GREBE

Northern Periphery and Arctic Programme 2014–2020

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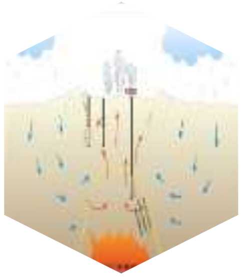
Iceland Deep Drilling Project
IDDP

Introduction

The international research project, Iceland Deep Drilling Project (IDDP) is a consortium of three Icelandic energy companies HS Orka hf, Landsvirkjun (LV) Orkuveita Reykjavíkur (OR), Orkustofnun (OS), and the National Energy Authority of Iceland. The project is carried out in highly geothermal active areas. The selected areas are located at the Krafla high temperature field in NE-Iceland.



Krafla is a caldera about 10 km in diameter with a 90 km long fissure zone, in the north of Iceland in the Mývatn region. The Reykjanes Peninsula is also well suited for project like this with its diversity of volcanic and geothermal activity. The three sites selected - Reykjanes, Nesjavellir, Krafla are at different stages in the tectonic development of the mid-ocean ridge.

The IDDP is a project focused on improving the economics of electrical production by major enhancements of the power output of geothermal wells. The main purpose of the IDDP project is to find out if it is economically feasible to extract energy and chemicals out of hydrothermal systems at supercritical conditions.

The above-mentioned consortium began by preparing the drilling of a 4-5 km deep drill hole into one of its high temperature hydrothermal systems in order to reach 400-600°C hot supercritical hydrous fluid at a rifted plate margin on a mid-ocean ridge. A feasibility report was completed in 2003. The IDDP is a long-term research and development project, which will take a decade or two to conclude. Therefore, IDDP is not an alternative solution to meet energy demand in the near or intermediate future.

Case Study Approach

The data on the market access of renewable energy technologies were collected both from the case studies in different renewable energy technology projects and from the secondary sources. To collect specific project data, a template was established with following subsections:

- **Technology description and a project summary**
  - Innovative characteristics
  - Technology readiness level
  - Available product / service supports from the manufacturer
  - Any standard procedures / requirements for integrating the technology into existing electricity networks, buildings and/or mainstream energy appliances / systems
- **Commercialisation of the technology**
  - Is the technology already a commercial solution?
  - Are there re-sellers of the technology, or is the technology available only from the manufacturer?
  - Identified main market area
- **Cooperation partners and networks**
  - Description of the roles of the co-operation partners and networks in the RE technology project.
  - How have they supported the market access of the technology?
- **Assessment of the technical and economic risks**
  - What kind of procedures have been made for assessing the technical and economic risks of the project
  - Who is bearing the risk of the investment (manufacturer, client, shared between them)?
  - Is the public sector involved in risk sharing? (e.g. co-financing, or platform for technology demonstration)
- **Drivers and barriers in the RE technology project**
  - Main drivers in carrying out the RE technology project
  - Barriers, and how they have been overcome (such as price of energy, availability of resource, specific expertise, policy enabling the technology)
- **Funding and support mechanisms**
  - The financial support received by the project: amount/support rate, type and purpose of the support, agency providing the support, significance of the support for the project
  - Types of soft support/advisories received during the project: the use of soft supports (advisory, training, mentoring etc.) during the technology development or implementation, and how successful these have been
- **Monitoring the performance**
  - How are the technical/non-technical aspects of the RE technology case monitored?
  - Information on the design, installation requirements and procedures, operational performance, and costs/financial arrangements
- **Conditions for the technology transfer & adaptation in different partner regions**
  - What are the main requirements/preconditions for transferring the technology and applying it in other partner regions?
  - Description of the main drivers and barriers for the technology transfer (such as. Energy price, resource needs, certain support etc.)
- **Project results**
  - Benefits & lessons learnt
  - Post- project benefits

Technology Description

An advanced drilling technology needs to be applied combined with a novel fluid handling and evaluation system designed in order to be able to perform the drilling. The IDDP want to drill deep enough into the roots at a conventional high temperature hydrothermal system to produce water at supercritical conditions and bring it to the surface as 400-600°C superheated steam, at subcritical pressures (<220 bar). In the case of low permeability systems, by injecting cold fluid into the hot rocks, fractures can be induced to complete the thermal mining cycle. Monitoring of utilization combined with computations of mass and heat flow suggest that there is a considerable supply of heat and mass in the system which is expected to be a good source for a long time.

