Workshop 4,
Drilling cost effectiveness and feasibility of high-temperature
Reykjavík, 2-5 July 2007, Iceland

ICELAND DEEP DRILLING PROJECT

Deep drilling

Status July 2007

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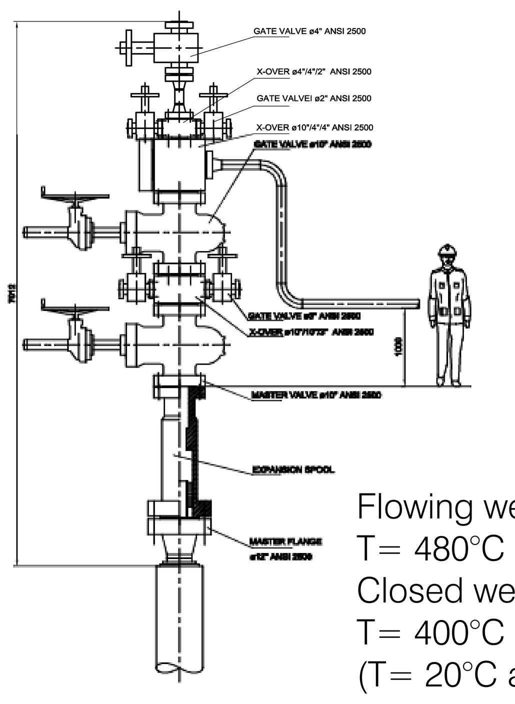
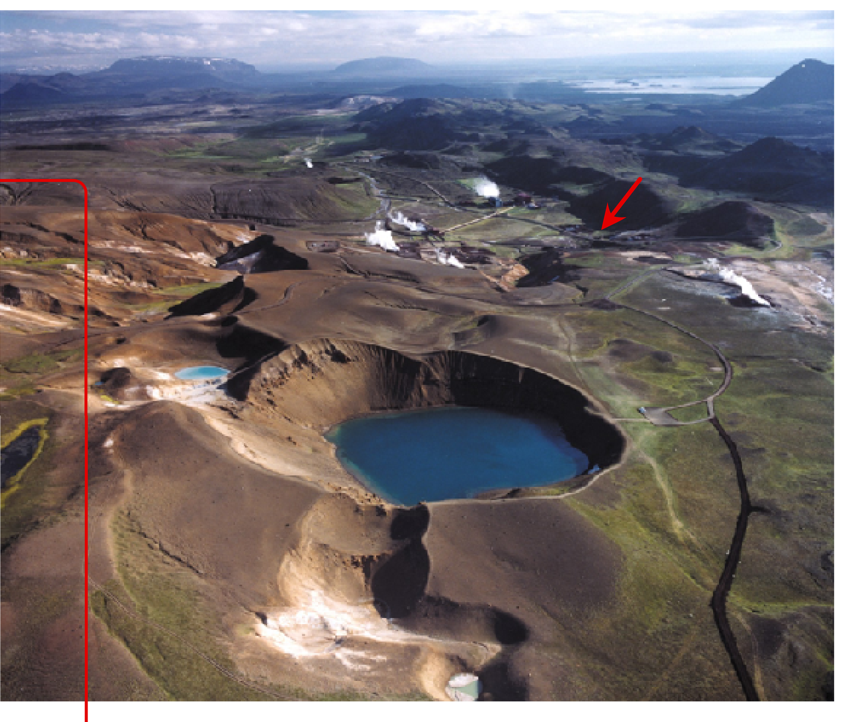
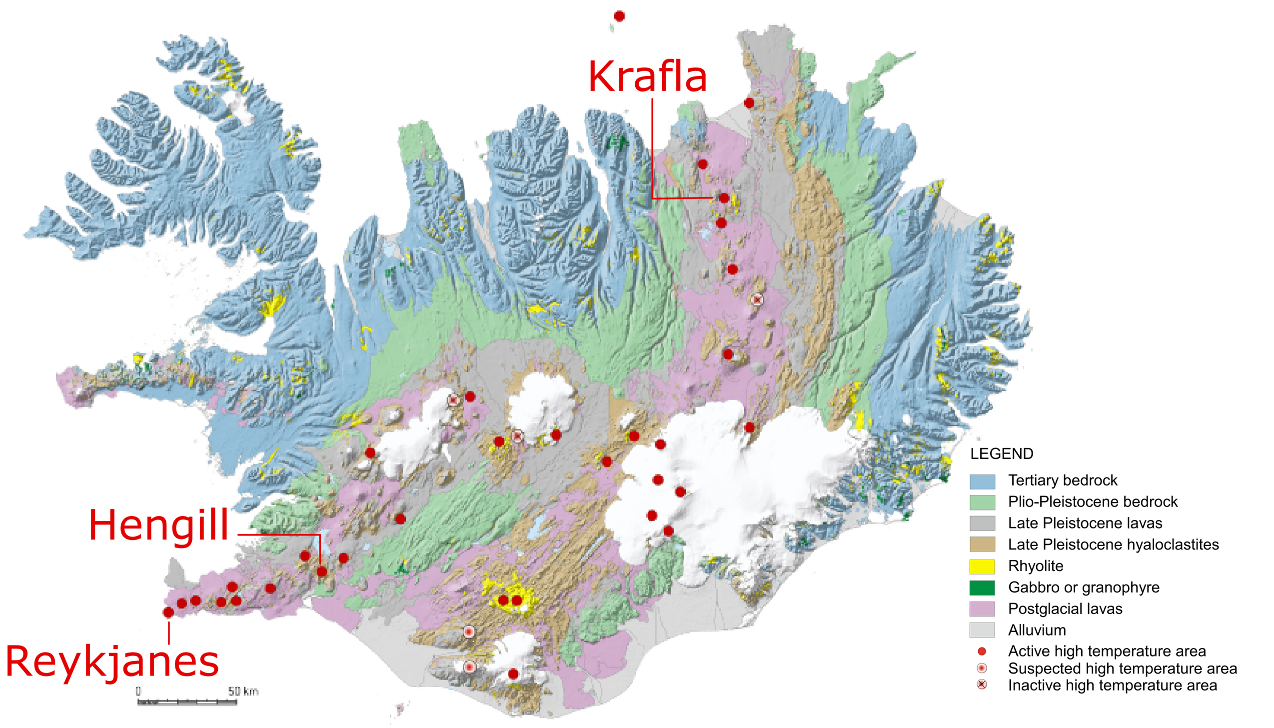
Current plan for Krafla

