GEOSCIENCE FOR LEAVING CERTIFICATE GEOGRAPHY

Continuing Professional Development Course 2021

GEOTHERMAL ENERGY MODULE

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iCRAG
SFI RESEARCH CENTRE IN APPLIED GEOSCIENCES

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

An Roinn Comhshaoil, Aeráide agus Cumarsáide
Department of the Environment, Climate and Communications

About the programme

The aim of this resource is to encourage the teaching and inclusion of geology in Leaving Certificate Geography classrooms. To achieve this, iCRAG and Geological Survey Ireland developed this CPD course which partnered up 6 Leaving Certificate teachers with 12 geoscience practitioners across Ireland. The course involved a series of talks by the geoscience practitioners which informed the teachers of current and ongoing geoscience research happening in Ireland. They then worked together to create either a classroom-based or field-based lesson or module plan for a particular subject area, complete with presentation and teacher and student notes. The teachers brought in their expertise and experience with teaching Leaving Certificate Geography and how the various aspects of geoscience can be linked to the curriculum, and the geoscience practitioners contributed their knowledge and relevant applications of geoscience at a classroom level.

The subjects covered by these 6 resources include a Glendalough field study, geothermal energy, an introduction to geology, Irish geohazards, seismic activity, and volcanoes.

The CPD course was led by Elspeth Sinclair and Fergus McAuliffe, from iCRAG, and Siobhán Power and Amrine Dubois Gafar, from Geological Survey Ireland. We would like to thank Peter Lydon for his help in recruiting our wonderful teachers.

About us

Geological Survey Ireland, a division of the Department of Environment, Climate and Communications, has been mapping Ireland since 1845. They continue to map the Irish land and marine territories, as well as mineral and groundwater resources. They have responsibility for actions in the current Climate Action Plan including monitoring coastal change, the Just Transition in the midland counties, and providing data for de-risking offshore renewable energy. Irish geoscience research, particularly as it contributes to the development of government policy, is an important part of their work and they fund and co-fund many research projects, including some of the iCRAG research work. Their data and maps are freely available to all at www.gsi.ie.

iCRAG, the Science Foundation Ireland (SFI) Research Centre in Applied Geosciences, are a team of researchers creating solutions for a sustainable society. They develop innovative science and technologies to better understand Earth's past, present, and future and how people are connected to it. iCRAG drives research into areas that are critical to society, including:

- The minerals and metals we need for decarbonisation and sustainable energy.
- Securing and protecting groundwater and marine resources.
- Protecting society from Earth's hazards, such as floods and landslides.

Further information is available at: www.icrag-centre.org

About this resource

Geothermal Energy Module

This resource has been developed by Elaine Egan, a geography teacher at Synge Street CBS, alongside geoscience professionals Rory Dunphy and Koen Verbruggen, both from Geological Survey Ireland. The resource is a deep dive into geothermal energy, covering at least four lessons. It is suitable for TY students as well as Leaving Certificate Students.

Disclaimer

Geothermal Energy: Module plan

Links to curriculum

Core unit 1: Patterns and Processes in the Physical Environment

1.2	**The rock cycle** **Statement:** **Rocks are continually formed, modified, destroyed and reconstituted as part of the rock cycle. They are formed and modified by endogenic forces; they are destroyed by exogenic forces of erosion on exposure to weather and climate; they are reconstituted by the deposition of sediments.** Students should study		
	The human interaction with the rock cycle, paying particular attention to **one** of the following: mining, extraction of building materials, oil gas exploitation, geothermal energy production.	Appropriate national examples.	Appropriate international examples.

Elective unit 4: Patterns and Processes in Economic Activities

4.5	**Environmental impact** **Statement: Economic activities have an environmental impact.** Students should study • the use of renewable and non-renewable resources in the economy • the impact of the burning of fossil fuels and the use of alternative energy sources	National energy resources. Smoke free zones. Patterns of production and consumption.	Production and consumption of energy - appropriate European examples. Acid rain - a European issue.