The depths at which supercritical conditions are reached depend on the temperature and pressure gradients that may be controlled by cold or hot water hydrostatic conditions. In deeper system, they can be controlled by lithostatic load, depending on the permeability. If a natural hydrostatic hydrothermal system is boiling from the surface down to the critical point, the maximum pressure and temperature at each depth is determined by the boiling point/depth curve, and the critical point for pure water would be reached at about 3.5 km depth.

All of this is contingent on the conditions in different areas. For instance in the Reykjanes geothermal system, the fluid concerned is modified seawater, so the critical temperature will be elevated to about 410°C. Based on data from existing wells on the Reykjanes Peninsula, we anticipate temperatures in the range of >320°C at 2.5 km and approaching 400°C at 3.7 km, so that reaching supercritical temperatures in modified seawater will require drilling deeper.

Figure 1. Iceland Deep Drilling Project site.[1]

[1] Innovation Center Iceland 2016.

TRL and Technology Scale

The technology readiness level of the IDDP project is considered to be TRL7, where the system prototype demonstration is carried out in a real operational environment. The project is a long-term R&D, aiming at significant geothermal industry development.

In determining the scale of the IDDP project, the consortium counselled the stakeholders in the project.

Cooperation partners and networks

The IDDP project is a consortium of three Icelandic energy companies: (Hitaveita Sudurnesja (HS) (since 2008: HS Orka hf), Landsvirkjun (LV) and Orkuveita Reykjavíkur (OR)), and Orkustofnun (OS), the National Energy Authority of Iceland.

ICDP (International Continental Scientific Drilling Program) granted financial supports to organize the scientific program. A start-up meeting was held in Reykjavík in June 2001, and two workshops were held at Nesjavellir in 2002, the earlier on drilling technology in March, the latter in October on science. As a result of this IDDP received approximately 60 research proposals from the international scientific community. More than half of these proposals require drill core samples.

Innovation Center Iceland (ICI), Mannvit, Iceland Geosurvey and Reykjavik University provided several analysis reports. For example on -high pressure temperature grouts. Furthermore, Innovation Center Iceland has done several testing in the drilling process (e.g. tensile testing of liner material). Their expertise was used to determine the drilling areas and for recommendations regarding the process.

Furthermore a group of advisors -SAGA was founded in the beginning. Specific recommendations of the SAGA meeting included:

- Performing an immediate review of existing geothermal wells in Iceland that could be utilised by the IDDP for scientific studies.
- Discussing opportunities for drilling and sampling of pilot holes to obtain scientific information and to test technologies for later use in the hot, hostile environment of the deep boreholes that will be drilled by the IDDP.
- Continued planning of and preparation for the long-term program of deep drilling.

In the process IDDP have done some modifications and the focus has sharpened in their feasibility studies in cooperation with SAGA. Today they have reached 3.640 m depth and is now the deepest hole in Iceland.

Risk assessments and supports received

The total cost of the IDDP project is estimated to be 13.5 – 15 million euros. The costs increase along the depth of the drilling production wells.

As this is a research project involving both private and public sector the financing risk is shared. The funding is provided by the companies, the public sector and co-financed by international and national research and development programmes (Horizon 2020, International Continental Scientific Drilling Program, and National Science Foundation NSF).

R&D support is received also through the Reykjavik University and Innovation Center Iceland.

Drivers and barriers

The main driver for the IDDP is the industry interest of finding out if it is economically feasible to extract energy and chemicals out of hydrothermal systems at supercritical conditions. These developments could result to significant economic and environmental benefits.

Drivers include both public and private commitment to the project, as well as adequate resources for the project.

Barriers identified are mainly technological, as novel solutions are required for the hot environment of the deep boreholes.