Well head

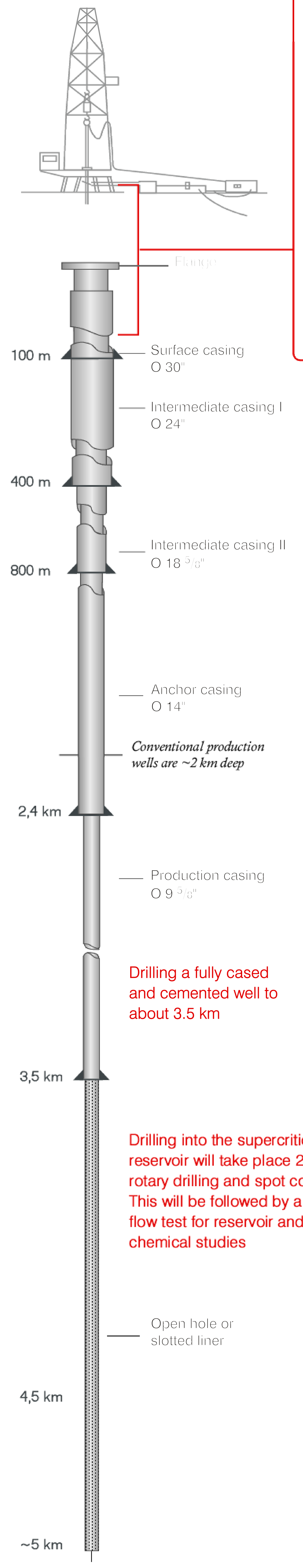


Flowing well:
T= 480°C and P= 195 bar
Closed well:
T= 400°C and P= 220 bar
(T= 20°C and P= 267 bar)