Learning Outcomes

Students should be able to:

- Understand the concept of geothermal energy and its link to rocks
- Gain a deeper understanding into the geological processes involved in geothermal energy
- Learn about the ways in which geothermal energy is captured and its uses
- Learn about a number of case studies; Iceland, Ireland & Paris
- Work together to investigate if geothermal energy is/can be a source of sustainable renewable energy for areas in Ireland and identify advantages and/or current limitations.

Keywords and definitions

Geothermal	The heat/energy generated by the earth naturally
Percolates	The movement of liquid through a semi solid material (water soaking into the ground/landscape)
Boreholes	Ground source heat pumps (GSHPs) use pipes which are installed in boreholes to extract heat from the ground.
Energy Intensive	Heavy use of energy (e.g. energy intensive industries)
Decarbonise	Reducing the amount of carbon emissions in the energy sector
OPEX	Daily operating expense (the cost to run a day-to-day project/business)
CAPEX	An expense a business/project incurs to create a benefit in the future
Ground Source Heat Energy	A renewable source of energy that can be used to heat buildings
Open loop (domestic/small commercial)	Type of Geothermal Capture for domestic and small commercial energy demand
Open loop (larger commercial/industrial processes)	Type of Geothermal Capture for larger commercial and industrial energy demand

Linkage and Integration

Linkage

- English: Oral discussion, debating, various styles of writing techniques to learn core facts
- SPHE/Team building: Working as part of a group to investigate a plan and provide an outcome
- Maths: Problem solving, logistics & critical thinking
- STEM: Engineering
- Geography/Science/Green schools: Investigating the wider environmental aspects

Differentiation

- Teaching Style: Identifying what students already know in a verbal (discussion)/nonverbal (wall sticky notes) manner. Various methods of learning (visual/verbal; higher order, lower order discussions and recall/reading/writing)
- Group work: Each group assigned a role but roles within the group assigned between them so as those comfortable to lead/talk/research can do so as they feel comfortable to do.

Geothermal Energy: Teacher Notes

Lesson one: Introduction to Geothermal Energy (Case study: Iceland)

Learning Activities

-Discuss the links that volcanic activity and the rock cycle has with geothermal activity (brainstorm map of all suggestions on the board) 5mins

-Wall stickers: Given sticky notes to write advantages/limitations to stick on the wall before video (5mins)

-How Geothermal Energy Revolutionised Iceland's Greenhouses | Earth Lab - YouTube (9mins students asked to think of further advantages/ limitations)

-Wall stickers (sticky notes): add advantages/limitations (5 mins)

Homework (Explanation 5 mins)

-Textbook case study on p79/80 of Iceland- given placemat to break down into bullet points for 4 headings:

1. Iceland and Geothermal Energy
2. How is geothermal energy captured?
3. Uses of Geothermal energy
4. Benefits of Geothermal Energy

Assessment:

-Teacher questioning of their understanding of the links between and roles that are played with rocks/volcanic activity & geothermal energy, discussion.

-Teacher observation and comparison of wall stickers advantages/limitations before the video and then further assessment of additions to that after the video

-Homework task to extract important facts from case study to assist note making and summarising skills.

Resources Given:

Planet & People Textbook Case Study on Geothermal Energy in Iceland (p 79/80 Print for each student)

(Video Youtube- 9 mins) How Geothermal Energy Revolutionised Iceland's Greenhouses | Earth Lab - YouTube

(Video Youtube- 3 mins) Energy 101: Geothermal Energy – YouTube

Placemat (Print for each student)

Exit card (Print for each student)

Materials Needed:
Printed resources above

Sticky notes (2/3 per student) & blue tack to stick to wall

Lesson two: Geothermal Energy Capture Types and Case Study: Ireland

Part 1: Geothermal Energy Capture & Ireland

Learning Activities
-Document "Geothermal Energy Explained (Dr. Sarah Blake GSI) handed out to each student and read in sections, with discussion/clarification after each section. (10 mins)

-Geothermal Energy in Ireland FAQ (10 mins) Students spend time reading this, noting important facts- highlight to them that this is very useful information that they may wish to use when given the main module task)