Conditions for the technology transfer, adaptation and new market deployment

- Increased power output per well, perhaps by an order of magnitude, and production of higher-value, high-pressure, high-temperature steam.
- Development of an environmentally benign, high-enthalpy energy source below currently producing geothermal fields.
- Extended lifetime of the exploited geothermal reservoirs and power generation facilities.
- Re-evaluation of the geothermal resource base.
- Industrial, educational, and economic spin-off.
- Knowledge of permeability within drill fields below 2 km depth.
- Knowledge of heat transfer from magma to water.
- Heat sweeping by injection of water into hot, deep wells.
- Possible extraction of valuable chemical products.
- Advances in research on ocean floor hydrothermal systems.

The market development and technology transfers are dependent on the large-scale industry operators, the public policy sector and the set of objectives for this specific industry.

Project Results

Benefits

A significant milestone has been reached in the Iceland Deep Drilling Project at the Reykjanes Peninsula in Iceland when drilling of the IDDP-2 well was completed on the 25th of January at 4,659 meters depth. All of the initial targets - to drill deep, extract drill cores, measure the temperature and search for permeability, were reached.

Temperature at the bottom of the well has already been measured at 427°C, with fluid pressure of 340 bars, drill cores were retrieved, and the rocks appear to be permeable at depth. It´s clear that the reached fluids are at supercritical conditions, so that the main drilling phase objective of the project has been achieved. The drilling operation took 176 days since it began on the 11th August 2016.

Lessons Learnt

The primary goal of IDDP-1 was to drill down to and test a hydrothermal system at supercritical condition but it wasn't reached by the first IDDP well at Krafla in 2009. Drilling a well this deep and hot, comes with many different challenges. Drilling becomes more complicated as the well gets deeper and in this project we went deeper than before. In the beginning, there were difficulties extracting drill cores. However, they managed to extract 27.3 meter in 13 attempts and the last core was from the bottom of the well at 4.650 meters from the surface.

Using conventional drilling methods was not an option for many reasons so new methods had to be developed to ensure the progress of the project. The well is drilled vertically straight down to 2.750 meters and drilled directionally below that. The bottom of the well has a vertical depth of about 4.500 meters, and is situated 738 meters southwest of the well head. Various challenges arose as the drilling progressed, for example - the drill got stuck a few times. Nevertheless, on each instance the challenges were successfully solved.

A major unsolved challenge was a complete loss of circulation below 3.060 m depth. It could not be cured with lost circulation materials, or by multiple attempts to seal the loss zone with cement. At 3180 m they gave up cementing, so below that depth no drill cuttings returned to the surface. Consequently, the drill cored were the only deep rock samples recovered. They tried as many coring runs as the coring budget allowed.

Post Project Benefits

The depths beneath the production zone of the geothermal field at Reykjanes have never been explored before. The IDDP-2 well took advantage of HS orkas well RN-15 which was a2.500 meter deep production well. The first phase of the IDDP-2 project was to deepen the RN-15 well to 3.000 meters and cement a steel casing firmly into the surrounding formations.

The deepest existing geothermal wells at Reykjanes are about 3.000 meters deep so the IDDP-2 has the deepest casing in any well in Iceland. From there the well was deepened to its final depth of 4.659 m.

The best case scenario of the project outcome is where the well can be used for highly efficient energy production, which will open new dimensions in geothermal utilization.

This will be a result of the fact that supercritical fluid has a much higher energy content than conventional high-temperature geothermal steam. Potential utilization will not be known until the end of 2018 when all research, including substantial well stimulation and flow testing first indications are positive. If deep supercritical wells, here and elsewhere in the world, can produce more power than conventional geothermal wells, fewer wells would be needed to produce the same power output, leading to lesser environmental impact and improved economics.

Another option would be to use the IDDP2 for deep injection to enhance the performance of the overlying current production zone of the Reykjanes geothermal field.

The project has been a learning experience where it was demonstrated that it is possible to drill a long deep well in a high temperature geothermal field. They have collected valuable knowledge that will be useful in other projects, and other wells can surely be deepened. The purpose of the DDP-2 project is research and the drilling completion is only one phase of the project. The next steps will be to do further testing and research on the well, and most importantly follow tests and fluid handling experiments which will not be clear until end of 2018.

