structure a French offer that specialises in goods and services. Such a dynamic should result in operations in fault troughs and an active overseas prospecting and construction policy.

> for more information

The ADEME and BRGM website http://www.geothermie-perspectives.fr/

Association Française des Professionnels de la Géothermie http://www.afpg.asso.fr/

Site de Soultz-sous-Forêts http://www.geothermie-soultz.fr/

European geothermal energy association http://www.egec.org/

International geothermal energy association http://www.geothermal-energy.org/

Lexicon

Conduction: the transfer of heat through the vibration of the material (not the movement of the material). In a conductive environment, the temperature varies almost linearly with depth.

Convection: the transfer of heat due to the macroscopic movement of material, caused by buoyancy and induced by density variations in the fluid. In a convective environment, the temperature is homogeneous and hardly varies with depth.

Fault trough:

a rigid earthly envelope that stretches from the surface to a depth of a few hundred kilometres. It comprises 12 main plates whose edges move on a tectonic level by up to several centimetres a year.

Permeability: a physical property which represents the capacity of a material to allow a fluid to pass through it (porous or fractured environment).

Stimulation: an operation that involves injecting a water-based pressurised fluid into rock to increase the environment's permeability.

Plate tectonics: a theory that states that the Earth's large deformations are linked to the existence of rigid plates that are influenced by movements on the mantle. It defines three kinds of plate tectonic boundaries: divergent (ridges and rifts), convergent (subduction, collision) and transform (transform faults)

EDF
22-30 avenue de Wagram 75382 Paris Cedex 08
FRANCE

French limited company with a capital of 930,004,234 euros - 552 081 317 R.C.S. Paris 7

www.edf.fr

EDF R&D publication - 1 av Général de Gaulle 92141 Clamart Cedex
Clamart Cedex Publishing Director: **Stéphane Andrieux**
Editorial secretary: **Florence Metge-Laymajoux**
The author, and not EDF, is solely responsible for the content of this publication.

Photo credits: Wilfrid Krauel, EDF / Groupe ES / GEIE, EDF / Groupe ES / ECOGI.

The EDF Group is ISO 14001 certified

Contact:
communication-rd@edf.fr
http://innovation.edf.com