-Use of the Geothermal Suitability maps for Ireland **Geoenergy (gsi.ie)** Student Questions (10 mins)

-Using the Geothermal Suitability map to explore data available (10 mins)

-Homework Activity: Identifying areas of suitability for each of the 3 types (vertical closed loop, open loop domestic and open loop commercial)

Assessment
-Teacher and students discuss what main points of Geothermal Energy Explained are

-Students highlight/note what they feel are interesting facts from Geothermal Energy FAQ

-Students answer questions on Geothermal Energy Suitability Map & can navigate the map using different layers

-Homework Task: Use the map on a device to identify 3 areas for each of the 3 layers (vertical closed loop, open loop domestic and open loop commercial)

Resources Given:

-Handout on Geothermal Energy Explained (Dr. Sarah Blake GSI) Can be found in the Resources Appendix section- teacher may wish to print as handout/ put online document on student accessed platform for further access during class

-Geothermal_energy_FAQ.pdf (gsi.ie) can be accessed by students in class on a device

-**Geoenergy (gsi.ie)** Map page on Geothermal Suitability Map for Questions in Activity 3

-Link **Geoenergy (gsi.ie)** used for Activity 4 and Homework Activity also

Materials Needed:

-Copies of documents above if teacher wished to print for each student/copies per group

-Internet Access (for students)

-Devices for each student/in groups to read documents and access the Geothermal Suitability Map

Part 2: Geothermal Energy Capture Types & Ireland

Learning Activities:
-5 min video on use of the Irish District Heat Atlas Map

-Students use devices in groups to experience the data available on Irish District Heat Atlas Map (15 mins)

-Investigation of the Tallaght District Heating Scheme and Questions to answer (15 mins)

-Homework Activity to investigate further information available through links provided

Assessment:
-Teachers observe students using the Irish Heat Maps as shown in the video previous to work together on finding data available to them

-Teacher assess questions outlined on PowerPoint in relation to Tallaght District Heating Scheme

Resources Given:
Irish Heat Atlas: Version 1 – YouTube (Instruction video)

Irish Heat Atlas Version 2.1 (arcgis.com) (Interactive Map)

Tallaght District Heating Scheme | Energy Efficiency Agency Dublin | Codema (Case Study)

(Further Information)

district_heating_brochure.pdf (codema.ie) (Further Information)

Geothermal Energy (gsi.ie)

Energy 101: Geothermal Heat Pumps – YouTube

Geothermal Energy | A Student's Guide to Global Climate Change | US EPA

Shallow Geothermal Energy (gsi.ie)

Materials Needed:
-Internet access (Students)

-Use of devices for students to access links and investigate further information

Lesson 3: Student Investigation into Geothermal Energy viability in Dublin City

Learning Activities

-Arrange students into groups of approx. 4 students each

-Direct students to school platform (or online classroom) where they can access links/resources used in the module and/or additional resources to assist their research.

-Outline research question and break down the body of the research

-Outline methods of producing/submitting findings (video, PowerPoint presentation, report)

-Students may be given an extra class to work on this if needed.

Assessment

-Teacher assess that the students understand each section of the instructions

-Teacher observes if the students are organising the roles in the group and are able to access and find the links for further research

-Teacher checks if each person in each group understands their role

-Teacher assess if students, at the end of the class understand the research question, how to gather the information and what is expected as a final result.

Resources Given

-Breakdown of the criteria expected (can also show students assessment rubric in Lesson 4 Assessment so students can set result target)

-Full PowerPoint presentation, documents, and links available to students on an online platform in order to do their own group research

Materials Needed

-Internet Access (students)

-Devices for groups to access online platform and investigate material available to them

Lesson 4: Group Presentation of Findings

Learning Activities

-Groups will be given 5-10mins to present their findings in the format they have chosen (video/PowerPoint/report)

-Other students will be given an opportunity to ask questions once the group has finished presenting

-Students will then be able to add their findings to the Geothermal Wall where suitable

Assessment:

-Teacher can use own assessment method or that which is provided in the PowerPoint presentation "Lesson 4"