Basemap: Geological map of Iceland by Haukur Jóhannesson and Kristján Sæmundsson 1999. Iceland. 1:1.000.000. Icelandic Institute of Natural History.



Drilling a fully cased and cemented well to about 3.5 km

Drilling into the supercritical reservoir will take place 2008 by rotary drilling and spot coring. This will be followed by a major flow test for reservoir and chemical studies

The IDDP program

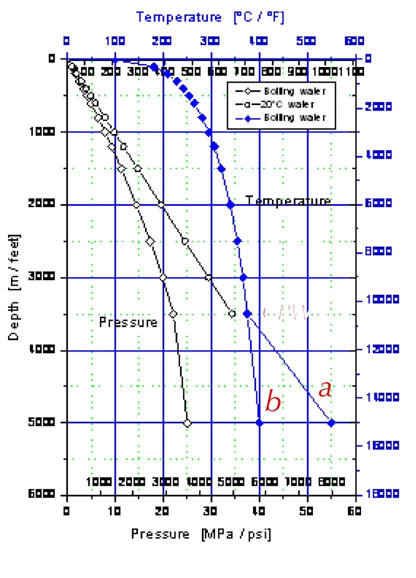
The IDDP (http://www.iddp.is/) is a long-term program to improve the efficiency and economics of geothermal energy by harnessing Deep Unconventional Geothermal Resources (DUGR). The aim is to produce electricity from natural supercritical hydrous fluids from drillable depths. This requires drilling wells in active high-temperature geothermal systems to depths of at least 3.5 to 5 km, to reach temperatures of 450-600°C, and pressures of 230-350 bar. Calculation indicates that one such well, with sufficient permeability, e.g. capable of producing ~200 ton/h of steam, at temperatures above 450°C, could generate some 40-50 MW electric. This exceeds by an order of magnitude the power typically obtained from conventional geothermal wells. The plan is to drill three such deep boreholes in Iceland, at Krafla, at Hengill, and one at Reykjanes (wells of opportunities). Beneath these three developed drill fields temperatures should exceed 550°C, and the occurrence of frequent seismic activity below 5 km, indicates that the rocks are brittle and therefore likely to be permeable.
The IDDP science program focuses on obtaining maximum information for characterization of the potential supercritical reservoirs.
The interest of the industrial program and of the science program overlap strongly.

Success criteria

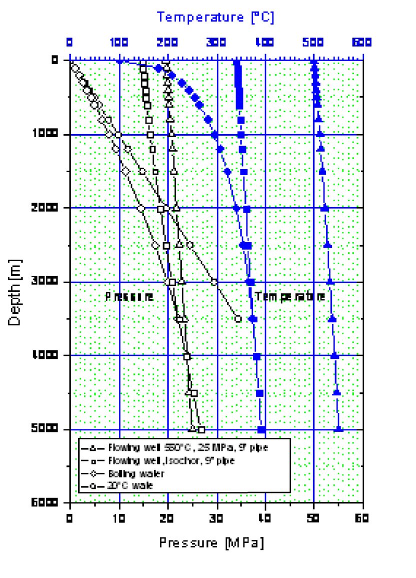
At an IDDP Workskop in March 2007 (SAGA Report 6), the SAGA group was asked to define how one would recognize that the first IDDP well had been successful. Success would be to drill a well to 4.5 km, to encounter supercritical temperatures and pressures, and to recover sufficient fluid and rock samples to begin to understand the nature of the supercritical geothermal reservoir.

