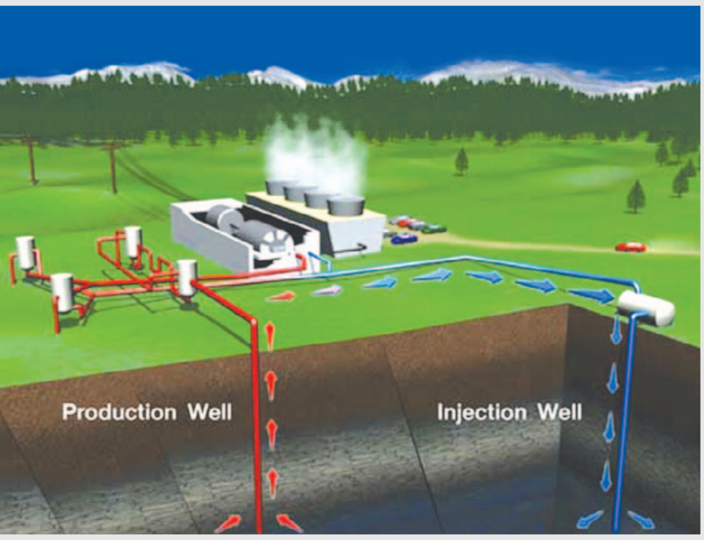
Harnessing energy from the heart of the earth

A project of the Regional Cooperative Agreement for Research, Development and Training in Nuclear Science and Technology in Asia and the Pacific (RCA)

In the search for increased sustainable energy and energy security, countries in Asia and the Pacific are turning their attention to a source of power beneath the Earth's surface: geothermal reservoirs. These are reservoirs of extremely hot water found underground in the pores and fractures of rock. Due to the presence of magma chambers or to friction between tectonic plates in the Earth's crust, the rock itself reaches a very high temperature, and it is this that heats the water. Drilling into these reservoirs releases the water and steam which can be used to drive turbines and generate electricity. Already geothermal power in the region generates about 3,500 megawatts of electricity, but studies indicate the potential for this natural resource to supply much more-and it is a clean, cost-effective, indigenous and renewable form of energy with far fewer harmful emissions than fossil fuels. The RCA has established a project to arm Member States with the latest nuclear techniques for subsurface hydrological exploration to assist in the selection of suitable sites for the development of geothermal power stations and the management of geothermal reservoirs.



A schematic showing running of turbine for power generation by geothermal steam from a production well and pumping down the condensed water in an injection well to sustain production.

To determine if a reservoir is suitable for exploitation and, if so, how it can be exploited sustainably and with minimal environmental impact, it is critical to have accurate information about its subterranean workings and its hydrological and geological surroundings: the nature of the heat source; the temperature of the reservoir; the sources of the reservoir's water supply and how quickly it gets replenished; the properties of geothermal fluids (water and gas), the processes shaping them, and the paths they travel. This information is critical for economic as well as environmental reasons. Capital investment costs for drilling are high, so it is important to site wells where there are strong chances of success. It is also important to be able to predict how the reservoir's behaviour will be affected-such as through changes in pressure, temperature and fluid flow-when it's connected to a fully-operational power plant.

Tapping energy from geothermal reservoirs requires great care and precision. Extracting water and steammay drain the reservoir faster than nature can replenish it. It may also reduce the pressure inside the reservoir; therefore generally the used geothermal water / steam condensate is pumped down an injection well to sustain production. Environmental isotopes and artificial radiotracers help manage the reservoir by providing information on the movement of injected fluid and on reservoir characteristics. Re-injection of the thermal fluids into the geothermal reservoir also solves the problem of disposing of potentially hazardous substances such as boron which may be present in the geothermal water and steam.

Injection of tritium tracer (370 GBq activity) at Kamojang, Indonesia for investigation of residence time and recovery of injected water

The best way to obtain all this information is through a combination of chemical and nuclear technologies. The RCA project has helped Member States acquire and develop the expertise to use these technologies. With financial and technical support from the International Atomic Energy Agency, the RCA has organised expert missions, workshops and training courses to build local capabilities to conduct sophisticated site investigations, analyse water samples for determination of environmental isotopes and chemical quality, apply isotope techniques (with the aid of both natural isotopes and artificial radiotracers), develop computer-simulated hydrological models of reservoir systems, conduct inter-laboratory comparison exercises, and devise reservoir management strategies.

Hot springs in Mae Hong Son area, Thailand, Hot springs in Mae Hong Son area, Thailand

Over the course of the RCA project, participating countries have carried out isotope investigations on 33 new geothermal prospects (about 130 springs). As a result, the Philippines National Oil Company has now commissioned an additional 49 MWe geothermal power, and has completed the exploration work for the development of 160-300 MWe. Indonesia has committed to increasing its current geothermal capacity of 807 MWe to 2500 MWe by the year 2015. India has developed a pilot geothermal power plant at the Tattapani geothermal field in Saurguja District, Madhya; and Pakistan is proceeding with a thorough exploration of the Murtazabad area, which has shown great promise as a source of geothermal power.

The RCA's work has made an important technical contribution to the expansion of geothermal energy resources in Asia and the Pacific. Its activities have also brought the application of advanced isotope techniques to the attention of the region's energy sector. The techniques are now becoming recognised as essential tools in geothermal exploration, development and reservoir management, and the number of organisations adopting this nuclear know-how continues to grow.

Production wells at Kamojang Geothermal Field , Indonesia

Radioisotope techniques in combination with geochemical and geophysical techniques are very effective at the exploration stage in evaluating a reservoir's properties, fluid characteristics and energy potential, and at the production stage in identifying a reservoir's response to drilling and extraction.

The isotope techniques themselves provide an accurate, and sometimes unique, method for determining the origin of geothermal fluids as well as for tracing water movement. Environmental isotopes like O-18, H-2, H-3, C-13, C-14, S-34, Sr-87, B-11, He-3/H-4. and artificial radioactive tracers such as I-131, I-125, H-3. used in combination with geochemical and geophysical techniques, are very effective in evaluating the energy potential of the prospect, characteristics of the fluids, subsurface processes, reservoir temperatures and properties of the reservoir at exploration stage and in identifying the response of the reservoir to exploitation at production stage.

Origin of fluids and subsurface processes. Stable isotopes indicate the source where fluids have originated (meteoric/connate /magmatic) and altitude of recharge in case of meteoric origin and subsurface processes like rock-water interaction, mixing of shallow groundwater, etc. The naturally occurring radioactive isotope of hydrogen(H-3, tritium) can indicate the presence of cold, young, meteoric water in the geothermal system.

Age/ residence time. The naturally occuring radioactive isotope of hydrogen (H-3, tritium) and carbon (C-14) indicate the age/circulation time of geothermal water.

Temperature. Fractionation factor of stable isotopes in different species in equilibrium depends on temperature therefore isotope geothermometers like O-18(H_2O-SO_4), C-13(CH_4-CO2), H-2(H_2O-H_2) provide estimates of reservoir temperature.

Flow. Artificially produced radioactive tracers such as I-131, I-125, H-3. provide information on the movement of injected fluid, especially breakthrough time, residence time distribution and reservoir characteristics.

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For Research, Development and Training
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