Resources Given

-Assessment rubric in slide 22

Materials Needed:

-Internet Access (students)

-Devices for groups to access online platform and investigate material available to them

Resources for Geothermal Energy Module

Lesson 1: Geothermal Energy in Iceland

-Link to YouTube video (9 mins)

How Geothermal Energy Revolutionised Iceland's Greenhouses | Earth Lab - YouTube

-Link to YouTube video (3 mins)

Energy 101: Geothermal Energy – YouTube

-Placemat (**Appendix**: full A4 to be printed and used landscape):

-Geothermal Energy in Iceland Case Study **(Appendix)**

-Exit card : 3 things you found out, 2 interesting things, 1 question **(Appendix)**

Lesson 2: Geothermal Energy in Ireland

PART 1

-3 A4 pages Document Geothermal Energy Explained (Adapted Dr. Sarah Blake GSI) (**APPENDIX)**

-Geothermal_energy_FAQ.pdf (gsi.ie) (reading document)

-Geoenergy (gsi.ie) (Geothermal Suitability Map)

PART 2

Irish Heat Atlas: Version 1 – YouTube (Instruction video)

Irish Heat Atlas Version 2.1 (arcgis.com) (Interactive Map)

Tallaght District Heating Scheme | Energy Efficiency Agency Dublin | Codema (Case Study)

(Further Information)

district_heating_brochure.pdf (codema.ie) (Further Information)

Geothermal Energy (gsi.ie)

Energy 101: Geothermal Heat Pumps – YouTube

Geothermal Energy | A Student's Guide to Global Climate Change | US EPA

Shallow Geothermal Energy (gsi.ie)

Lesson 3/ Lesson 4

Students own work and use of the materials found above through the links and in the following appendix.

Appendix:

Lesson 1:

- Placemat for Iceland case Study Summary
- Iceland Case Study (Planet & People Leaving Certificate Geography Textbook p 79/80)
- Exit Card: 3 things you found out, 2 interesting things, 1 question you still have

Lesson 2:

- 3 A4 page Document on Geothermal Energy Explained (adapted from Dr. Sarah Blake GSI)

Geothermal Energy In Iceland:

Capture, Uses & Benefits

Option 2: Geothermal energy in Iceland

CHAPTER 5
Case Study 2

Geothermal energy is heat energy captured from hot rocks in the earth's crust. Iceland is a major producer of geothermal energy.

1. Iceland is located on the Mid-Atlantic ridge. This is the constructive plate boundary between the North American and Eurasian tectonic plates. The two plates are moving apart at a rate of about 2 cm per year. This allows magma to reach the surface of the earth forming hot igneous rock that is used to make geothermal energy.
2. In Iceland the active volcanic zone stretches through the country from the south-west to the north-east and contains more than 200 volcanoes. This volcanic zone is used to generate geothermal energy.

Fig. 23 Map of Iceland showing geothermal zones

How is geothermal energy captured?

3. Magma rising from the mantle heats the ground to over 200°C just 1 km below the surface.
4. Precipitation (rain and snow) falling on the highland seeps (**percolates**) three kilometres into the bedrock where it is heated by the hot rocks beneath the surface. In some areas the water is heated to more than 380°C. The hot water then rises towards the surface often forming hot springs and steam vents.
5. The rocks are drilled (**boreholes**) to capture the hot water. As the hot water reaches the surface, the pressure drops causing it to turn into steam. The steam is used to turn a turbine to make electricity. After this the steam cools and condenses into cold water which is returned to the ground through a different borehole where it is reheated and the cycle starts again.