Basic T and P assumptions

Static



Flowing



Assumptions

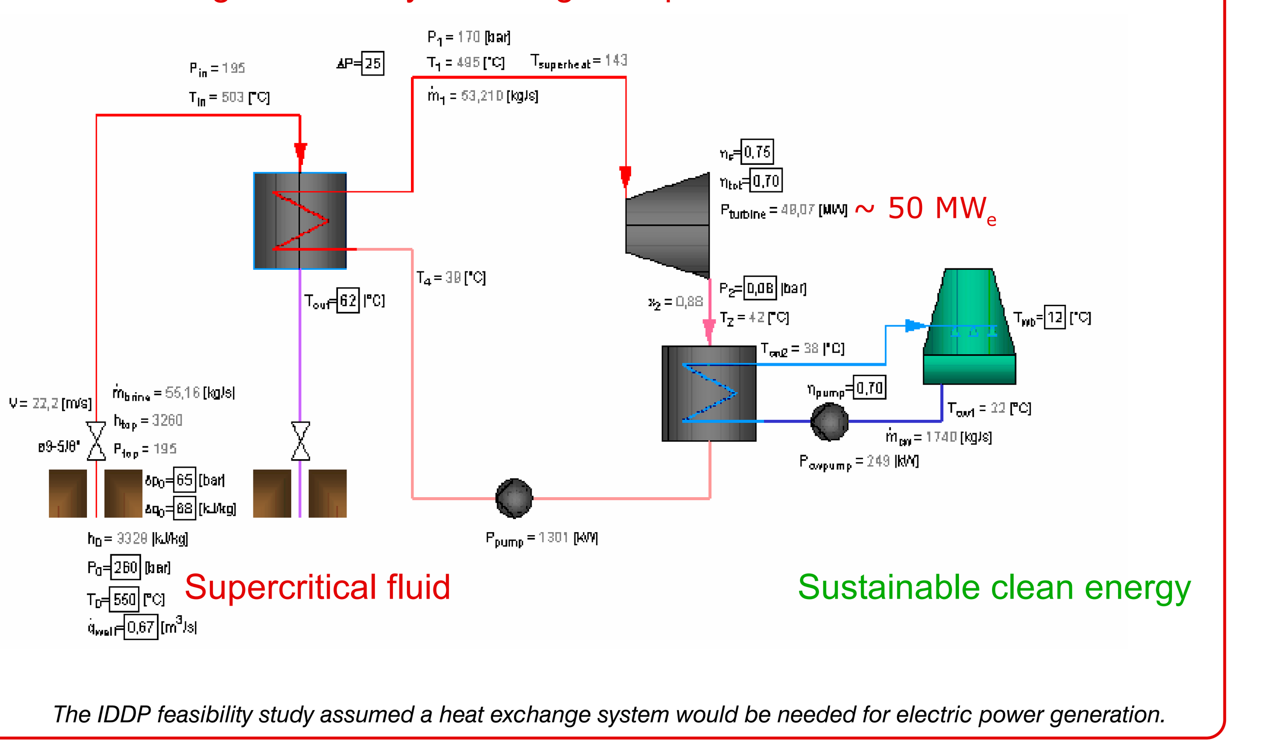
Down to the critical point for pure water (CPW) the boiling point with depth curve (BPD-curve) applies to 3,5 km.
Pressure hydrostatic down to the CPW.
Below CPW: a. Gradient 100°C/km
b. Constant density - isochore

Electric Power Generation

	Conventional dry-stream well	IDDP well
Downhole temperature	235°C	430 - 550°C
Downhole pressure	30 bar	230 - 260 bar
Volumetric rate of inflow	0.67 m^3/s	0.67 m^3/s
Electric power output	~ 5 MW_e	~ 50 MW_e

This comparison is based on the same volumetric flow rate of inflowing steam.
Energy output may increase by an order of magnitude by using supercritical fluid.