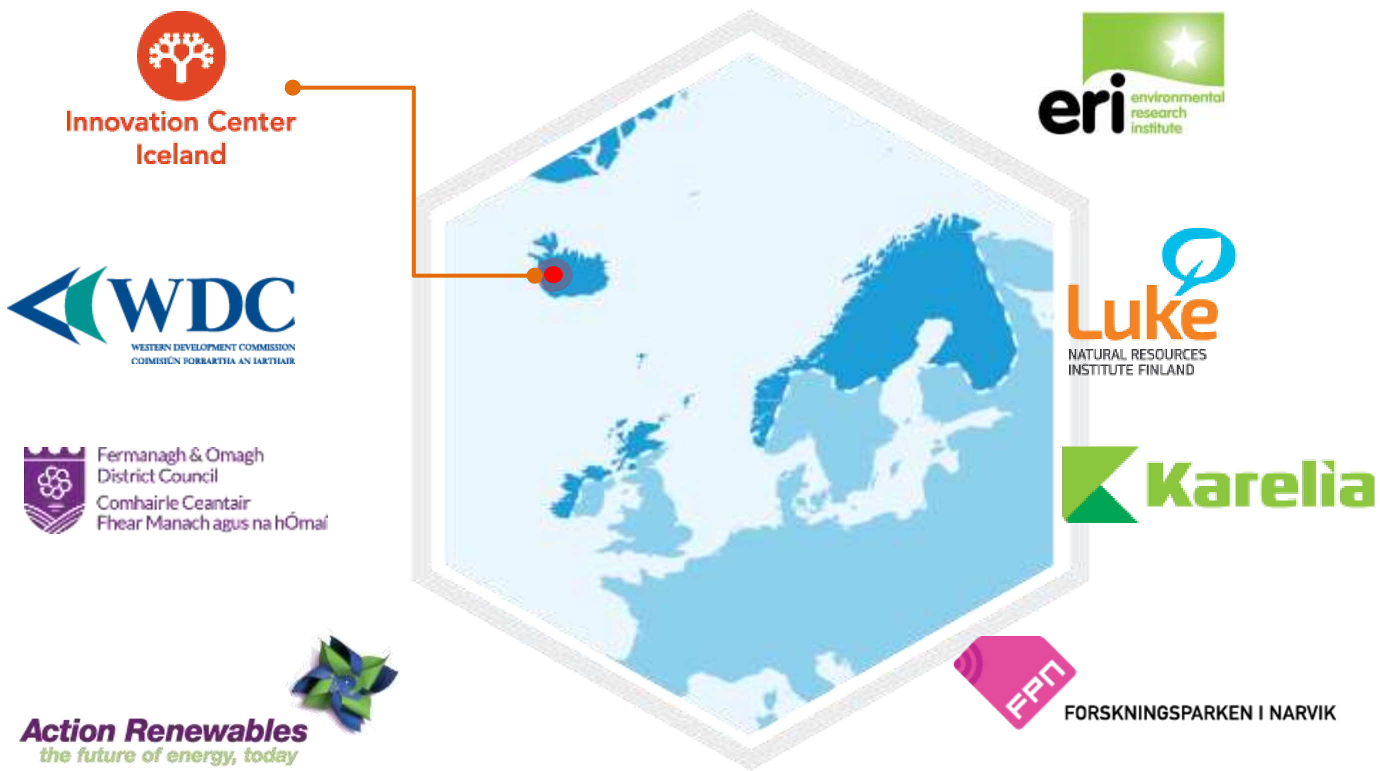
Contact Information

Contact Information IDDP
Gudmundur Ómar Friðleifsson
Heimilisfang (address): HS Orka hf Brekkustígur 36 IS-260 Reykjanesbær Farsími / Mobile : (+354)855 9351
Bréfsími (fax) (+354) 421 4727
Netfang (e-mail): gof@hsorka.is

PARTNERS

GREBE will be operated by eight partner organisations across six regions:

Innovation Center Iceland



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