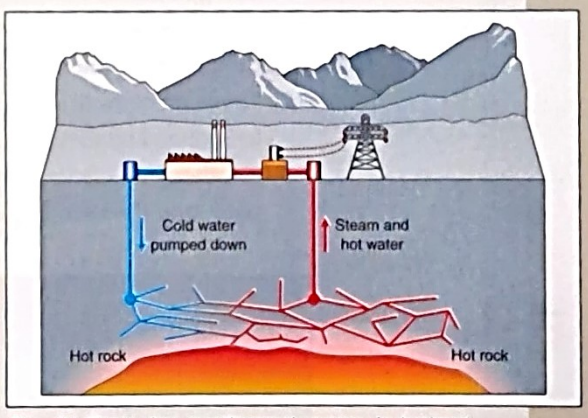


Fig. 24 Capturing geothermal energy in Iceland

Uses of geothermal energy

6. Iceland has used geothermal energy since the 1930s. Today five major and many other smaller geothermal power plants exist in Iceland. These produce over 30% of the nation's energy.
7. Geothermal energy plants provide heating and hot water for approximately 87% of all buildings in Iceland. Water usage is metered and people pay for the water they use.

8. In Iceland's two largest cities, the capital Reykjavík and Akureyri, pavements and car parks are kept ice-free during winter by underground heating systems.
9. One of Iceland's most important uses of geothermal energy is for heating greenhouses. For years, the naturally warm soil has been used for growing potatoes and other vegetables. Horticulture has benefited considerably from geothermal resources, as the heating of greenhouses has increased production, lengthened the growing season and reduced the cost of importing heating oil for growers.

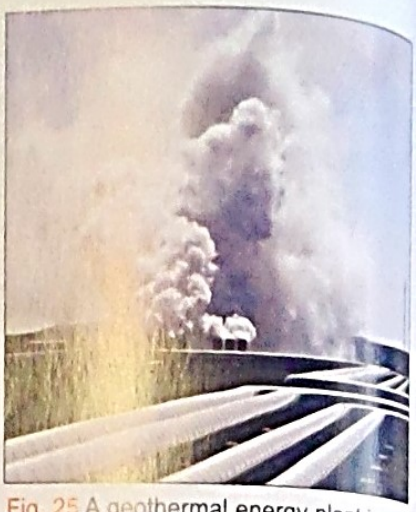


Fig. 25 A geothermal energy plant in Iceland

Benefits of geothermal energy

10. There is potential to generate 40% of Icelandic energy requirements from geothermal sources. This reduces the need to import expensive fossil fuels. The use of geothermal energy has also benefited the environment due to lower CO_2 emissions compared to fossil fuel power plants.
11. The availability of cheap electricity has made Iceland an attractive location for the **energy-intensive** [energy hungry] metal-smelting industries. Aluminium smelting is worth one-seventh of Iceland's GDP. For example, one American smelting company, Century Aluminium, produces 300,000 tonnes of aluminium per year in Iceland.
12. There are plans to lay 1,300 kilometres of submarine electricity cables from Iceland to Scotland so that geothermal energy can be exported to Europe.
13. Geothermal activity is important to the Icelandic tourist industry, e.g. geysers, hot pools and the Blue Lagoon (geothermal swimming pool).

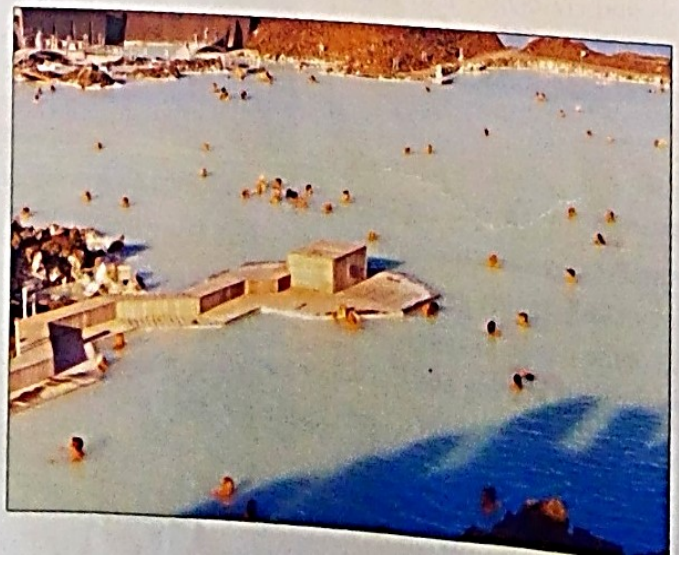


Fig. 26 The Blue Lagoon tourist attraction

weblinks

Cable between Iceland and Britain

Powering Scotland from Icelandic volcanoes

THINGS YOU FOUND OUT:

3

INTERESTING THINGS

2

QUESTION YOU STILL HAVE

1

Geothermal Energy Explained (adapted from Dr Sarah Blake Geological Survey of Ireland)

The Geology of Geothermal Energy

What is Geothermal Energy?