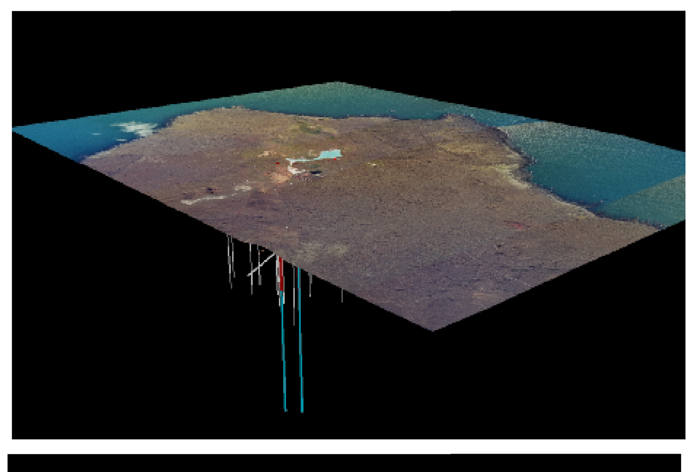
Power generation cycle for high-temperature fluid

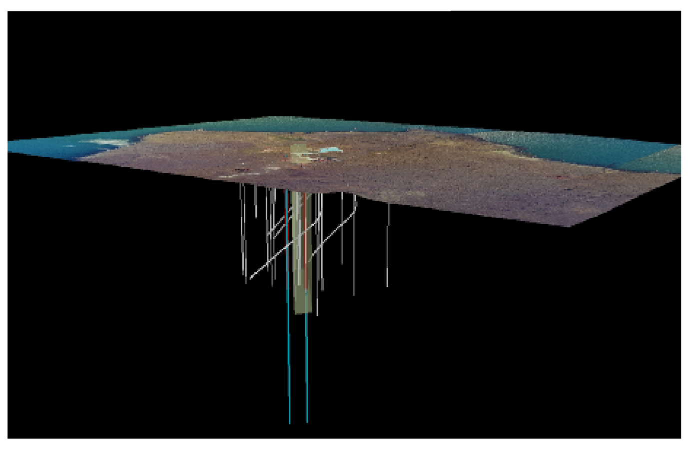


The IDDP feasibility study assumed a heat exchange system would be needed for electric power generation.

Reykjanes

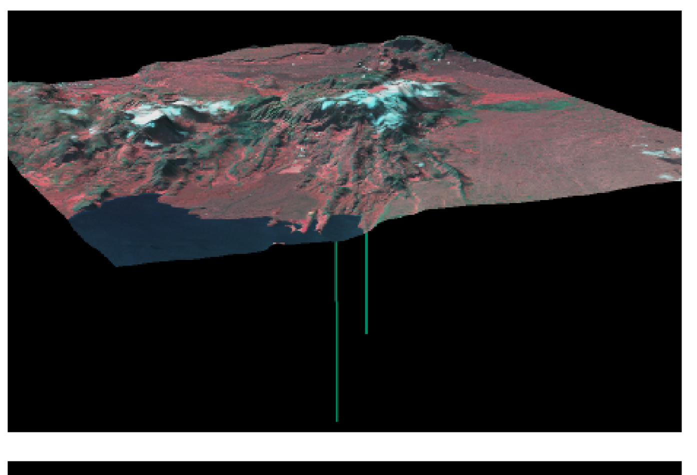
For the Reykjanes model a structure that represents upflow zone in Reykjanes is shown. Most of the wells are within this permeable structure.