Geothermal energy is heat energy stored below the surface of the Earth which can be used as heat or to generate electricity. Heat flows outwards from the centre of the Earth, and the temperature (and the amount of available energy) increases with depth at an average rate of 25 to 30 °C per kilometre for most places in the world. Heat flow is highest in volcanic regions, such as at tectonic plate boundaries and traditional exploitation of geothermal resources has occurred in these areas where the heat is easily accessible (e.g., Iceland, Italy, New Zealand).

Advances in technology over the past century have led to the development of geothermal resources for heating and/or electricity production away from these plate margins in places where the heat flow is not particularly high (e.g., France, Netherlands, Belgium, UK, Germany). Such geothermal energy types could be a viable, important source of energy for Ireland.

Of all of the thermal energy in the Earths crust, beneath a specific area, a geothermal resource is the portion of that energy that is shallow enough to be tapped by drilling and recovered as useful heat both economically and legally.

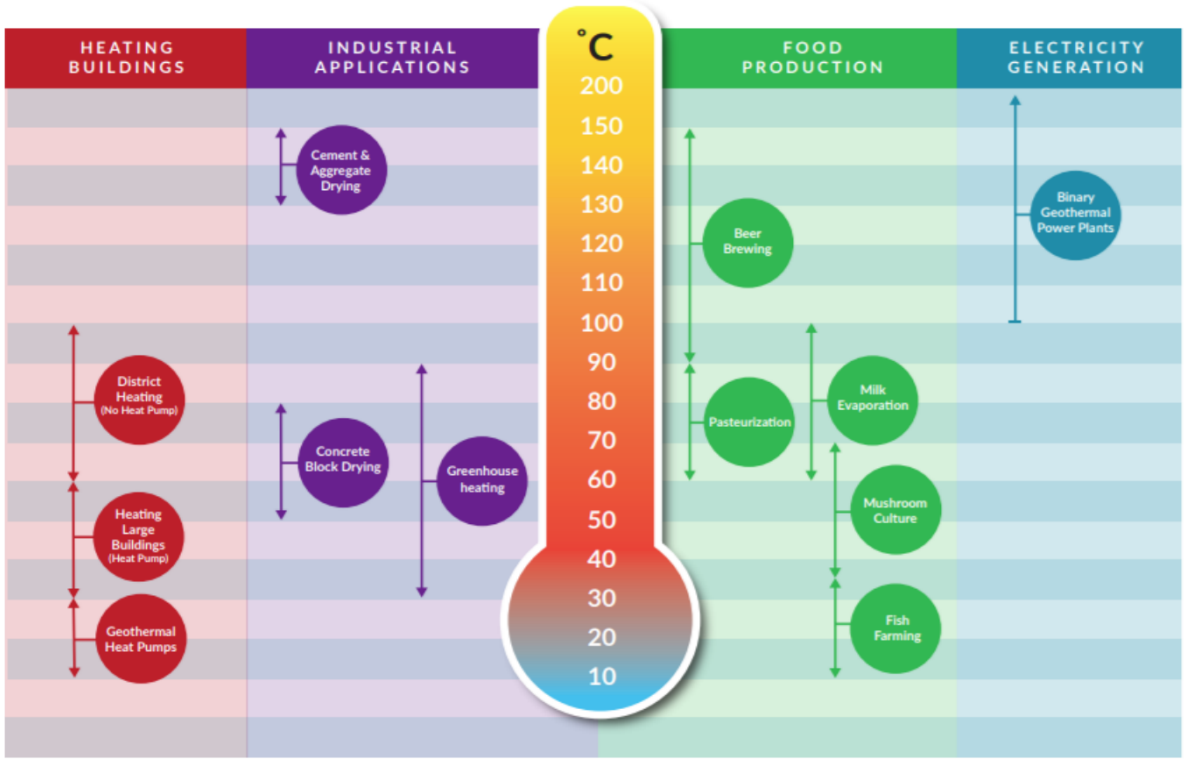
The size of the potential geothermal resource in Ireland has yet to defined and is a focus of the National Geothermal Database project which is being undertaken by the Geological Survey of Ireland as part of the Climate Action Plan.

For geothermal resources a shallow Ground Source Heat Pump (GSHP) will exploit the heat directly underneath the house it is heating and a geothermal powerplant will be located nearby to the wells that produce the water or steam that supply it.

Categories of Geothermal Resources:

Category	Temp	Description	Uses
Very Low Enthalpy	10-30 C	Shallow soil temp & sun influence	Heating single small building
Low Enthalpy	30-80 C	Located by deeper drilling	Bigger demand of energy
Mid- Enthalpy	80-120 C	Power plants are necessary for electricity production	Heating/electricity production of combined
High Enthalpy	120-300 C	Lower end of temp can be used for potential electricity in Ireland	Electricity production

How Geothermal Energy Can Be Used



Heat Generation/Distribution

District Heating: (also known as heat networks) is a system for distributing heat generated in a centralized location through a system of insulated pipes for residential and commercial heating requirements such as space heating and water heating.

More than 250 geothermal district heating systems were in operation in Europe in 2015. Progressive efficiency improvements in district heating technology has meant that lower temperature inputs are acceptable. Studies in South County Dublin have shown that geothermal fluid temperatures in excess of 60 ^{o}C are likely to be achieved at depths of 2.5 km, and such temperatures would enable geoDH to proceed without the use of a heat pump.

Agriculture, food production and food and beverage processing

At very low temperatures, geothermal heat can be used for aquaculture (e.g., Huka Prawn Park, Taupo, New Zealand) and soil warming. Geothermal heating can be effectively used for traditionally energy-intensive horticultural operations such as heating greenhouses to grow fruit, vegetables, flowers (e.g., Slovenia; the Netherlands) and mushrooms (e.g., Oregon, USA). Geothermal heat is used to brew beer in Reykjavik, Iceland and Colorado, USA. Geothermal heat can also be used to dry agricultural products, e.g., tomatoes, chillies, rice, cotton, timber, etc. Dairy processing requires large amounts of energy for heating and cooling, and geothermal energy can be successfully used for processes such as milk pasteurization (e.g., Oregon, USA), and cheese maturation and storage (near Lardarello, Italy).

Metal Extraction /Brine Mining

Hot fluids processed through geothermal electricity production plants could contain economic quantities of dissolved minerals and metals, which could be extracted at a profit under appropriate

market conditions. Extraction like this will generate much less environmental impact than traditional surface or underground mining operations, examples include USA where zinc is extracted in economic amounts and the United Downs project in Cornwall UK where lithium concentrations in the produced fluid are up to 250 mg/L.

Shallow Geothermal

Heat and Hot water – Domestic Buildings Low temperature, shallow geothermal resources are available everywhere in Ireland. They can be exploited in conjunction with a heat pump (GSHP), and the stability of the subsurface temperatures results in highly efficient, low-carbon and economical heating schemes. The use of heat pumps for individual dwellings is recognised as the best way to decarbonise the heat sector in rural areas where there is low density housing and low heat demand, and GSHPs represent the lowest-carbon option for a heat pump.

Recreation

In Ireland, the only example of a thermal spring being used for geothermal energy purposes is Lady's Well in Mallow, Co. Cork. There, waters of approximately 21 ^{o}C are used to heat a public swimming pool.

Types of Geothermal Technologies

-Shallow Geothermal Open & Close Loop

-Mine Water Extraction

-Deep Geothermal Open Loop Systems

-Deep Closed Loop Systems

-Engineered Geothermal Systems

The type of technology/ system used depends on several factors:

-Geology/topography of the site (suitability)

-Presence of groundwater aquifers

-Energy product and supply demand