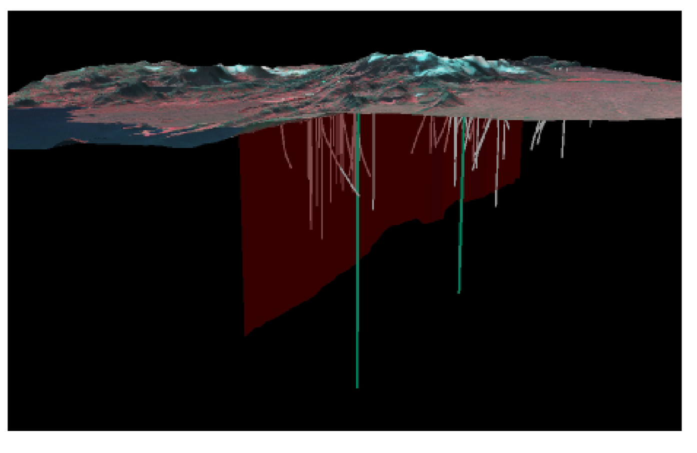




Hengill

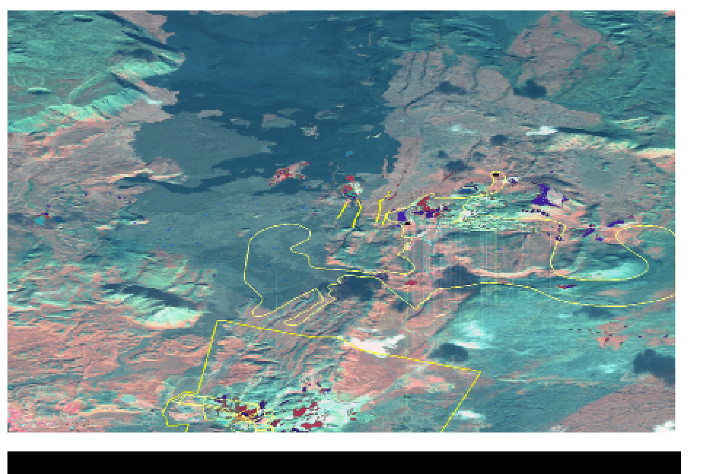
In Hengill a volcanic fissure zone is extended down to 3 km from the surface. The source of steam for many of the wells in Hengill area are from within this volcanic fissure zone.

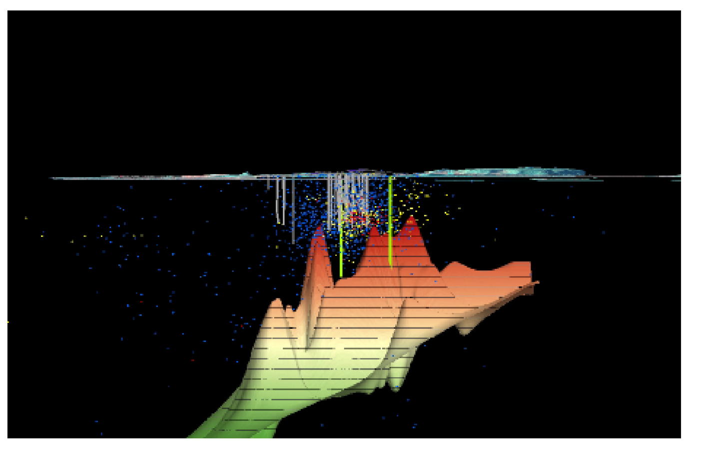




Krafla

In Krafla MT soundings have revealed a deep low resisitvity structure at 2 - 10 km depths.





Financing

The main financial supporters are three leading Icelandic energy companies together with the government of Iceland. Participation by Alcoa Inc., an international aluminum company is being finalized.

The International Continental Drilling Program (ICDP) and the US National Science Foundation (NSF), are supporting core drilling and scientific studies.

The EC-FP6 is supporting the HITI (HIgh Temperature Instruments for supercritical geothermal reservoir characterization and exploration) project which is intimately linked to the IDDP project.

Pilot plant study for power production is planned for 2009-2010 and funds will be sought from EC-FP7 and others.

Numerous science projects have been proposed to IDDP from the international science community, from 10-15 countries. Most of these projects will be funded from domestic sources in each case.

For more information: www.iddp.is